UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE PATENT TRIAL AND APPEAL BOARD

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GOOGLE LLC , CELLCO PARTNERSHIP D/B/A VERIZON WIRELESS, T-MOBILE USA, INC., AT&T SERVICES, INC., NOKIA OF AMERICA, CORP., AND ERICSSON INC.
Petitioners

v.

KT CORPORATION (Patent Owner) and
PEGASUS WIRELESS INNOVATION LLC (Exclusive Licensee)

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Case No. IPR2025-00291
Patent 10,594,460

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# DECLARATION OF CRAIG BISHOP

**Petitioners' Exhibit 1033 (Part 1 of 2)**
**Google et al. v. KT Corporation et al.**
**IPR2025-00291**

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# I. INTRODUCTION

I, Craig Bishop, declare as follows:

1. I have been retained as an independent expert witness on behalf of GOOGLE LLC, CELLCO PARTNERSHIP D/B/A VERIZON WIRELESS, T-MOBILE USA, INC., AT&T SERVICES, INC., NOKIA OF AMERICA, CORP., and ERICSSON INC., (to whom I will refer to as Petitioners) for this *inter partes* review proceeding (which I may refer to at times as an "IPR").

2. I am being compensated for my work in this matter at my accustomed hourly rate. I am also being reimbursed for reasonable and customary expenses associated with my work and testimony in this investigation. My compensation is not contingent on the results of my study, the substance of my opinions, or the outcome of this matter.

3. In the preparation of this expert report I have reviewed the documents cited herein, each of which is a type of material that experts in my field would reasonably rely upon when forming their opinions, as well as all of the Appendices attached hereto.

4. In forming the opinions expressed within this expert report, I have considered:

- The appendices listed above; and

- My own academic background, knowledge, and professional experiences in the field of wireless communications.

5. Although I have attempted to organize the information presented in this report into helpful sections and/or divisions, my opinions are supported by the information in the report in its entirety.

## II. QUALIFICATIONS

6. My complete qualifications and professional experience are described in my *curriculum vitae*, a copy of which is attached as **Appendix 1 and is filed concurrently herewith as Exhibit 1034.** The following is a summary of my relevant qualifications and professional experience.

7. I earned my Bachelor of Electronic Engineering degree with Honors from Polytechnic of Central London in 1989. In 2006, I earned my MSC in Computer Science with Distinction from the University of Kent.

8. After graduating with my first degree, I worked as an operations engineer at the British Broadcasting Corporation (BBC) for 4 years, then as a civil servant at the UK Radiocommunications Agency until 1996, during which time I became involved in telecommunications standardization in the European Telecommunication Standards Institute ("ETSI"), working in particular in Technical Committee Radio Equipment and Systems (TC RES2) concerned with the standardization of Private Mobile Radio (PMR). From 1994 through 1996, I acted

as Rapporteur for voice and data related PMR standards ETS 300 113, ETS 300 219 and ETS 300 390. I participated as the only TC RES2 delegate on behalf of the UK Radiocommunications Agency, generating proposals in support of UK administration and business requirements, downloading and reviewing other meeting input documents, and proposing changes as necessary to ensure input documents and the resulting specifications were in line with said requirements.

9. In 1996, I joined Samsung Electronic Research Institute as a Senior Standards Engineer where I worked for 16 years, eventually becoming Director of Standards and Industry Affairs in 2011. My work at Samsung mainly focused on the standardization of Global System for Mobile Communications (GSM)/ General Packet Radio Service (GPRS), Universal Mobile Telecommunications System (UMTS), the IP Multimedia subsystem (IMS), and Long-Term Evolution (LTE)/ Evolved Packet System (EPS) systems. Initially, I participated in ETSI Special Mobile Group (SMG) committees SMG1, SMG2, SMG4, SMG5, and SMG9, and relevant UMTS related sub-committees working on the air interface radio access network protocols, service, and terminal aspects of UMTS and GSM/GPRS until 1999. In particular, I was a participant in the ETSI SMG2 meetings leading up to selection of Wideband Code Division Multiple Access (WCDMA) as the radio access technology for the Frequency Division Duplex (FDD) mode of UMTS.

10. Beginning in 1998, I worked as a Principal Standards Engineer on the 3rd Generation Partnership Project (3GPP) on UMTS. I attended the inaugural 3GPP Technical Specification Group (TSG) meetings held in December 1998, and I began attending Working Group (WG) meetings in 1999. Specifically, I was a regular participant in Radio Access Network (RAN) WG1, Services & System Aspects (SA) WG1, Terminals (T) WG2, but I also attended TSG RAN and T plenary meetings and sometimes other Working Groups and covering similar technical aspects as in my previous work in ETSI. As an example, RAN WG2 was, and is, a Working Group responsible for the specification of layer 2 and layer 3 Radio Resource, protocols for the UE. As part of this work, I would prepare meeting contributions in support of Samsung's research and development activities. Also, by way of preparation for each meeting, I would download all contributions and review those of interest to Samsung, and where necessary, prepare additional input to the meeting based on said review.

11. Beginning in 2000, I acted as project manager and then as system engineering manager at Samsung, providing technical requirements for the team working on Samsung's UMTS modem development. This involved scrutiny of ongoing standardization work, particularly in RAN WG1, RAN WG2, and TSG Core Network (CN) WG1, from which I would download, and assess the impact of, contributions on Samsung's development projects, ensuring that Samsung's

development team was kept informed about the latest developments as layers 2 and 3 of the UMTS standard were stabilized.

12. During this period, in addition to authoring and presenting technical contributions for the 3GPP standard, and producing technical requirements for the radio modem, I acted as Rapporteur for 3GPP Technical Reports covering User Equipment ("UE") capability requirements (3GPP TR 21.904) from 1999–2000, and the Evolution of the 3GPP System (3GPP TR 21.902) in 2003 (the first Study Item to consider the 3GPP system beyond UMTS towards LTE/EPS).

13. In 2005, I became Head of Advanced Technologies, Standards, and Regulation (ATSR) at Samsung. In addition to my managerial duties which included responsibility for standards, research, and regulatory engineers—including three standards engineers who were regularly attending 3GPP RAN WG2 and Core Network and Terminals (CT) WG1 Working Groups—I personally continued to work on 3GPP standardization issues. From 2005 until 2008, I regularly attended and participated in SA WG2 meetings, mainly focusing on IP Multimedia Subsystem (IMS) including voice over IMS but also looking at wider Evolved Packet System (EPS) related issues. From 2008 until 2011, I regularly attended and participated in SA WG1 meetings. I also attended SA plenary meetings from 2008 until I left Samsung in 2013. As well as generating contributions in support of Samsung's research and development as preparation for each meeting, I would download and

review documents from other 3GPP members, identifying those of interest to Samsung and, where necessary, preparing additional contributions on behalf of Samsung. The work required a sound working knowledge of the broader 3GPP system to ensure effective management of the ATSR team, effective participation in meeting discussions, expert assessment of third-party standards contributions, and provision of implementation guidance to Samsung developers.

14. From 2005 until I stopped attending SA WG1 meetings in 2011, I authored and presented over 100 contributions to SA WG2 and SA WG1 meetings at 3GPP and appeared as an author/co-author on 18 patent applications related to User Equipment operation in the IMS and the 3GPP Core Network.

15. In 2011, I became Director of Standards and Industry Affairs at Samsung, and in November of that year I was elected to the Board of ETSI on which I served for a term of 3 years until November 2014. In this position I gained further perspective on the organisation, management, and activities of ETSI and its Technical Committees and Partnership Projects including 3GPP.

16. Since leaving Samsung in January 2013, I have formed my own consulting company which is a member of ETSI, and as part of various projects undertaken, I have continued to regularly access the ETSI and 3GPP document servers, and to keep abreast of ETSI and 3GPP document handling and publication practices.

17. Through my extensive work in ETSI and on 3GPP standardization issues over the years, I have become very familiar with ETSI and 3GPP practices for when and how the technical standards (including revisions thereto) and other standards-related contributions are made publicly available, including in the 1999–2012 timeframe when I was attending or monitoring various 3GPP Working Groups, including RAN WG1 and RAN WG2, and since 2013 in support of my work as an independent standardisation consultant.

18. For purposes of my analysis in this declaration, I have been informed that a person of ordinary skill in the art ("POSITA") would have had a bachelor's degree in electrical engineering, computer engineering, or a related discipline, knowledge of the relevant 3GPP standards as of this time, and at least 2 years of experience working in a field involving wireless communications. A person with a different degree but with additional relevant experience could still qualify if the additional experience compensates for the different educational background. A person with less than 2 years of experience working in a field involving wireless communications could still qualify if the person has additional education that compensates for their lesser experience.

## III. PUBLIC AVAILABILITY OF 3GPP STANDARDS PROPOSALS AND OTHER DOCUMENTS

19. Based on my years of experience working in various capacities in 3GPP and on 3GPP standards issues, I am familiar with the regular business practices of

the 3rd Generation Partnership Project (3GPP) relating to technical documents including specifications, draft standards and proposals, and standards-related technical contributions, as well as the business practices through which 3GPP makes these documents public.

**A. Prominence and Purpose of 3GPP**

20. 3GPP was inaugurated in December 1998 to produce Technical Specifications and Technical Reports for the Universal Mobile Telecommunications System (UMTS), a 3G Mobile System based on evolved GSM core networks and a new radio access network known as UTRA (UMTS Terrestrial Radio Access). **Appendix 2** at 2, 3 ("[3GPP] Partnership Project Description"); **Appendix 3** at 1; **Appendix 4** at 5. At that time, various standards organisations agreed to cooperate to produce a "complete set of globally applicable Technical Specifications" that would then be transposed into standards by the relevant standardization bodies (also known as Organizational Partners). **Appendix 2** at 3, 5 ("[3GPP] Partnership Project Description"). 3GPP "attracted a very strong commitment from organisations and companies around the world, reflecting the truly global nature of the project." **Appendix 4** at 7.

21. 3GPP is a global initiative partnership made up of Organizational Partners, Market Representation Partners, and Individual Members. **Appendix 5** at 8, 9; **Appendix 2** at 10. Today, 3GPP unites seven telecommunications standard

development organisations ("Organizational Partners") from around the world: the Association of Radio Industries and Businesses (ARIB) and the Telecommunication Technology Committee (TTC) from Japan, the China Communications Standards Association (CCSA) from China, the Telecommunications Standards Development Society, India (TSDSI) from India, the Telecommunications Technology Association (TTA) from Korea, the European Telecommunications Standards Institute (ETSI), and the Alliance for Telecommunications Industry Solutions (ATIS) from the United States. These Organizational Partners are regional standards organisations that have the authority to define, publish, and set standards for their respective regions. **Appendix 2** at 12. 3GPP also includes "Market Representation Partners" that represent various industry perspectives and offer market advice. **Appendix 5** at 9 (3GPP Working Procedures, "Market Representation Partnership"); **Appendix 2** at 14; **Appendix 4** at 5. Additionally, 3GPP includes individual member companies ("Individual Members") that participate in 3GPP through their membership in a 3GPP Organizational Partner. **Appendix 5** at 9 (3GPP Working Procedures, "Individual Membership"); **Appendix 6** at 5 (textbook including a chart showing 3GPP structure at the time of publication); **Appendix 8** at 9, 10. As an example of how prominent 3GPP was (and remains) in the industry, there were 450 participating Individual Members in 2015. **Appendix 7** at 7 (3GPP

Project Coordination Group document showing 3GPP membership numbers to 2015). There were 835 individual members as of August 2024. **Appendix 9**.

22. As noted in paragraph 20, a primary goal of 3GPP is to provide an environment to produce Technical Specifications and Technical Reports that define and standardize technologies covering cellular telecommunications networks, including User Equipment or Mobile Device (UE) technologies, Radio Access Network (RAN) technologies, Core Network (CN) technologies, and service and system capabilities such as work on codecs, security, and quality of service. The specifications also provide hooks for interworking with non-3GPP networks including, but not limited to, Wi-Fi networks. **Appendix 2** at 32–40; **Appendix 3** at 2.

23. Given the prominence of 3GPP in the wireless communication industry, beginning in 1999 and continuing through today, interested POSITAs were tracking the developments of the latest 3GPP specifications and reports to ensure timely development of products and services by their companies that were consistent with the standards being developed. In other words, it is my opinion that a POSITA would have to be familiar with 3GPP and with the specification-related documents produced as part of the 3GPP process in order to properly perform his or her job. Without access to and knowledge of the 3GPP documentation, including, for example, the substantive contents of 3GPP technical specifications, an engineer

could not develop products that were interoperable with the worldwide 3G, 4G, and 5G standards. Because 3GPP documents were an important aspect of a POSITA's professional experience, textbooks and articles about cellular communications commonly directed readers to the 3GPP website for information regarding standards development. **Appendix 4** at 9 (directing readers to the 3GPP website at the conclusion of the chapter on the success of 3GPP in the standards development process). As a POSITA myself, I would regularly visit the 3GPP website for the latest developments in mobile communications standards setting and refer colleagues involved in the development of such devices to the 3GPP website as a valuable reference.

24. My personal experience at Samsung confirms 3GPP's prominence in the wireless industry. For example, engineers and managers at Samsung who were responsible for implementing 3GPP compliant modem software (and who were not attending 3GPP meetings or involved with development of the 3GPP standard in any direct way) would enquire as to which version of a given 3GPP specification they should be developing, or to the interpretation of specified requirements. Further, between 2000 and 2004, part of my role at Samsung involved advising software engineers implementing the 3GPP standard on the correct interpretation of the specifications and ensuring that they were made aware of any changes and proposals made during the 3GPP standards development process that would impact their work.

In short, the technical output of 3GPP was, and continues to be, well known at 3GPP member companies, even by engineers who were not directly involved with designing the 3GPP system or contributing to the 3GPP standard process.

### B. 3GPP's Policy of Making Documents Public

25. 3GPP's policy was to make 3GPP documents available to the public, including to interested POSITAs. The free availability of 3GPP documents to any interested member of the public was widely recognized in the industry. As an example of the prominence of 3GPP and its place in the wireless standards industry, I note that textbooks directed readers to the 3GPP website for information about relevant standards. For example, **Appendix 6** at 6, 9 ("The latest specifications can be obtained from 3GPP [9]", "[9] http//:www.3GPP.org"); **Appendix 8** at 10 ("3GPP TSs and TRs are publicly available at the 3GPP web site at either of the following URIs: http://www.3gpp.org/specs/specs.htm [or] http://www.3gpp.org/ftp/Specs/archive/"). Because the purpose of 3GPP is the worldwide adoption of a common standard, no restrictions on distribution or discussion have ever been placed on 3GPP documents. **Appendix 10** at 9 ("No password is needed to access any information on the 3GPP Web site, all information is openly published").

### C. 3GPP Structure and Standards Development Process

26. Within 3GPP, responsibility for producing specifications was delegated to the Technical Specification Groups (TSGs). **Appendix 5** at 10, 13 (3GPP Working Procedures, "TSG tasks"). At its inception, 3GPP was divided into four Technical Specification Groups (TSGs), each covering a particular category of technology. **Appendix 2** at 31 (3GPP Partnership Project Description); **Appendix 6** at 5, 6 (textbook listing four TSGs and noting the subsequent addition of a fifth TSG); **Appendix 4** at 6, 11, 12. Each TSG is further divided into a number of Working Groups (WGs). **Appendix 8** at 8, 9; **Appendix 4** at 6; *see also* **Appendix 5** at 13 (3GPP Working Procedures). Two of the TSGs from 1998 are still in existence in 2024: TSG Radio Access Networks (RAN) and TSG Service & Systems Aspects (SA). The activities of two other TSGs, TSG Core Networks (CN) and TSG Terminals (T), were amalgamated under Core Network and Terminals (CT) following the closure of TSG T in 2005, with responsibility for terminal test specifications being moved to a RAN working group (RAN WG5). The fifth TSG, GSM EDGE Radio Access Networks (GERAN), was responsible for evolution of the GSM radio technology from 2000 until that TSG closed in 2016 and its work was transferred to a RAN working group (RAN WG6) which was itself closed in July 2020.

27. The TSGs held quarterly plenary meetings where members' contributions, draft specifications/reports, and other documents that had been agreed upon by the Working Groups were presented for discussion and approval. **Appendix 5** at 23 (3GPP Working Procedures, "Deliverable types," stating that Technical Specifications and Technical Reports are "drawn up by the TSGs" and are approved by TSGs); **Appendix 8** at 9 ("3GPP Deliverables"). Once a Technical Specification was, or Change Requests creating a new version of a Technical Specification were, formally approved by TSG plenary, the latest version of said Technical Specification would be created by the Mobile Competence Centre (MCC) and uploaded to the file server. **Appendix 10** at 6, 7; **Appendix 11** at 1. In that way, the conclusion of 3GPP TSG plenary meetings serves as notice that new versions of specifications incorporating Change Requests approved by the TSG meeting will shortly be made available on the public 3GPP server.

28. As part of the standards development process, delegates could submit contributions on behalf of the Individual Members. Members had an incentive to stay updated on 3GPP developments because those members usually wanted to contribute to the standard and make suggestions as to what technology and/or features should (or should not) be included. Delegates also attended 3GPP meetings to keep their employers abreast of developments related to the standards that would ultimately apply to those members and the products those members (*e.g.*, companies)

produced. 3GPP members around the world, and the interested POSITAs employed by them, would have been motivated to stay up to date regarding 3GPP technology evolution to ensure their research and development programmes remained relevant to the systems being specified and that their products were compliant with the published 3GPP specifications. In light of this need to follow the standards development process, delegates often distributed 3GPP-related documents far beyond the attendees at 3GPP meetings. This was certainly my experience at Samsung.

### D. 3GPP Documents

#### 1. Technical Specifications and Reports

29. The Technical Specifications and Reports developed by 3GPP were, and still are, driven by the technical contributions of 3GPP members. As part of that development process, various types of documents were produced. The 3GPP process involved the consideration of temporary documents ("TDocs," also referred to as "contributions"), many of which constituted technical proposals for how the system should be implemented and some of which were adopted as the basis for parts of the Technical Specifications.

30. As I noted in paragraphs 20 and 22, a primary purpose of 3GPP is to prepare, approve, and maintain globally applicable Technical Specifications and Technical Reports. **Appendix 5** at 7 (3GPP Working Procedures, "Purpose"). A

"Technical Specification" as defined by 3GPP is "[a] 3GPP output document containing normative provisions approved by a Technical Specification Group." **Appendix 5** at 28. 3GPP would (and still does) periodically freeze a complete set of standards (referred to as a "Release"), and each set would include new specifications. **Appendix 10** at 6. 3GPP would also make publicly available draft specifications that would usually be included as part of the next Release once approved.

31. It was widely known that Technical Specifications (and Technical Reports) were publicly available on 3GPP's website. It was also well known that the latest version of a given specification that was under change control would be made available following each TSG Plenary meeting responsible for that specification, and that TSG Plenary meetings usually occur four times per year. **Appendix 10** at 6; **Appendix 11** at 1.

32. Latest and previous versions of Technical Specifications could be easily accessed from the 3GPP website. The specifications page provided direct links to the specifications area in the 3GPP website's file repository. **Appendix 11** at 1. In the 2014 timeframe, the specifications page listed the specifications by the date of the approval of the latest versions reflecting the TSG plenary meeting date. *E.g.*, **Appendix 11** at 1.

33. Additionally, the 3GPP specifications followed a clear numbering scheme to help the public, including interested POSITAs, identify the subject matter

of each specification. **Appendix 12** at 1. As described on the 3GPP Numbering Scheme webpage, all 3G and GSM specifications had a specification number of 4 or 5 digits, where the first two digits defined the series. **Appendix 12** at 1. The Numbering Scheme webpage included a table showing the subject matter corresponding to each series. **Appendix 12** at 1. For example, the "36 series" focused on "LTE (Evolved UTRA) and LTE-Advanced radio technology" aspects (*i.e.*, 4G or LTE). **Appendix 12** at 1. An interested POSITA could narrow down the relevant specifications based on whether the specification applied to only evolved UTRA (*i.e.*, 4G or LTE), 3G, GSM, or to GSM, 3G and evolved UTRA (GSM-only specifications were transferred from ETSI to 3GPP in July 2000). **Appendix 12** at 1. For a specification in the 21–35 series, this could be determined based on the third digit of the specification number, where a "0" indicates that the specification applies to both systems. Specifications outside the 21–37 series in 2014 applied only to GSM systems. **Appendix 12** at 1.

34. The specifications were stored on the 3GPP website's file repository as zipped files, where the filenames followed the structure: SM[-P[-Q]]-V.zip. This format corresponded to the numbering scheme discussed in paragraph 33. **Appendix 12** at 2. "S" represented the series number; "M" represented the mantissa (the part after the series number); "P" represented an optional part number; "Q" represented

an optional sub-part number; and "V" represented the version number (without the separating dots). **Appendix 12** at 2.

35. The Working Groups would create incremental versions of the draft specifications (*e.g.*, V0.2.1, V1.0.0, V1.1.0, etc.). These versions were made available on the 3GPP website's file repository which is accessible from the 3GPP specifications page. The version numbering scheme for Technical Specifications and Technical Reports was standardized by 3GPP. The version number included three fields: the major version field, the technical version field, and the editorial version field. **Appendix 13** at 3. The major version field reflects the stage of the specification, with "0" representing an immature draft and a value of "3" or greater representing a specification that has been approved by the relevant TSG and thus placed under change control. **Appendix 13** at 3. The technical version field begins at zero and is incremented every time a technical change is made to the specification (either as part of the drafting process or as part of an approved change request). **Appendix 13** at 3. The editorial version field begins at zero and is incremented each time a non-technical change is made to the specification (*e.g.*, to fix a typographical or formatting issue). **Appendix 13** at 3.

36. I understand that the alleged invention in the '460 patent relates to cellular telecommunications networks, and more particularly to an UL data transmission procedure. Any POSITA interested in UL data transmission procedures

would have been monitoring 3GPP's activities in this area and would probably have been already participating as a full or associate member or observer in the standard development process, or would have at least known that information regarding the proposed revisions to the technical specifications under discussion were available through 3GPP.

**2. 3GPP TDocs**

37. As mentioned in paragraph 29, the technical specifications and reports developed by 3GPP were and are driven by the technical contributions of 3GPP member companies. As part of that development process, various types of documents were produced and submitted. Relevant to this case, the 3GPP process involved the consideration of temporary documents or "TDocs," which are also referred to as proposals, contributions, or change requests. The agreement of proposals submitted as TDocs results in the production of technical specifications.

38. Prior to each Working Group meeting, members of the Working Group would prepare TDocs to identify, discuss, and/or propose a new feature or change(s) to an existing feature or to identify a technical issue for discussion. Interested POSITAs would have known that TDocs could be a helpful source of technical information regarding the 3GPP specifications.

39. Each TDoc was assigned a TDoc number, according to a standard format set by 3GPP.[1] As described in the 3GPP Working Procedures, the numbering system followed the format xminnzzzz. **Appendix 5** at 19. This general naming convention has been in use since at least 1999 with only minor variations. Within that format, "x" referred to the relevant TSG. **Appendix 5** at 20. For example, "R" was used for TSG RAN. **Appendix 5** at 20. Likewise, "m" referred to the relevant Working Group. **Appendix 5** at 20. A document for RAN WG1 would therefore begin with "R1." **Appendix 5** at 20. The "i" is normally a hyphen character but may take on other values depending on the meeting to which the Tdoc is sumbmitted. The two digits "nn" represented the year (*e.g.*, 17), and the digits "zzzz" represented the unique document number. **Appendix 5** at 20. This document number was used as the TDoc's filename. **Appendix 5** at 20.

40. Each TDoc would include in its header the meeting at which the contributor intended the TDoc to be discussed. Most TDocs were uploaded to the 3GPP website for public viewing prior to the relevant Working Group meeting listed on the TDoc, although some TDocs, including those created at meetings, were

[1] Documents other than technical contributions (such as meeting reports) were also assigned TDoc numbers for ease of reference.

uploaded during or after the meeting. **Appendix 10** at 10. The documents were uploaded to the public file repository in an area allocated to the particular Working Group, *e.g.*, **Appendix 14** at 2 (RAN WG1 homepage with link to WG1's "Documents area"). Immediately upon upload, any member of the public could download and access the TDocs and other documents offered for discussion. This process has been in place since I began attending Working Group meetings in 1999.

**E. The 3GPP Website's Public File Repository**

41. All TDocs, Technical Reports, and Technical Specifications were also freely available to interested members of the public through the public file repository accessible via the 3GPP website. Interested members of the public would have been well aware of 3GPP and of the 3GPP website. 3GPP documents were accessible to any member of the public through the 3GPP website without providing any login credentials or other exclusive access criteria. **Appendix 10** at 9.

42. It is my recollection that in the 2014 to 2018 timeframe, any interested member of the public could locate relevant documents of interest on the 3GPP website using reasonable diligence based on the website's indexing scheme, the specification numbering, and/or the TDoc's naming convention. The TDocs on the 3GPP website file server were (and remain) organized according to the relevant Working Groups within 3GPP (each of which focused on particular subject matter) and then further organized based on the meetings of those groups. The Technical

Specifications and Reports were (and remain) organized according to their subject matter as indicated by their series number and version. POSITAs would have known which Working Groups focused on particular subject matter.

43. An interested member of the public could locate documents of interest by first navigating a web browser to the 3GPP website (www.3gpp.org). In the 2014 to 2018 timeframe, to locate documents from the 3GPP home page, a user could have clicked "Specification Groups" **Appendix 15**. The corresponding webpages contained links to the 3GPP's public file repository (*e.g.*, through the "Documents area" link of a Working Group page). **Appendix 14**. To locate specifications, a user could have clicked "Specifications" and followed links as described in section III.D.1 above. Instead of accessing the 3GPP file repository from the 3GPP website home page, a user could have also accessed the file repository through the web address www.3gpp.org/ftp or directly using ftp client software connected to ftp.3gpp.org. A POSITA was also able to search for relevant documents using keywords on the search facility on the 3GPP website from at least 2000, and from at least 2015 using the 3GPP search portal (https://portal.3gpp.org/#/), where an interested person could search for documents by title and source, among other things.

44. The top two levels of indexing within the file repository were based wholly on subject matter, as reflected by the division of subject matter among the various TSGs and Working Groups, or into various Specifications. Specifically, an

individual could select the relevant TSG (or specification series) covering the subject matter of interest. **Appendix 16**.

45. For example, if the individual were interested in the radio access aspects of 3GPP, they would click "tsg_ran." From there, the individual would click on the particular RAN Working Group covering the subject matter of interest. **Appendix 17**.

46. Then, if the individual were interested in the Radio Interface Radio layer 1, the individual would know to choose the folder for WG1. **Appendix 17**. Once a user is in the relevant Working Group folder (RAN WG1 in this example), an individual would see a list of all meetings held by RAN WG1 including ad hoc meetings. **Appendix 18**, **Appendix 19**.

47. As shown in **Appendix 18** and **Appendix 19**, a folder existed for each meeting including ad hoc meetings ("TSGR1_AH"). For example, "NR_AH_1801" corresponded to TSG RAN WG1 NR ad hoc meeting January 2018.

48. A POSITA would know which meeting(s) would have covered particular subject matter based on the working groups area of responsibility (*e.g.*, for RAN WG1 - **Appendix 14)**, and from publicly available meeting agendas. See e.g., Agenda link in **Appendix 20**. Many POSITAs received notification of the meeting agenda directly via the 3GPP Working Group email reflector lists. **Appendix 21**.

Further, an individual could ascertain what subject matter was addressed at each meeting by reviewing the report issued after each meeting. **Appendix 22.**

49. In my experience, whilst the servers used for 3GPP file repository and many of its directories have been updated since 1999, and directories may as a result have later dates associated with them (*e.g.*, reflecting the last time they were modified in some way or their contents were updated), the original upload date for files including specifications has always been preserved, providing a true and accurate indication of their earliest availability for download.

50. Once an individual navigated to the desired meeting folder, for example "NR_AH_1801" the individual could then select the "Docs" folder to view the documents associated with that meeting. **Appendix 23.** The documents within this folder were listed by TDoc number, and interested members of the public would have known to review the meeting report for each meeting to confirm which topics were discussed at that meeting. *E.g.*, **Appendix 22**. The meeting report also contained a complete list of TDocs submitted to the meeting which could be sorted by title, agenda item and agenda item description among other things. **Appendix 22a** (Annex A of the meeting report). The TDoc list is also accessible from the "Docs" folder. **Appendix 23** at 38.

51. Many TDocs were uploaded to the public file server for public viewing prior to the relevant meeting (although some TDocs, particularly those created

during meetings, were uploaded during or soon after the meetings). **Appendix 10** at 10. Throughout and since my participation in 3GPP, it has been recommended that delegates attending a meeting download the relevant set of documents from the 3GPP file repository onto their personal computers prior to each meeting. **Appendix 10** at 8. Given that any interested member of the public could and was likely to subscribe to the Working Group email reflector, it would also have been simple to locate the location of relevant TDocs on the 3GPP server based on the information sent out to said email reflector.

52. 3GPP's public file repository provides a reliable mechanism for identifying the date and time a document was uploaded to the website and then available to download for public viewing. When a document is uploaded, the file server automatically assigns the document a time stamp—*i.e.*, an accurate and automatically computer-generated electronic record of when the document was uploaded—as part of the regular business practices of 3GPP. **Appendix 10** at 10 (3GPP FAQs). This has been the practice regarding uploading documents to the 3GPP file repository since 3GPP was inaugurated, and my personal experience confirms that the time stamps have always been a reliable way to determine when a file was uploaded to the 3GPP website and immediately available for public download.

53. Following each 3GPP meeting, there would be post meeting discussion of various issues arising at the meeting, and the secretary would usually distribute a draft meeting report or the chairman's notes of the meeting via the corresponding email list,. *E.g.*, **Appendix 24**. Such emails would effectively inform subscribers that the meeting had taken place, would inform subscribers of the documents that had been treated (or not), and in the event that the meeting was a TSG plenary meeting, would serve as notice that new versions of specifications incorporating approved Change Requests, would shortly be made available on the 3GPP public server. Further, an interested member of the public following a certain topic would have known to check said report for related contributions.

## IV. 3GPP EXHIBITS

### A. EXHIBIT 1017: 3GPP R1-1801080 "Offline summary for AI 7.3.3.4 UL data transmission procedure"

54. R1-1801080 is a technical contribution submitted to 3GPP TSG RAN WG1, NR ad hoc meeting NR_AH_1801, which was held between January 22 – 26, 2018. It follows the general naming format ("xminnzzzz") described in paragraph 39. Accordingly, "R1" indicates that the contribution was submitted to RAN WG1, "18" indicates the year (2018) that this technical contribution was submitted, and

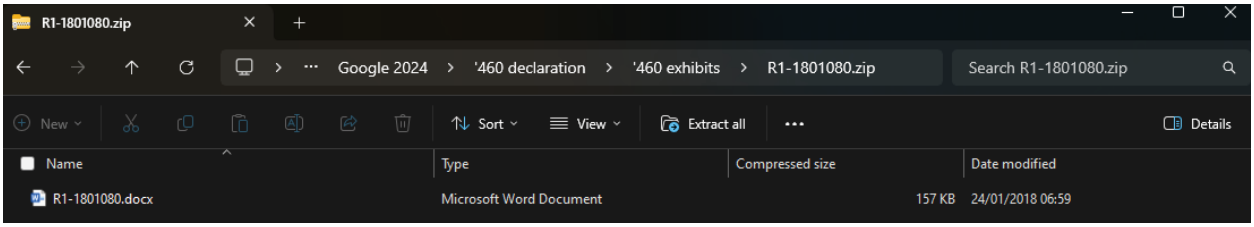
"01080" is the unique number that was assigned to this contribution document[2]. It is titled "Offline summary for AI 7.3.3.4 UL data transmission procedure".

55. As I mention in paragraph 41 above, 3GPP meeting documents have always been and were in the 2014 to 2018 timeframe, made publicly available on the 3GPP public file server from where an interested member of the public exercising reasonable diligence could freely access them. To confirm the availability of R1-1801080 on the 3GPP document server in 2018, I navigated to the 3GPP website at http://www.3gpp.org, selected "3GPP Groups" from the drop down menu, and then selected the "RAN1 – Radio Layer 1" from the 3GPP Groups page, and the "Documents area" link to access the public file server where documents for the TSG-RAN Working Group 1 are stored, and from where I navigated to the documents for RAN WG1 NR_AH_1801. A true and correct copy of the relevant portion of the Documents directory listing produced by the file server website is provided below and in **Appendix 23** at 32.

[2] TSG RAN WG1 added an extra 'z' digit to the TDoc number from August 2016 to cater for the increasing number of contributions that were being submitted.

| | | |
|---|---|---|
| R1-1801079.zip | 2018/01/24 14:16 | 74,3 KB |
| R1-1801080.zip | 2018/01/24 14:16 | 156,4 KB |
| R1-1801081.zip | 2018/01/24 14:16 | 85,4 KB |

56. The Docs directory index stated that R1-1801080 was uploaded on "2018/01/24". I selected the link for "R1-1801080.zip" and downloaded a zip file of the same name. The zip file contained a Microsoft Word document, "R1-1801080.docx", with a date stamp of "24/01/2018" (European date format) the same date that the zip file was uploaded.




57. A true and correct copy of the document within the zip file (R1-1801080.zip) is provided as EX1017. Based on my experience, I understand that these date stamps mean that R1-1801080.zip was uploaded to 3GPP's publicly available website on January 24, 2018, prior to the RAN WG1 NR_AH_1801 meeting, and that any member of the public could have downloaded the zip file, extracted the Word document enclosed, and viewed the contents of said document without restriction on January 24, 2018 and thereafter. The report from RAN WG1 NR_AH_1801, confirms the availability of R1-1801080 at the meeting (**Appendix 22** at 91, **Appendix 22a** at index 1082). I have no reason to believe that either the

date stamp or the report from RAN WG1 NR_AH_1801 are inaccurate. I have therefore determined that R1-1801080 was publicly available on the file server no later than January 24, 2018.

58. Based on the information above, it is my opinion that R1-1801080 titled "Offline summary for AI 7.3.3.4 UL data transmission procedure" and provided as EX1014 was publicly available to download from the 3GPP file server no later than January 24, 2018 and could have been distributed thereafter without restriction. Further, it was publicly available at the 3GPP TSG RAN WG1 NR_AH_1801 meeting held from January 22 – 26, 2018.

### B. EXHIBIT 1024: 3GPP TS 36.211 v11.6.0 (2014-09) 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 11)

59. 3GPP TS 36.211 v11.6.0 is a Technical Specification titled "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 11)".

60. The date on the face of the specification ("2014-09") corresponds to the year (2014) and month (September) that this version of the specification having been approved by 3GPP TSG RAN was made publicly available.

61. 3GPP TS 36.211 v11.6.0 being an approved version of the Release 11 Physical channels and modulation specification,, was approved by TSG RAN #65

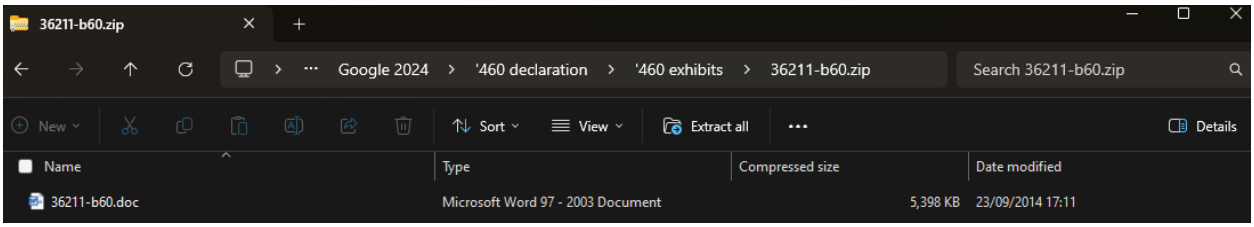
held September 9 – 12, 2014. An interested member of the public would know that the latest version of an approved specification or report would be available following the plenary meeting responsible for that specification (in this case TSG RAN) in accordance with 3GPP standard practice as described in paragraphs 31. The approval of the TS 36.211 v11.6.0 is confirmed by the approval of the Change Request to TS 36.211 v11.5.0 documented in the meeting report from TSG RAN #65 (**Appendix 25** at 158).

62. The 3GPP file server is and always has been open to all and free from restriction such as username or password. By way of example of how an interested member of the public could access the TS 36.211 v11.6.0 technical specification from the 3GPP website, I accessed the file server by going to the 3GPP website at http://www.3gpp.org/, selected "Specifications & Technologies" from the menu bar, and then selected "Specifications by series" from the dropdown menu. I then selected the "36 Series" link to access the public file server where the specifications are stored. I then searched for "36.211" in the specification number search bar, and for the TS 36.211 specification selected the eyeglasses icon that says "See details" when a cursor is placed on it. From there, I selected "Click to see all versions of this specification," which took me to the archive housing all versions of TS 36.211 found at the following URL: https://www.3gpp.org/ftp/Specs/archive/36_series/36.211. A true and correct copy of the relevant portion of the directory listing produced by the

file server website is provided below and in **Appendix 26** at 2

| | | |
|---|---|---|
| 36211-b50.zip | 2013/12/14 9:47 | 5475,6 KB |
| 36211-b60.zip | 2014/09/23 14:11 | 5397,9 KB |
| 36211-b70.zip | 2017/03/23 11:06 | 5398,8 KB |

63. The archive directory index stated that TS 36.211 v11.6.0 was uploaded on "2014/09/23". Selecting the link for "36211-b60.zip", I downloaded a zip file of the same name. The zip file contained a Microsoft Word document with the filename "36211-b6" and having date stamps of "23/09/2014" (European date format)[3]. An excerpt of the zip file directory is provided below.




64. I have confirmed that the Word document with the filename "36211-b60" is TS 36.211 v11.6.0. A true and correct copy of the compiled Microsoft Word

[3] The apparent later time of the date modified field for the Word document is explained by the time zone of the PC on which the Word document was last saved, prior to being compressed and uploaded, being later than the time-zone of the 3GPP server.

documents with the filename "36211-b60" is the TS 36.211 v11.6.0 that is provided in EX1024.

65. Based on my experience, I understand these date stamps to mean that 36211-b60.zip was uploaded to 3GPP's publicly available website on September 23, 2014, and that an interested member of the public could have downloaded the zip file, extracted the Word document enclosed, viewed the contents of the Word document, and further disseminated said document without restriction on September 23, 2014 and thereafter.

### C. EXHIBIT 1025: 3GPP TS 36.213 v11.6.0 (2014-03) 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 11)

66. 3GPP TS 36.213 v11.6.0 is a Technical Specification titled "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 11)".

67. The date on the face of the specification ("2014-03") corresponds to the year (2014) and month (March) that this version of the specification having been approved by 3GPP TSG RAN was made publicly available.

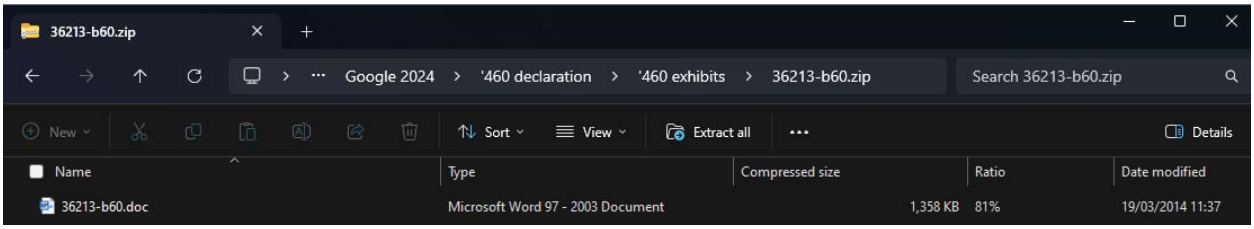
68. 3GPP TS 36.213 v11.6.0 being an approved version of the Release 11 Physical layer procedures specification, was approved by TSG RAN #63 held March 3 – 6, 2014. An interested member of the public would know that the latest version

of an approved specification or report would be available following the plenary meeting responsible for that specification (in this case TSG RAN) in accordance with 3GPP standard practice as described in paragraphs 31. The approval of the TS 36.213 v11.6.0 is confirmed by the approval of the Change Request to TS 36.213 v11.5.0 documented in the meeting report from TSG RAN #63 (**Appendix 27** at 118).

69. The 3GPP file server is and always has been open to all and free from restriction such as username or password. By way of example of how an interested member of the public could access the TS 36.213 v11.6.0 technical specification from the 3GPP website, I accessed the file server by going to the 3GPP website at http://www.3gpp.org/, selected "Specifications & Technologies" from the menu bar, and then selected "Specifications by series" from the dropdown menu. I then selected the "36 Series" link to access the public file server where the specifications are stored. I then searched for "36.213" in the specification number search bar, and for the TS 36.213 specification selected the eyeglasses icon that says "See details" when a cursor is placed on it. From there, I selected "Click to see all versions of this specification," which took me to the archive housing all versions of TS 36.213 found at the following URL: https://www.3gpp.org/ftp/Specs/archive/36_series/36.213. A true and correct copy of the relevant portion of the directory listing produced by the file server website is provided below and in **Appendix 28** at 2

| | | |
|---|---|---|
| 36213-b50.zip | 2013/12/15 8:18 | 1491,4 KB |
| 36213-b60.zip | 2014/03/19 10:37 | 1357,4 KB |
| 36213-b70.zip | 2014/06/19 14:34 | 1357,9 KB |

70. The archive directory index stated that TS 36.213 v11.6.0 was uploaded on "2014/03/19". Selecting the link for "36213-b60.zip", I downloaded a zip file of the same name. The zip file contained a Microsoft Word document with the filename "36213-b60" and having date stamps of "19/03/2014" (European date format)[4]. An excerpt of the zip file directory is provided below.




71. I have confirmed that the Word document with the filename "36213-b60" is TS 36.213 v11.6.0. A true and correct copy of the compiled Microsoft Word documents with the filename "36213-b60" is the TS 36.213 v11.6.0 that is provided

[4] The apparent later time of the date modified field for the Word document is explained by the time zone of the PC on which the Word document was last saved, prior to being compressed and uploaded, being later than the time-zone of the 3GPP server.

in EX1025.

72. Based on my experience, I understand these date stamps to mean that 36213-b60.zip was uploaded to 3GPP's publicly available website on March 19, 2014, and that an interested member of the public could have downloaded the zip file, extracted the Word document enclosed, viewed the contents of the Word document, and further disseminated said document without restriction on March 19, 2014 and thereafter.

## V. CONCLUSION

73. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that, if required, I will make myself available for cross-examination to take place within the United States, during the time allotted for cross-examination.

74. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Date: December 18, 2024

Craig Bishop

**3GPP TSG RAN WG1 NR Ad Hoc Meeting** **R1-1801080**
**Vancouver, Canada, 22-26 January, 2018**

**Source:** **NTT DOCOMO, INC.**
**Title:** **Offline summary for AI 7.3.3.4 UL data transmission procedure**
**Agenda Item:** **7.3.3.4**
**Document for:** **Discussion and Decision**

# 1. Introduction

This document summarizes key issues relevant to AI 7.3.3.4 UL transmission procedures. In the following, the discussions are organized with the priority of the issues having RAN2 impacts first.

# 2. Correction on RRC parameters

## 2.1. SR configurations

At RAN1 #90bis meeting, SR periodicity was agreed as following:

Agreements:
- At least support following as the periodicity of resources for SR
  - FFS other values with taking into account the alignment with 14 symbols
  Supported periodicity

Supported periodicities

| **Subcarrier spacing (kHz)** | **Supported periodicities [ms]** |
|---|---|
| 15 | 2 symbols, 7 symbols, 1,2,5,10,20,40,80 |
| 30 | 2 symbols, 7 symbols, 0.5,1,2,5,10,20,40,80 |
| 60 | 2 symbols, 7 symbols (6 symbols for ECP), 0.25,0.5,1,2,5,10,20,40,80 |
| 120 | 2 symbols, 7 symbols, 0.125,0.25,0.5,1,2,5,10,20,40,80 |

In [3], it was proposed to align with 2ms cell-specific UL/DL configuration, SR configuration with periodicity values of $2^k$ slots, where k is {1, 2, 3, 4}.

Any comments?

| Company | View |
|---|---|
| | |

## 2.2. Repetition number *K* for mini-slot

It was agreed that the value of the K repetitions is 1, 2, 4, and 8. It is noted that for multiple mini-slot scheduling using repetitions, these values cannot be well aligned with the slot boundary. Therefore, it is better to support {1, 2, 7, Reserved} as the values of K repetitions for multiple mini-slot scheduling.

Any comments?

| Company | View |
|---|---|
| | |



**Petitioners' Exhibit 1017**
**Google et al. v. KT Corporation et al.**
**IPR2025-00291**

## 2.3. Frequency hopping

At the RAN1 #91 meeting, following agreements were made for frequency hopping:

Agreements:

- For PUSCH transmission with UL grant (other than Msg.3) and Type 2 UL transmission without UL grant with intra-slot FH,
  - frequency hopping offset(s) in frequency domain is/are explicitly configured by UE-specific RRC signaling
  - explicit frequency hopping flag is included into DCI format scheduling/activating UL transmission
- If the frequency hopping flag is enabled, the following number of hopping bits are taken from the resource allocation Type 1 indication field:
  - 1 bit: if the active BWP less than X1 PRB
    - To indicate one of two RRC configured offsets
  - 2 bit: if the active BWP is larger or equal than X1
    - To indicated one of four RRC configured offsets
  - The value of X1 is fixed in the spec with a value of [50]

Agreements:

- For Type 1 UL transmission without UL grant with intra-slot FH, a separated frequency hopping offset field from the frequency resource allocation field is explicitly configured by UE-specific RRC signaling.
  - The possible values for frequency hopping offset are the same as that for UL transmission with UL grant.

Current spec. 38.214 section 6.3 defines UE PUSCH frequency hopping procedure.

[…]

When frequency hopping on PUSCH is enabled and for resource allocation type 1, frequency offsets are configured by higher layer parameter *Frequency-hopping-offsets-set*:

- when the size of the active BWP is less than [50] PRBs, one of two higher layer configured offsets is indicated in the UL grant
- when the size of the active BWP is greater than [50] PRBs, one of four higher layer configured offsets is indicated in the UL grant

[6], [15] and [18] proposed to confirm the 50 PRBs as the BWP size boundary between two offsets and four offsets. Then, each value of the frequency hopping offset can be in the range of [0, $N_{BWP}^{size} - 1$].

**Proposal 1:**

- *Confirm the value 50 as the boundary number of PRBs in the active UL BWP between the bandwidths having two or four frequency offsets for frequency hopping on PUSCH.*
  - *Each value of the frequency hopping offset can be any integer value between 1 and* $N_{BWP}^{size} - 1$.

Any comments?

| Company | View |
|---|---|
| | |

## 2.4. Configured Grant (CG) Type 1 and Type 2 UL transmissions

Appnedix lists the RRC configurations for UL trasnmission with configured grant captured in the spec. 38.331. Following additions/corrections or clarifications are necessary:

- For both Type 1 and Type 2:
  1. Power control parameters: P_0 and alpha, the value and range are the same as for UL transmission with dynamic grant
  2. nrofHARQ-processes: any integer value between 1 and 16
  3. frequency hopping offset: 2 or 4 values depending on the BWP size $N_{BWP}^{size}$, each value an be any integer value between 1 and $N_{BWP}^{size} - 1$

Any comments?

| Company | View |
|---|---|
| | |

- For Type 1
  1. timeDomainOffse: [1] propoed that the value range should be any integer between 0 and 319 slot using SCS = 480KHz, i.e., $\mu$=5 as defined in spec. 38.211.
  2. timeDomainAllocation: one row index of the table [pusch-symbolAllocation] for UL transmission with dynamic grant, note that the slot offset K2 indicated by the row index of the table [pusch-symbolAllocation] should be ignored
  3. dmrs
  4. mcsAndTBS
  5. Indication of UL/SUL
  6. frequencyDomainAllocation

- Some ambiguous RRC parameters, they should be configured separately or jointly for UL transmission with dynamic UL grant or configured grant?
  1. Repetition number K, i.e., repK: ENUMERATED (1, 2, 4, 8)
  2. frequencyHopping: ENUMERATED {mode1, mode2}
     - mode1 and mode2 refer to Intra-slot frequency hopping and Inter-slot frequency hopping mode

Currently, parameter frequencyHopping only exsists for PUSCH configuration that is for dynamic grant based transmission. While it is understood that the parameter Repetition number K should be separately configured for configured grant Type 1/Type 2 trasnmission and dynamic grant based transmission. Then it is also reasonable to propose that the parameter frequencyHopping should also be separately configured for UL transmission with dynamic UL grant and with configured grant.

In addition, it is worthwhile to also consider the joint or separate configuration of repetition K for long PUCCH cross multiple slots.

Any comments?

| Company | View |
|---|---|
| | |

3. Resource allocation type: at the RAN1 #91 meeting, following agreements made in resource allocation session:

Agreements:
- For fallback DCI, only a single layer transmission can be scheduled
- For non-fallback DCI, NR supports RRC configuration separately for DL and UL:
  - using resource allocation type 1 only, or,
  - using resource allocation type 0 only, or,
  - dynamic switching between resource allocation type 0/1 using a 1 bit flag in the DCI
  - Note: in either case, one or more layers transmission can be scheduled

For UL transmission using configured grant Type 1, the frequency domain resource allocation can follow the same way as dynamic grant-based UL transmissions if RRC configures using resource allocation type 1 only, or, using resource allocation type 0 only. However, for grant based PUSCH transmission, if RRC configures dynamic switching between resource allocation type 0/1 using a 1 bit flag in the DCI, what the exact resource allocation type should be used for configured grant Type 1 PUSCH trasnmission needs to be discussed.

Any comments?

| Company | View |
|---|---|
| | |

4. Comparing the RRC parameters of PUSCH-Config and SPS-Config in current spec. 38.331, (also listed in appendix), following paramters need to be discussed. It is noted that we agreed to reuse the MCS table and TBS calculation formula and the configuration as in grant-based case for both Type 1 and Type 2.
   - dmrs-Type
   - dmrs-AdditionalPosition
   - phaseTracking-RS
   - tpcAccumulation
   - tpc-PUSCH-RNTI
   - rateMatching
   - rateMatchResources
   - uci-on-PUSCH
     - dynamic
     - semi-static

Any comments?

| Company | View |
|---|---|
| | |

## 2.5. SP-CSI reporting on PUSCH

Appendix also list the RRC parameters for SP-CSI report on PUSCH. It is common understanding that the mechanism including the higher layer configuration and L1 activation/deactivation siganlling for SP-CSI reporting on PUSCH is similar as configured grant Type 2 PUSCH transmission. Still some aprameters listed below are not clear for SP-CSI reporting on PUSCH, i.e., whether it can reuse the parameters configured in PUSCH-config..

- dmrs-Type
- dmrs-AdditionalPosition
- phaseTracking-RS
- tpcAccumulation
- tcp-PUSCH-RNTI
- frequencyHopping
- rateMatching
- rateMatchResources
- symbolAllocationIndexs
- mcs-Table
- mcs-TableTransformPrecoder
- transformPrecoder
- rbg-Size
- uci-on-PUSCH
- xOverhead
- Repetition number *K*

Any comments?

| Company | View |
|---|---|
| | |

# 3. Corrections on current spec.

## 3.1. UL Waveform determination

At the RAN1 #90bis meeting, following agreements were made for UL waveform determination:

**Agreements:**

- For UL transmission with grant,
  - By UE-specific RRC signaling, a UE can be configured with UL waveform that is different from the one configured by RMSI for Msg3. Once configured;
    - When the non-fallback DCI schedules the PUSCH transmission, the UE uses the UL waveform configured by the UE-specific RRC signaling; when the fallback DCI schedules the PUSCH transmission, the UE uses the UL waveform configured by RMSI for the PUSCH transmission.
  - If the UE is not configured with UL waveform that is different from the one configured by RMSI for Msg3;
    - The UE uses the UL waveform configured by RMSI for the PUSCH transmission.
  - FFS: whether the fallback DCI is based on DCI format/size or on search space.
  - RMSI informs single waveform to the UE

**Agreements:**

- For Type 1 and Type 2 UL transmission without grant,
  - By UE-specific RRC signaling, a UE can be separately configured with UL waveform that is different from the one configured by RMSI for Msg3.

– Note: even if the UE is configured with Type 1 and Type 2 UL transmission without grant, the UE may transmit PUSCH that is scheduled by UL grant, in which case the UL waveform determination for UL transmission with grant is used.

Based on above agreements, the transform precoding parameter should not be the optional parameters, higher layer should always configure for UL transmission with dynamic grant and without grant separately. Therefore following modifications are made for spec. 38.214 section 6.1.3.

### 6.1.3 UE procedure for applying transform precoding on PUSCH

For Msg3 PUSCH transmission, the UE shall consider the transform precoding either enabled or disabled according to the higher layer configured parameter *msg3-tp*.

For PUSCH transmission scheduled with a ~~DL~~ UL DCI:

- If the DCI with the scheduling grant was received with DCI format ~~1~~0_0, the UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to the higher layer configured parameter *msg3-tp*.
- If the DCI with the scheduling grant was not received with DCI format ~~1~~0_0
  - ~~If the UE is configured with the higher layer parameter [*transform-precoding-scheduled*], t~~The UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to the higher layer configured parameter [*transform-precoding-scheduled*] ~~this parameter~~.
  - ~~If the UE is not configured with the higher layer parameter [*transform-precoding-scheduled*], the UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to the higher layer configured parameter *msg3-tp*.~~

For PUSCH transmission using ~~Uplink Transmission without a grant~~ configured grant

- ~~If the UE is configured with the higher layer parameter [transform-precoding-TWG], t~~The UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to the higher layer configured parameter [*transform-precoding-TWG*] ~~this parameter~~.

~~If the UE is not configured with the higher layer parameter [transform-precoding-TWG], the UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to the higher layer configured parameter msg3-tp.~~

Any comments?

| Company | View |
|---|---|
| | |

## 3.2. Frequency hopping

In this section, the issues related to frequency hopping without involving RRC impacts are discussed. In spec. 38.214 section 6.3, following description for the inter-slot frequency hopping can be confirmed, that is to remove square brackets of the following.

[…]

~~[~~In case of inter-slot frequency hopping, hopping happens at each slot. The starting RB during slot $n_s^\mu$ is given by:

$$\mathrm{RB}_{\mathrm{start}}\left(n_s^\mu\right)=\begin{cases}\mathrm{RB}_{\mathrm{start}} & n_s^\mu \bmod 2=0\\ \left(\mathrm{RB}_{\mathrm{start}}+\mathrm{RB}_{\mathrm{offset}}\right)\bmod N_{BWP}^{size} & n_s^\mu \bmod 2=1\end{cases}, ~~]~~$$

where $n_{s,0}^{\mu}$ is the slot number within a radio frame of the first PUSCH slot of a multi-slot PUSCH transmission, $n_s^{\mu}$ is the current slot number within a radio frame, where a multi-slot PUSCH transmission can take place, $RB_{start}$ is the starting resource within the UL BWP, as calculated from the resource block assignment information of resource allocation type 1 (described in sub-clause 6.1.2.2.2) and $RB_{offset}$ is the frequency offset in RBs between the two frequency hops.

**Proposal 2:**

- *Confirm the description of inter-slot frequency hopping in 38.214 and remove the square brackets.*

Any comments?

| Company | View |
|---|---|
| | |

Another remaining issue is that the intra-slot frequency hopping boundary in time-domain for PUSCH needs to be defined. It is straightforward and desirable to apply the same rule as for PUCCH, that is for PUSCH occupying N symbols within one slot, the number of symbol in the first hop is floor(N/2), the number of symbol in the 2nd hop is ceil(N/2). So far, duration of each hop for intra-slot frequency-hopping with a PUCCH duration is not captured in the specification. Once it is captured in the spec, PUSCH can refer to the description.

**Proposal 3:**

- *Describe time-domain frequency hopping boundary for PUSCH.*

Any comments?

| Company | View |
|---|---|
| | |

For Msg.3 transmission, the possible values of hopping offsets are fixed in the specification and determined based on the size of initial active UL BWP. If the number of hopping offsets is more than one, 1 or 2-bit L1 signaling is needed in the UL grant carried by RAR to indicate which offset is used. Table 1 gives an example.

Table 1: hopping bit definition for Msg.3

| **Initial active UL BWP size** | **Number of hopping bits** | **Hopping offsets for Msg.3** |
|---|---|---|
| [24] | 0 | $N_{BWP}^{size}/2$ |
| [48] | 1 | $N_{BWP}^{size}/2$, $N_{BWP}^{size}/4$ |
| [96] | [2] | [reserved, $N_{BWP}^{size}/2$, $N_{BWP}^{size}/4$, $-N_{BWP}^{size}/4$] |

**Proposal 4:**

- *Adopt above table for frequency hopping on PUSCH for Msg.3.*

Any comments?

| Company | View |
|---|---|
| | |

## 3.3. Configured grant Type 1 and Type 2 transmission

[12] and [15] proposed to include another condition to terminate the *K* repetitions that UL grant for re-scheduling the same TB is received in sepc. 38.214 section 6.1.2.3.

**Proposal 5:**

- *Add the condition of terminate K repetitions: UL grant for re-scheduling the same TB. Example description is following:*

| […]<br>For any RV sequence, the repetitions shall be terminated after transmitting *K* repetitions, or at the last transmission occasion among the *K* repetitions within the period *P*, or when UL grant for re-scheduling the same TB is received within the period *P* whichever is reached first.<br>[…] |
|---|

Any comments?

| Company | View |
|---|---|
| | |

# 4. Other remaining issues

This section lists some open issues. It is worth emphasizing that these issues are also relevant to the discussion or decisions made by other AIs. For example:

- 7.3.3.1 DL/UL resource allocation for K repetitions of the same TB, where K>=1, especially for mini-slot based repetitions.
- 7.3.3.2 DL/UL scheduling and HARQ management especially for transmission/reception collisions between slot-based and non-slot-based PDSCH/PUSCH/PUCCH.
- 7.3.1.3 Remaining details on group-common PDCCH for collision handling;

### 4.1.1. Resource allocation for mini-slot based repetitions

Following two issues need to be discussed:

- Whether to allow mini-slot transmission cross the slot boundary
- Whether to support at most one repetition of the TB per slot in the case of repetitions using mini-slots?

Above issues should be discussed in session 7.3.3.1. When above issues are sloved, the frequency hopping for mini-slot can be further progressed. It is understood that the target is to have a common frequency hopping design between slot and mini-slot.

**Proposal 6:**

- *Frequency hopping offset(s)/signalling for mini-slot-based PUSCH can be based on frequency hopping offset(s) for slot-based-PUSCH*

Any comments?

| Company | View |
|---|---|
| | |

Regarding the hopping boundary in time domain or hopping mode for mini-slot, it is realted to the decision whether to allow one slot contain multiple mini-slots. If it is allowed, then the inter-mini-slot FH boundary should be aligned with the intra-slot FH; If it is not allowed, then inter-mini-slot FH boundary can be determined using the same rule as for inter-slot FH.

Any comments?

| Company | View |
|---|---|
| | |

### 4.1.2. UCI pigyyback on Configured grant

We haven't discussed whether to support UCI on PUSCH which is scheduled by configured grant. 4 companies [4 vivo], [10, Panasonic], [15, DCM], [18, Ericsson] support UCI on PUSCH with configured grant; while one company [1, HW] does not support, one company [7, LGE] seems neutral.

**Proposal 7:**

- *At lease support HARQ-ACK multiplexing on Configured Grant PUSCH.*

Any comments?

| Company | View |
|---|---|
| | |

### 4.1.3. Collision handling

#### 4.1.3.1. Collision with dynamic SFI

Following agreements were achieved for the interaction between the dynamic SFI and configured grant PUSCH transmission at RAN1 #90bis and #91 meeting.

***#90bis***
**Agreements:**

- For the states from semi-static DL/UL assignment
  - **"Unknown" in semi-static DL/UL assignment can be overwritten by measurement,** dynamic SFI, and UE specific data
  - DL/UL in semi-static DL/UL assignment cannot be overwritten to the other direction (DL to UL or UL to DL) by measurement, dynamic SFI and UE specific data
  - DL/UL in semi-static DL/UL assignment cannot be overwritten by "unknown" by dynamic SFI
- For the states from measurement in symbols not under DL/UL from semi-static DL/UL assignment:
  - **DL/UL direction implied by measurement can be overwritten by unknown in dynamic SFI**
    - **UE behavior will be the cancellation of the measurement or measurement related transmission**
  - **DL/UL direction implied by measurement can be overwritten by UL/DL from dynamic SFI**
    - **UE behavior will be the cancellation of the measurement or measurement related transmission**
  - **DL/UL direction implied by measurement can be overwritten by UE's own UE-specific data if the UE specific data imples the other direction**
    - **UE behavior will be the cancellation of the measurement or measurement related transmission**
    - **UE will follow the DCI for UE-specific data transmission and reception**

*#91*

**Agreements:**

- **Transmission direction implied by UE-specific RRC configuration is treated together as "measurement"**
  - Currently already include: Measurement related signals semi-statically configured by UE-specific RRC (eg. periodic/semi-persistent CSI-RS for CSI report, periodic CSI report, periodic/semi-persistent SRS) where a DL or UL direction will be assumed
  - **This includes UE-specific RRC PRACH configuration per each BWP, type 1 grant free UL transmission, type 2 grant free UL transmission**
    - **For type 2 UL transmission without grant, only the transmission at the first activated resource is treated as "UE-specific data"**
  - FFS: Configured resources for RRM for neighbor cell measurement

**Agreements:**

- NR does not support the following:
  - Transmission of UL UE-specific data and measurement related signals not semi-statically configured by RRC is overriden by "unknown" in dynamic SFI

Regarding the interaction between the SFI and configured grant transmission, current agreements define that the UE can use the symbols indicated as "uplink" by semi-static DL/UL assignment for configured grant transmission and symbols indicated as "uplink" by dynamic SFI. While resource configuration and ignores the dynamic SFI. While the measurement e.g. configured grant Type 1 and configured grant Type 2 other than the first activated resource can be can be overwritten by unknown and DL in dynamic SFI and can be overwritten by UE's own UE-specific DL data if the UE specific data imples the other direction. Then the remaining issue for such collision is for configured grant with K repetition, whether to skip and/or postpone the current transmission.

- **UE behavior**
  - Option 1: Drop/skip the transmission
  - Option 2: Postpone the transmission
  - Option 3: if common understanding between UE and gNB on the unavailable resource is aligned, UE postpones the transmission; Otherwise, UE skips the transmission.

Any comments?

| Company | View |
|---|---|
| | |

### 4.1.3.2. Collision with dynamic UL grant

In addition, RAN2 #100 meeting aslo made the agreements regarding the collision between the PUSCH transmission with configured grant and PUSCH transmission with dynamic grant for latency tolerant services:

Agreement:
[…]
15. The dynamic grant addressed to C-RNTI shall override the configured grant for this transmission in case of overlap in time domain, for type 1 and SPS.
**FFS if/how we handle the URLLC case (e.g. we only allow to override the configured grant if the dynamic grant can be used for the higher priority data or if the URLLC can preempt eMBB transmission.**

As for traffic with tight latency requirement, prioritizing later scheduled or configured transmissions or receptions is preferable, so that urgent traffic is prioritized. Indeed, LTE shortened TTI already specifies all the possible collision cases, such that short-TTI is prioritized over 1ms TTI. NR can borrow the specifications of LTE short-TTI [19].

Any comments?

| Company | View |
|---|---|
| | |

#### 4.1.3.3. Collision with SRS

Regarding the collision between the configured grant and SRS transmission, following UE behavior can be discussed:

- Option 1: Drop/skip the configured grant transmission
- Option 2: Postpone the configured grant transmission
- Option 3: Drop/skip the SRS transmission
- Option 4: shortened configured grant PUSCH transmission
- Option 5: others?

Any comments?

| Company | View |
|---|---|
| | |

### 4.2. Details of activation and deactivation signalling

Appendix lists the agreements achived for DCI contents/formats. In addition, following agreements made in RAN1 #90bis meeting:

**Agreements:**

- The value(s) of TPC-PUSCH-RNTI, TPC-PUCCH-RNTI, and/or TPC-SRS-RNTI, are provided by RRC signaling.
- The association between at least each of the following RNTIs and a DCI format is specified in the specification.
  - C-RNTI, TPC-PUSCH-RNTI, TPC-PUCCH-RNTI, TPC-SRS-RNTI, INT-RNTI, SFI-RNTI. FFS: other RNTI(s).
- The value of C-RNTI is obtained as part of random access procedure.
- The association between a DCI format and a type of search space (UE-common search space and UE-specific search space) is specified in the specification.
  - **UE-common search space contains a DCI format of C-RNTI, RNTI(s) for SPS/grant-free, TPC-PUSCH-RNTI, TPC-PUCCH,RNTI, TPC-SRS-RNTI, and INT-RNTI.**
  - **UE-specific search space contains a DCI format of C-RNTI and RNTI(s) for SPS/grant-free.**

Based on above agreements, both DCI format 0_0 and 0_1 should be used to activate and deactivate the configured grant PUSCH transmission; and both DCI format 1_0 and 1_1 should be used to activate and deactivate the DL SPS transmission.

Any comments?

| Company | View |
|---|---|
| | |

Three companies discussed the details on the activation and deactivation signaling in [5], [15], [18].

Following proposals can be made:

**Proposal 8:**

- *At least support following special fields for activation/release validation PDCCH for DL SPS, Configured Grant Type.*

Table: Special fields for DL SPS and Configured grant Type 2 UL transmission Activation PDCCH Validation

| | DCI format 0_0/0_1 | DCI format 1_0 | DCI format 1_1 |
|---|---|---|---|
| TPC command for scheduled PUSCH | set to '00' | N/A | N/A |
| HARQ process number | set to all '0's | set to all '0's | set to all '0's |
| Modulation and coding scheme | MSB is set to '0' | MSB is set to '0' | For the enabled transport block: MSB is set to '0' |
| Redundancy version | set to '00' | set to '00' | For the enabled transport block: set to '00' |

Table: Special fields for DL SPS and Configured grant Type 2 UL transmission Release PDCCH Validation

| | DCI format 0_0/0_1 | DCI format 1_0 | DCI format 1_1 |
|---|---|---|---|
| TPC command for scheduled PUSCH | set to '00' | N/A | N/A |
| HARQ process number | set to all '0's | set to all '0's | set to all '0's |
| Modulation and coding scheme | set to all '1's | set to all '1's | set to all '1's |
| Resource block assignment | set to all '1's | set to all '1's | set to all '1's |
| Redundancy version | set to '00' | set to '00' | set to '00' |

Any comments?

| Company | View |
|---|---|
| | |

## 4.3. Issues for SP-CSI report on PUSCH

Following issues have not been discussed for SP-CSI report on PUSCH.

- **Whether to support SP-CSI report skipping once it is activated?**
  - Option 1: No
  - Option 2: Yes
    - Please provide the cases for SP-CSI report skipping.

| Company | View |
|---|---|
| | |

- **Acknowledgement for activation/deactivation signalling for SP-CSI report on PUSCH**
  - If SP-CSI report skipping is not allowed, acknowledgement is not supported, gNB can confirm whether UE receives the activation/deactivation signalling through DTX detection.
  - If SP-CSI report skipping is allowed, acknowledgement is supported by MAC CE.

| Company | View |
|---|---|

| | |
|---|---|
| | |

- **Retransmission of SP-CSI on PUSCH is not supported.**

| Company | View |
|---|---|
| | |

- **Details of activation and deactivation signalling**

**Proposal 9:**

- *Support the same special fields for activation/release validation PDCCH between DL SPS, Configured Grant Type 2, and SP-CSI reporting on PUSCH.*
  - *The activation/deactivation signaling for DL SPS/Configured grant PUSCH trasnmsision and for SP-CSI reporting on PUSCH can be differentiated by different RNTI.*

## 5. Others

- If there are any other issues, please add in this section.

| Company | Issues and related views |
|---|---|
| | |

## 6. Possible proposals summary

**Proposal 1:**

- *Confirm the value 50 as the boundary number of PRBs in the active UL BWP between the bandwidths having two or four frequency offsets for frequency hopping on PUSCH.*
  - *Each value of the frequency hopping offset can be any integer value between 1 and* $N_{BWP}^{size} - 1$.

**Proposal 2:**

- *Confirm the description of inter-slot frequency hopping in 38.214 and remove the square brackets.*

[…]

[In case of inter-slot frequency hopping, hopping happens at each slot. The starting RB during slot $n_s^\mu$ is given by:

$$\mathrm{RB}_{\mathrm{start}}\left(n_s^\mu\right)=\begin{cases}\mathrm{RB}_{\mathrm{start}} & n_s^\mu \bmod 2=0\\ \left(\mathrm{RB}_{\mathrm{start}}+\mathrm{RB}_{\mathrm{offset}}\right)\bmod N_{BWP}^{size} & n_s^\mu \bmod 2=1\end{cases},$$ ]

where $n_{s,0}^\mu$ is the slot number within a radio frame of the first PUSCH slot of a multi-slot PUSCH transmission, $n_s^\mu$ is the current slot number within a radio frame, where a multi-slot PUSCH transmission can take place, $\mathrm{RB}_{\mathrm{start}}$ is the starting resource within the UL BWP, as calculated from the resource block assignment information of resource allocation type 1 (described in sub-clause 6.1.2.2.2) and $\mathrm{RB}_{\mathrm{offset}}$ is the frequency offset in RBs between the two frequency hops.

**Proposal 3:**

- *Describe time-domain frequency hopping boundary for PUSCH.*

**Proposal 4:**

- *Adopt table below for frequency hopping on PUSCH for Msg.3.*

Table: hopping bit definition for Msg.3

| Initial active UL BWP size | Number of hopping bits | Hopping offsets for Msg.3 |
|---|---|---|
| [24] | 0 | $N_{BWP}^{size}/2$ |
| [48] | 1 | $N_{BWP}^{size}/2$, $N_{BWP}^{size}/4$ |
| [96] | [2] | [reserved, $N_{BWP}^{size}/2$, $N_{BWP}^{size}/4$, $-N_{BWP}^{size}/4$] |

**Proposal 5:**

- *Add the condition of terminate K repetitions: UL grant for re-scheduling the same TB. Example description is following:*

> […]
>
> For any RV sequence, the repetitions shall be terminated after transmitting *K* repetitions, or at the last transmission occasion among the *K* repetitions within the period *P*, or when UL grant for re-scheduling the same TB is received within the period *P* whichever is reached first.
>
> […]

**Proposal 6:**

- *Frequency hopping offset(s)/signalling for mini-slot-based PUSCH can be based on frequency hopping offset(s) for slot-based-PUSCH*

**Proposal 7:**

- *At lease support HARQ-ACK multiplexing on Configured Grant PUSCH.*

**Proposal 8:**

- *At least support following special fields for activation/release validation PDCCH for DL SPS, Configured Grant Type.*

Table: Special fields for DL SPS and Configured grant Type 2 UL transmission Activation PDCCH Validation

| | DCI format 0_0/0_1 | DCI format 1_0 | DCI format 1_1 |
|---|---|---|---|
| TPC command for scheduled PUSCH | set to '00' | N/A | N/A |
| HARQ process number | set to all '0's | set to all '0's | set to all '0's |
| Modulation and coding scheme | MSB is set to '0' | MSB is set to '0' | For the enabled transport block: MSB is set to '0' |
| Redundancy version | set to '00' | set to '00' | For the enabled transport block: set to '00' |

Table: Special fields for DL SPS and Configured grant Type 2 UL transmission Release PDCCH Validation

| | DCI format 0_0/0_1 | DCI format 1_0 | DCI format 1_1 |
|---|---|---|---|
| TPC command for scheduled PUSCH | set to '00' | N/A | N/A |
| HARQ process number | set to all '0's | set to all '0's | set to all '0's |
| Modulation and coding scheme | set to all '1's | set to all '1's | set to all '1's |
| Resource block assignment | set to all '1's | set to all '1's | set to all '1's |
| Redundancy version | set to '00' | set to '00' | set to '00' |

**Proposal 9:**

- *Support the same special fields for activation/release validation PDCCH between DL SPS, Configured Grant Type 2, and SP-CSI reporting on PUSCH.*
  - *The activation/deactivation signaling for DL SPS/Configured grant PUSCH trasnmsision and for SP-CSI reporting on PUSCH can be differentiated by different RNTI.*

# 7. References


[1]. R1-1800060 Summary of remaining issues on UL data transmission procedure Huawei, HiSilicon
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[5]. R1-1800260 Remaining issues on grant-free UL transmission CATT
[6]. R1-1800334 Remaining details on UL transmission procedures in NR Intel Corporation
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[8]. R1-1800455 Correction on Procedures for UL Transmissions Samsung
[9]. R1-1800513 Text proposal on UL data transmission procedure Guangdong OPPO Mobile Telecom.
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[12]. R1-1800595 TP for termination of the repetition for UL transmission without grant Sony
[13]. R1-1800632 On explicit HARQ-ACK feedback for configured UL grant InterDigital, Inc.
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[16]. R1-1800780 UE behaviour when direction confliction between UL GF and dynamic SFI Xiaomi Communications
[17]. R1-1800940 Remaining details on PUSCH hopping procedure Nokia, Nokia Shanghai Bell
[18]. R1-1800953 Remaining Details in UL Transmission Procedures Ericsson
[19]. R1-1721313, 'RAN1 decisions for WI Shortened TTI and processing time for LTE (LTE_sTTIandPT)-per topic,' Ericsson.


# 8. Appendix

So far, the following agreements on UL data transmission procedures in RAN1 and SPS/grant free in RAN2 were achieved:

**RAN1**

***AH#1***

Agreements:

- For an UL transmission scheme without grant
  - at least semi-static resource (re-)configuration is supported
    - FFS: The resource configuration includes at least physical resource in time and frequency domain and RS parameters

        - Higher-layer signaling could be similar to Rel-8 LTE SPS
        - FFS: MCS
    - RS is transmitted together with data
        - channel structure of grant-based data transmission can be starting point

***#88***

Agreements:

- For UL transmission without grant,
    - The resource configuration includes at least the following
        - Time and frequency resources, FFS: including resources for repetitions, implicitly or explicitly
        - Modulation and coding scheme(s), possibly including RV, implicitly or explicitly
        - Reference signal parameters
            - FFS: Details
        - FFS: The number of repetitions K
            - FFS: Whether multiple number of K can be configured to one UE
        - FFS other parameters
    - FFS: A UE may continue repetitions for a TB until one of the following conditions is met
        - An ACK is successfully received from gNB
        - The number of repetitions for the TB reaches K

Possible agreements:

- For UL transmission with grant,
    - A UE continues repetitions for a TB until one of the following conditions is met
        - An ACK is successfully received from gNB
        - The number of repetitions for the TB reaches K

Agreements:

- For UE configured with K repetitions for a TB transmission with/without grant, the UE can continue repetitions (FFS can be different RV versions, FFS different MCS) for the TB until one of the following conditions is met
    - If an UL grant is successfully received for a slot/mini-slot for the same TB
        - FFS: How to determine the grant is for the same TB
    - FFS: An acknowledgement/indication of successful receiving of that TB from gNB
    - The number of repetitions for that TB reaches K
    - FFS: Whether it is possible to determine if the grant is for the same TB
    - Note that this does not assume that UL grant is scheduled based on the slot whereas grant free allocation is based on mini-slot (vice versa)

Note that other termination condition of repetition may apply

***#88b***

None

***#89***

Agreements:

- If network configures, UL data transmission without UL grant can be performed after semi-static resource configuration in RRC without L1 signalling
- If network configures, L1 signaling for activation/deactivation and/or modification on parameters for UL data transmission without UL grant can be applied

- RAN1 is discussing whether the mechanism to distinguish UL SPS and UL data transmission without UL grant is necessary.
- Prepare draft LS to RAN2 in R1-1709745 to inform above agreements

***AH#2***

Agreements:

- In addition to the RS parameters, time and frequency resource are configured in a UE-specific manner.
    - Note: it is common understanding that the time and frequency resources configured for a UE may or may not collide with those for another UE (to be captured in the LS).
- WA: Both DFT-S-OFDM and CP-OFDM are supported for UL transmission without grant.
- NR supports more than 1 HARQ process for UL transmission without grant

Agreements:

- The same TA adjustment procedure/mechanism (including expiration of TA timer) is applied to UL transmission with and without UL grant
- For UL transmission without UL grant,
    - Open-loop power control based on pathloss estimate is supported.
    - FFS: Closed-loop power control is supported, which is based on NW signaling.
- A UE shall not transmit anything on configured resources for UL transmission without UL grant when there is no transport block to transmit.
- FFS: UCI piggybacking with transport block is supported for UL transmission without UL grant.

Agreement: RAN1 considers that UE transmitting UL transmission without UL grant can be identified based on time/frequency resources and RS parameter(s).

Agreements:

- Type of UL data transmission without grant
    - Type 1: UL data transmission without grant is only based on RRC (re)configuration without any L1 signalling
    - Type 2: UL data transmission without grant is based on both RRC configuration and L1 signalling to activation/deactivation for UL data transmission without grant
        - Note: functionality of modification is achieved the L1 signalling by activation
    - Type 3: UL data transmission without grant is based on RRC configuration, and allows L1 signalling to modify some parameters configured by RRC but no L1 signalling for activation
- For UL data transmission without grant, type 1 and type 2 have already been agreed, FFS type 3.
- FFS the reliability issues for L1 signalling.
- For Type 1 UL transmission without UL grant, the RRC (re-)configuration includes at least the following
    - Periodicity and offset of a resource with respect to SFN=0
    - Time domain resource allocation
    - Frequency domain resource allocation
    - UE-specific DMRS configuration
    - Note:
        - one TB is mapped to a resource at least consisting of time/frequency-domain resource
        - RAN1 will not introduce specific resource allocation and DMRS configuration for UL data transmission without grant separate from UL data transmission with UL grant within the Rel.15 WI

- An MCS/TBS value
- Number of repetitions K
- Power control related parameters
- FFS HARQ related parameters
- FFS if multiple resources can be configured

- For Type 2 UL transmission without UL grant
  - The RRC (re-) configuration for resource and parameters includes at least the following
    - Periodicity of a resource
    - Power control related parameters
  - At least the following additional parameters for the resource are given by L1 signalling
    - Offset associated with the periodicity with respect to a timing reference indicated by L1 signalling for activation
      - FFS: the timing reference
    - Time domain resource allocation
    - Frequency domain resource allocation
    - UE-specific DMRS configuration
    - An MCS/TBS value
    - Note:
      - one TB is mapped to one resource
      - RAN1 will not introduce specific resource allocation and DMRS configuration for UL data transmission without grant separate from UL data transmission with UL grant within the Rel.15 WI
  - FFS multiple resources can be configured
  - FFS HARQ related parameters
  - FFS whether number of repetitions K is configured by RRC signalling and/or indicated by L1 signalling

***#90***

Agreements:

- Confirm the Working assumption: Both DFT-S-OFDM and CP-OFDM are supported for UL transmission without grant.

It is not necessary to support Type 3 UL transmission without UL grant

Agreements:

- Support using MAC CE as an acknowledgement for L1 signalling for activation/deactivation of Type 2 UL transmission without grant (similar/same behaviour as in LTE SPS).
- Regarding the RV determination for K repetitions including the initial transmission, further study following options including possible down-selection:
- For Type 1:
  - Option 1: Fixed to
    - 1-1: a single value
    - 1-2: a RV pattern
  - Option 2: RRC configured
    - 2-1: a single value
    - 2-2: a RV pattern
- For Type 2:
  - Option 1: Same as Type 1
  - Option 2: Based on the L1 signalling
- Repetition number K for Type 2 UL transmission without grant is down-selected from the following:
  - Option 1: Only RRC signalling

- Option 2: Combination of RRC + L1 activation signalling
- At least when an UL grant is used for retransmissions of Type 1 UL transmission without UL grant, different RNTI from the RNTI for UL transmission with grant is needed.
  - FFS how to determine the RNTI.
- For Type 2 UL transmission without UL grant, different RNTI from the RNTI for UL transmission with grant is needed for activation/deactivation and at least for re-transmission.
  - FFS how to determine the RNTI.
- Send a LS to RAN2 to inform all the agreements (Lihui)

Agreements:

- If HARQ feedback is supported, to indicate HARQ feedback of UL transmission without grant, following options and related UE behavior should be further studied.
  - Option 1: Based on UL grant to indicate "ACK"
  - Option 2: Group-common DCI
    - 2-1: Only ACK
    - 2-2: ACK and NACK
  - Option 3: Define a Timer, UE assumes following, when the Timer expires
    - 3-1: ACK if an NACK is not received after the K repetitions
    - 3-2: NACK if an ACK is not received
- FFS: Option 1, Option 2 and Option 3-2 can be used during and after the K repetition
- Note: UL grant for the same TB initially transmitted without grant can indicate "NACK"

***AH#3***

Agreement: Type 3 UL transmission without UL grant is not supported in Rel.15.

Agreements:

- The design for Type 1 and Type 2 UL transmission without UL grant is based on both slot and mini-slot based tx (at least 7, 4, and 2 OFDM symbols for Dec. 2017)
- FFS BWP related information for frequency domain resource allocation

Agreements:

- For Type 1 UL transmission without grant, to down-select (including possible combinations) from:
  - Option 1: waveform type is determined from UE-specific RRC
    - 1-1: Explicitly configured by the RRC
    - 1-2: Implicitly derived by other information in RRC
      - E.g., some entries of MCS table are for DFT-s-OFDM for 1 layer transmission, while others for CP-OFDM
  - Option 2: waveform type follows the information by RMSI for Msg3

Agreements:

- For Type 2 UL transmission without grant, to down-select (including possible combinations) from:
  - Option 1: waveform type is determined from DCI
    - 1-1: Explicit 1-bit field in the UL grant
    - 1-2: Implicitly derived by other information
      - 1-2-1: Some entries of MCS table are for DFT-s-OFDM for 1 layer transmission, while others for CP-OFDM
      - 1-2-2: Based on the different DCI sizes
      - 1-2-3: Based on the search space where the UL grant is detected

        - FFS: the DCI-based determination is always enabled or is enabled/disabled by RRC signalling
    - Option 2: waveform type is configured by UE-specific RRC
    - Option 3: waveform type follows the information by RMSI for Msg3
    - Option 4: waveform type is indicated by MAC CE
    - Note: For Msg3, waveform is informed by the RMSI
        - If no agreement is done, all UE follows the information by the RMSI
    - Aim to have the same solution as in the UL with grant case

Agreements:

- Multiple resource configurations for UL tx without UL grant can be configured to a UE
- For UL tx without UL grant, the same resource configuration is used for K repetitions for a TB including the initial transmission

***#90b***

Agreements:

- For Type 1 and Type 2 UL transmission without grant,
    - By UE-specific RRC signaling, a UE can be separately configured with UL waveform that is different from the one configured by RMSI for Msg3.

Note: even if the UE is configured with Type 1 and Type 2 UL transmission without grant, the UE may transmit PUSCH that is scheduled by UL grant, in which case the UL waveform determination for UL transmission with grant is used.

Agreements:

- At least support following periodicities of resources for UL transmission without UL grant
    - FFS other values with taking into account the alignment with 14 symbols

| **Subcarrier spacing (kHz)** | **Supported periodicities [ms]** |
|---|---|
| 15 | 2 symbols, 7 symbols, 1, 2, 5, 10, 20, 32, 40, 64, 80, 128, 160, 320, 640 |
| 30 | 2 symbols, 7 symbols, 0.5, 1, 2, 5, 10, 20, 32, 40, 64, 80, 128, 160, 320, 640 |
| 60 | 2 symbols, 7 symbols (6 symbols for ECP), 0.25,0.5,1,2,5,10,20, , 32, 40, 64, 80, 128, 160, 320, 640 |
| 120 | 2 symbols, 7 symbols, 0.125,0.25,0.5,1,2,5,10,20, 32, 40, 64, 80, 128, 160, 320, 640 |

**Agreements:**

- For UL transmission without UL grant, for each configuration
    - The number of configured HARQ processes is explicitly configured by RRC
    - Each configuration can have multiple HARQ processes T
        - The value range is {1, 2, …, M}, where M value is FFS

**Agreements:**

- For Type 1 and Type 2 UL transmission without grant, RNTI(s) is/are configured by UE-specific RRC signaling.
    - Whether the same or different RNTI(s) for Type 1 and Type 2 can be decided by RAN2.
- Within each type, an RNTI is configured by UE-specific RRC signaling at least for one resource configuration in a serving cell

**Agreements:**

- For UL transmission without UL grant,

- The HARQ ID for a TB should be the same during the repetitions and retransmissions if any.
- The HARQ ID is at least determined by
  - the number of HARQ processes in the configuration
  - the time-domain resource for the UL data transmission
  - FFS: other factors such as frequency-domain resource, DMRS, repetition K dependency on initial transmission.

**Working assumption:**

- For UL transmission without UL grant, for a TB transmission with K repetitions
  - The repetitions follow an RV sequence and it is configured by UE-specific RRC signalling to be one of the following:
    - Sequence 1: {0, 2, 3, 1}
    - Sequence 2: {0, 3, 0, 3}
    - Sequence 3: {0, 0, 0, 0}

***#91***

Agreements:

- Following parameters are configured for SP-CSI on PUSCH by UE-specific RRC signaling
  - semiPersistSchedInterval for SP-CSI reporting on PUSCH
  - Power control parameters P_0 and alpha

Agreements:

- Send an LS to RAN2 to inform following:
  - Answer to Q1: RAN1 believes that it is feasible to support DL SPS operation in NR. The NR DL SPS scheme has no significant differences compared with LTE DL SPS scheme.
  - Answer to Q2: RAN1 believes that at least the set of periodicities of DL SPS resource is same as that of LTE DL SPS. RAN1 has not been studied the periodicities shorter than that of LTE range. Note that there is no implication and impacts on any design and decision on uplink data transmission without grant.
  - Answer to Q3: At least for type 1 UL transmission without UL grant:
    - RAN1 agreed to support multiple resource configurations for UL transmission without UL grant for single serving cell.
      - Up to RAN2 to decide whether or not the RNTI is separately configured for the multiple resource configurations
  - Following parameters are configured for DL SPS by UE-specific RRC signaling
    - a new RNTI for SPS (e.g. SPS C-RNTI)
    - semiPersistSchedIntervalDL
    - numberOfConfSPS-Processes
    - PUCCH-AN-PersistentList

Agreement:

- The possible values of the repetition K are four values and are {1, 2, 4, 8}.

Agreements:

- For PUSCH transmission with UL grant (other than Msg.3) and Type 2 UL transmission without UL grant with intra-slot FH,
  - frequency hopping offset(s) in frequency domain is/are explicitly configured by UE-specific RRC signaling
  - explicit frequency hopping flag is included into DCI format scheduling/activating UL transmission

- If the frequency hopping flag is enabled, the following number of hopping bits are taken from the resource allocation Type 1 indication field:
  - 1 bit: if the active BWP less than X1 PRB
    - To indicate one of two RRC configured offsets
  - 2 bit: if the active BWP is larger or equal than X1
    - To indicated one of four RRC configured offsets
  - The value of X1 is fixed in the spec with a value of [50]

Agreements:

- For Type 1 UL transmission without UL grant with intra-slot FH, a separated frequency hopping offset field from the frequency resource allocation field is explicitly configured by UE-specific RRC signaling.
  - The possible values for frequency hopping offset are the same as that for UL transmission with UL grant.

Agreements**:**

- The hopping offset for Msg3 is indicated in RAR/DCI respectively, along with a separate information field for the hopping flag
  - No RRC impact for frequency hopping applied to Msg.3.
  - The possible values of hopping offsets are fixed in the specificiation

Agreement**:**

- No additional RRC configuration is needed in determining the hopping boundary for PUSCH

Agreement:

- For PUSCH other than Msg.3 over multiple slots, the intra-slot hopping and inter-slot hopping are not enabled at the same time for a given carrier for a UE.

Agreements:

- RRC parameters for Type 1
  - An MCS/TBS value
    - Reuse the MCS table and TBS calculation formula and the configuration as in grant-based case
  - Indication of UL/SUL (same as the grant-based case)

Agreements:

- RRC parameters for Type 2
  - Number of repetitions K
- An MCS/TBS value
  - Reuse the MCS table and TBS calculation formula and the configuration as in grant-based case

Agreement:

- For grant-free UL transmission, the UE is not expected to be configured with the time duration for the transmission of K repetitions larger than the time duration derived by the periodicity P.

Agreement**:**

- Activation and deactivation signaling for Type 2 UL transmission without UL grant/DL SPS is differentiated by different values of two fields in the DCI.
  - FFS details.

Agreements:

- For UL transmission without UL grant, the HARQ ID associated with the K repetitions of a TB is derived from the following equation:
  - HARQ Process ID = floor (*X / UL-TWG-periodicity)* mod *UL-TWG-numbHARQproc*
    - Where X= (SFN * SlotPerFrame * SymbolPerSlot + Slot_index_In_SF * SymbolPerSlot + Symbol_Index_In_Slot)
    - *X* refers to the symbol index of the first transmission occasion of repetition bundle that takes place.

Agreements:

- For UL transmission without UL grant,
  - The n-th transmission occasion of a K repetitions is associated with the (mod(n-1,4)+1)-th value in the configured RV sequence **{RV1, RV2, RV3, RV4},** where n=1, 2, …, K.
  - For RV sequence {0, 2, 3, 1},
    - The initial transmission of a TB shall start at the first transmission occasion of the K repetitions.
  - For RV sequence {0, 3, 0, 3},
    - The initial transmission of a TB can start at any of the transmission occasions of the K repetitions that are associated with RV=0.
  - (working assumption) For RV sequence {0, 0, 0, 0},
    - The initial transmission of a TB can start at any of the transmission occasions of the K repetitions when K=1, 2 or 4;
    - The initial transmission of a TB can start at any of the transmission occasions of the K repetitions, except the last transmission occasion when K=8.
  - For any RV sequence, repetition end at the last transmission occasion within the period P.
  - Note: The transmission occasion (TO) refers to the time domain resource allocation of one repetition in an aggregation with factor K where the aggregated transmission occasions start in resources configured by the offset and the period.
  - FFS: interaction with SFI

**RAN2**

***#97***

**Agreements**

1 NR supports an SPS scheme similar to LTE

2 NR supports skipping UL grant scheme similar to LTE

***#97b***

**Agreements on grant-free**

=> From RAN2 point of view it would be beneficial to be able to share "SPS/grant free" UL resources amongst different UE. Mechanism to identify the UE for collision resolution purpose may be needed. The details can be discussed in RAN1.

**Agreements on SPS:**

- Like in legacy LTE, at least SPS period is configured by RRC. FFS how frequency resources, MCS, etc., for SPS are provided to the UE depends on RAN1 discussion.
- UL skipping for dynamic grant should be configurable. FFS if UL skipping for SPS is configurable

- Working assumption: Like in LTE, DRX behaviour with SPS UL should be to restart inactivity timer when UL data is transmitted, and not to restart when SPS UL grant is not used. This behaviour depends on outcome of DRX design.

***#98***

**Agreements**

1. In NR, when the UE is configured with SPS, the UE should always skip SPS grant if there is no data to transmit, i.e., Skipping SPS grant is mandated in NR regardless of SPS periodicity.
2. LCP is performed the same regardless whether the grant is dynamic or SPS. SPS is a "configured grant".
3. FFS is multiple SPS is supported for duplication or to support different numerologies
4. Implicit release of UL SPS resources is not supported

***AH#2***

**Agreements**

=> Modelling in the MAC for grant-free will be discussed after the difference between the two schemes is better understood pending RAN1 progress. RAN2 will aim to have a unified MAC operation for common functionalities between grant-free and UL SPS with understanding that there can be differences after input from RAN1.

=> RAN2 understands that to support UL SPS similar to LTE a mode of operation in which RRC configuration (with no initial PHY resources) with L1 activation/deactivation needs to be supported. RAN2 will continue discussion on UL SPS, with LTE functionality.

=> A common RRC signalling can be design to allow the configuration of different UL transmissions schemes.

**Agreements**

- Multiple SPS for the same cell will not be supported.
- SPS on PSCell will be supported
- FFS if SPS on SCell will be supported

***#99***

**Agreements**

1. UL/DL SPS configuration can be configured and activated simultaneously on both PCell and PSCell
2. SPS can be configured for a SCell. FFS if it is restricted to a single configuration or can be allowed on multiple SCells.

**Agreements:**

1. As in LTE SPS UL, retransmission for SPS UL transmission are based only on UL dynamic grant

**Agreement**

=> For UEs in RRC_Connected mode, resources for "Type 1" resources are configured by dedicated RRC signalling

***#99b***

**Agreements:**

1. SPS/GF operation can be active simultaneously for PCell/PSCell and SCell. This applies to both Type 1 and Type 2.
2. For SPS, no optimizations to MAC CEs are pursued to support simultaneous activation/deactivation. The UE identifies the serving cell based on the grant mechanism (i.e. nothing special needs to be done)

3. SPS is configured per serving cell. For SPS, multiple SPS configurations per serving cell are not supported.

**Agreements:**
1. For SPS, as in LTE, UE acknowledges release of DL resources using L1 signaling
2. For Type 1, no additional acknowledgment mechanism is introduced on top of RRC acknowledgment
3. When a SCell is deactivated, the UE stops using all configured downlink assignments and configured uplink grants using resources of this SCell. FFS - when a SCell is deactivated, whether all configured downlink assignments and uplink grants for this SCell are kept and re-started or are cleared
4. FFS – if MAC is aware of state of the BWP (active or inactivate)
5. FFS - When a BWP is deactivated, the UE stops using all configured downlink assignments and configured uplink grants using resources of this BWP. FFS whether it is suspends the configured grants of the or it clears it.
6. If there is overlap in time between a configured downlink assignment and a dynamically scheduled downlink assignment, the dynamically scheduled downlink assignment overrides the configured downlink assignment.
7. FFS If there is overlap in time between a configured uplink grant and a dynamically scheduled uplink grant, the dynamically scheduled uplink grant overrides the configured uplink grant

**Agreements**
1. For SPS, as in LTE-SPS, retransmissions for SPS transmission are based an uplink grant/DL assignments received on SPS C-RNTI. SPS C-RNTI is configuration is provided by RRC signalling.
2. For SPS, MAC CE is used for confirmation of UL activation/deactivation.

For both Type1 GF and SPS.
3. FFS - A time T is started after an UL transmission on a HARQ process is configured to wait. FFS whether the UL Transmission is considered as ACK or NACK after expiry.
4. FFS – HARQ ID calculation

***#100***

**Agreements**
1. GF Type 1 resource shall be activated upon RRC configuration according to resource allocation in terms of periodicity and offset provided within the configuration
2. When GF Type 1 or SPS is released by RRC, the all corresponding configuration shall be released.
3. For SPS, the MAC entity shall clear the configured resource assignments immediately after transmitting confirmation MAC CE for the SPS release, as in LTE.
4. For GF Type 1, the MAC entity shall clear the configured uplink resource assignments immediately when receiving RRC reconfiguration message of GF Type 1 release.
5. Retransmissions (except for repetition) of GF Type 1 and SPS use dynamic grant
6. As in LTE, the pool of HARQ processes are shared between dynamic and configured grants.
7. From RAN2 perspective, type 1 and SPS cannot be configured for the same cell but can be configured for different cells at the same time.
8. From RAN2 perspective, at most one type 1 configuration is active at a time (e.g. one type 1 configuration per active BWP) per cell at least for Dec. freeze.
9. Upon SCell deactivation the GF type 1 the RRC configuration is kept. From the MAC point of view the resources are suspended (the UE is considered to not have a valid configured grant). Upon SCell activation the UE starts using the configured grant free resources.

10. The MAC entity shall clear the configured resources of one SCell for SPS when the SCell is deactivated.
11. Type 1 resource configuration can be configured per BWP and RRC configuration for SPS can be configure per BWP. A common RNTI for SPS and type 1 is configured per MAC entity.
12. For SPS when a BWP is deactivated, the from the MAC perspective the UE clears the configured resources within the BWP
13. The MAC entity shall clear all configured resources for Type1/ (SPS) when the TA timer associated with pTAG expires. Type 1 and SPS resources can be reactivated by RRC configuration and DCI respectively.
14. The MAC entity shall clear all configured resources for Type1/ (SPS) for all Serving Cells belonging to this TAG when TA timer associated with sTAG expires. Type 1 and SPS resources can be reactivated by RRC configuration and DCI respectively
15. The dynamic grant addressed to C-RNTI shall override the configured grant for this transmission in case of overlap in time domain, for type 1 and SPS.
FFS if/how we handle the URLLC case (e.g. we only allow to override the configured grant iff the dynamic grant can be used for the higher priority data or if the URLLC can preempt eMBB transmission.
16. For SPS and type 1, if the received uplink grant or DL assignment addressed to SPS C-RNTI. If the NDI in the received HARQ information is 1, consider the NDI for the HARQ process not to been toggled, as in LTE.
17. For SPS if the NDI in the received HARQ information is 0, it is for SPS activation/deactivation
18. From RAN2 perspective, a timer T is introduced. While the timer is running the UE does not use the SPS or Type 1 resource for new trasnmisson for this HARQ process (e.g. UE assumes ACK if the timer is not running).
19. T is configured by RRC and it can be stopped when a dynamic grant is received for this HARQ process.
20. It is started/restarted after the initial transmission/retransmission regardless of whether repetition is configured or not
21. It is up to RAN1 to decide the definition of period which is related to HARQ ID determination
22. “Configured grant” / “configured assignment” is kept in MAC
23. Main umbrella name title “Transmission/reception without dynamic scheduling” and below is the description of Type 1 and Type 2
24. Use Configured Grant Type 1 and Configured Grant Type 2 and DL SPS

**38.331-f00**

***PUSCH-Config***

The IE *PUSCH-Config* IE is used to configure the UE specific PUSCH parameters.

***PUSCH-Config* information element**

```
-- ASN1START
-- TAG-PUSCH-CONFIG-START

PUSCH-Config ::=                        SEQUENCE {
    -- Indicates whether to use code-block-group (CBG) based transmission (see 38.214, section x.x.x.x)
FFS_Ref
    -- FFS: Is this BOOLEAN parameter needed or can it be derived from the presence of the
codeBlockGroupsPerTransportBlock?
    codeBlockGroupTransmission                  ENUMERATED {true}
                OPTIONAL,    -- Need R
    -- Maximum number of code-block-groups (CBGs) per TB (see 38.xxx, section x.x.x, FFS_Ref)
    maxCodeBlockGroupsPerTransportBlock         ENUMERATED {n2, n4, n6, n8},

    -- Selection of the DMRS type to be used for UL (see section 38.211, section 6.4.1.1.2)
    dmrs-Type                                   ENUMERATED {type1, type2}
                    OPTIONAL,    -- Need R
    -- Position for additional DM-RS in DL, see Table 7.4.1.1.2-4 in 38.211.
```

```
    -- The four values represent the cases of 1+0, 1+1, 1+1+1. 1+1+1+1 non-adjacent OFDM symbols for DL.
    dmrs-AdditionalPosition                 ENUMERATED {pos0, pos1, pos2, pos3}
                    OPTIONAL,    -- Need R

    -- Configures uplink PTRS (see 38.211, section x.x.x.x) FFS_Ref
    phaseTracking-RS                        SetupRelease { Uplink-PTRS-Config }
                OPTIONAL,    -- Need M



    -- If enabled, UE applies TPC commands via accumulation. If not enabled, UE applies the TPC command
without accumulation.
    -- (see 38.213, section 7)
    -- FFS: Collect all power control parameters in a common section or keep them per channel?
    tpcAccumulation                         ENUMERATED { enabled }
                    OPTIONAL,    -- Need R

    -- RNTI used for PUSCH TPC
    -- Corresponds to L1 parameter 'TPC-PUSCH-RNTI' (see 38.213, section 10)
    tcp-PUSCH-RNTI                          BIT STRING (SIZE (16))
                    OPTIONAL,
    -- Configured one of two supported frequency hopping mode. If not configured frequency hopping is not
configured
    -- Corresponds to L1 parameter 'Frequency-hopping-PUSCH' (see 38.214, section 6)
    -- When the field is absent the UE applies the value Not configured
    frequencyHopping                        ENUMERATED {mode1, mode2},
    -- Configure either LBRM or FBRM for PUSCH. FBRM = Full buffer rate-matchingLBRM = Limited buffer rate-
matching
    -- Corresponds to L1 parameter 'LBRM-FBRM-selection' (see 38.212, section 5.4.2)
    rateMatching                            ENUMERATED {FullBufferRM, LimitedBufferRM},
    -- Resources that the UE should rate match PUSCH around (see 38.214, section REF)
    rateMatchResources                      TYPE_FFS!,
    -- Configuration of DCI code points that determine PUSCH resource allocations.
    -- Corresponds to L1 parameter 'PUSCH-symbol-allocation' (see 38.214, section 6.1.2.1)
    symbolAllocationIndexs                  FFS_Value        OPTIONAL,

    -- Indicates which MCS table the UE shall use for PUSCH without transform precoder
    -- Corresponds to L1 parameter 'MCS-Table-PUSCH' (see 38.214, section 6.1.4)
    -- When the field is absent the UE applies the value 64QAM
    mcs-Table                               ENUMERATED {64QAM, 256QAM},
    -- Indicates which MCS table the UE shall use for PUSCH with transform precoding
    -- Corresponds to L1 parameter 'MCS-Table-PUSCH-transform-precoding' (see 38.214, section 6.1.4)
    -- When the field is absent the UE applies the value 64QAM
    mcs-TableTransformPrecoder              ENUMERATED {64QAM, 256QAM},
    -- The UE specifically selection of transformer precoder for PUSCH. When the field is absent the UE
applies the value msg3-tp.
    -- Corresponds to L1 parameter 'PUSCH-tp' (see 38.211, section 6.3.1.4)
    transformPrecoder                       ENUMERATED {enabled}
            OPTIONAL,

    -- Selection between config 1 and config 2 for RBG size for PUSCH. Corresponds to L1 parameter 'RBG-size-
PUSCH' (see 38.214, section 6.1.2.2.1)
    rbg-Size                                ENUMERATED {config1, config2},

    -- Select between and configuration of dynamic and semi-static beta-offset
    -- Corresponds to L1 parameter 'UCI-on-PUSCH' (see 38.214, section 9.3)
    uci-on-PUSCH                            SetupRelease { CHOICE {
            dynamic                                 SEQUENCE (SIZE (1..4)) OF BetaOffsets,
            semiStatic                              BetaOffsets
    }    }
                    OPTIONAL, -- Need M

    -- Accounts for overhead from CSI-RS, CORESET, etc. FFS: Clarify value range and description.
    -- Corresponds to L1 parameter 'Xoh-PDSCH' (see 38.214, section 5.1.3.2)
    xOverhead                               FFS_Value
                    OPTIONAL,

    ...
}

-- Configuration of Uplink Phase-Tracking-Reference-Signals (PTRS)
--  FFS: Is it possible to configure PTRS for CP-OFDM and DFT-S OFDM simultaneously or just one. If the
latter, replace below by a CHOICE.
Uplink-PTRS-Config ::=                  SEQUENCE {
    -- Configuration of UL PTRS for CP-OFDM
    cp-OFDM                                 SetupRelease { SEQUENCE {
            -- Presence and  frequency density of UL PT-RS for CP-OFDM waveform as a function of scheduled BW
(see 38.214, section 6.1)
            -- FFS: Configuration is supposed to be per BWP according to RAN1
            frequencyDensity                    TYPE_FFS!,
```

```
            -- Presence and time density of UL PT-RS for CP-OFDM waveform as a function of MCS (see 38.214,
section 6.1)
            -- FFS: Configuration is supposed to be per BWP according to RAN1
            timeDensity                                 TYPE_FFS!,
            -- Indicator related to the number of UL PTRS ports for CP-OFDM. Details to be further decided.
            -- Corresponds to L1 parameter 'UL-PTRS-ports' (see 38.214, section 6.1)
            nrofPorts                                   ENUMERATED {n1, n2},
            -- Indicates the subcarrier offset for UL PTRS for CP-OFDM. Corresponds to L1 parameter 'UL-PTRS-
RE-offset' (see 38.214, section 6.1)
            resourceElementOffset               FFS_Value
                OPTIONAL
        }
    }
                OPTIONAL, -- Cond M
    -- Configuration of UL PTRS for DFT-S-OFDM.
    dft-S-OFDM                                  SetupRelease { SEQUENCE {
            -- Sample density of PT-RS for DFT-s-OFDM, pre-DFT, indicating a set of thresholds
T={NRBn,n=0,1,2,3,4},
            -- that indicates dependency between presence of PT-RS and scheduled BW and the values of X and K
the UE should
            -- use depending on the scheduled BW according to the table in 38.214 FFS_Section.
            -- FFS: Configuration is supposed to be per BWP according to RAN1
            -- Corresponds to L1 parameter 'UL-PTRS-pre-DFT-density' (see 38.214, section 6.1)
            sampleDensity                               FFS_Value
                OPTIONAL,
            -- Time density (OFDM symbol level) of PT-RS for DFT-s-OFDM
            -- Corresponds to L1 parameter 'UL-PTRS-time-density-transform-precoding' (see 38.214, section
6.1)
            timeDensity                                 ENUMERATED {d1, d2}
                OPTIONAL,
            -- PTRS sequence for DFT-s-OFDM. Corresponds to L1 parameter 'UL-PTRS-sequence-transform-
precoding' (see 38.214, section 6.1)
            sequence                            FFS_Value
                OPTIONAL
        }
    }
                OPTIONAL, -- Cond M
}

-- A set of beta-offset values
BetaOffsets ::=                             SEQUENCE {
    -- Up to 2 bits HARQ-ACK. Corresponds to L1 parameter 'betaOffset-ACK-Index-1' (see 38.213, section 9.3)
    -- When the field is absent the UE applies the value 11
    betaOffsetACK-Index1                        INTEGER(0..31)
                OPTIONAL, -- Need M
    -- Up to 11 bits HARQ-ACK. Corresponds to L1 parameter 'betaOffset-ACK-Index-2' (see 38.213, section 9.3)
    -- When the field is absent the UE applies the value 11
    betaOffsetACK-Index1                        INTEGER(0..31)
                OPTIONAL, -- Need M
    -- Above 11 bits HARQ-ACK. Corresponds to L1 parameter 'betaOffset-ACK-Index-3' (see 38.213, section 9.3)
    -- When the field is absent the UE applies the value 11
    betaOffsetACK-Index1                        INTEGER(0..31)
                OPTIONAL, -- Need M
    -- Up to 11 bits of CSI part 1 bits. Corresponds to L1 parameter 'betaOffset-CSI-part-1-Index-1' (see
38.213, section 9.3)
    -- When the field is absent the UE applies the value 13
    betaOffsetACK-Index1                        INTEGER(0..31)
                OPTIONAL, -- Need M
    -- Above 11 bits of CSI part 1 bits. Corresponds to L1 parameter 'betaOffset-CSI-part-1-Index-2' (see
38.213, section 9.3)
    -- When the field is absent the UE applies the value 13
    betaOffsetACK-Index1                        INTEGER(0..31)
                OPTIONAL, -- Need M
    -- Up to 11 bits of CSI part 2 bits. Corresponds to L1 parameter 'betaOffset-CSI-part-2-Index-1' (see
38.213, section 9.3)
    -- When the field is absent the UE applies the value 13
    betaOffsetACK-Index1                        INTEGER(0..31)
                OPTIONAL, -- Need M
    -- Above 11 bits of CSI part 2 bits. Corresponds to L1 parameter 'betaOffset-CSI-part-2-Index-2' (see
38.213, section 9.3)
    -- When the field is absent the UE applies the value 13
    betaOffsetACK-Index1                        INTEGER(0..31)
                OPTIONAL, -- Need M
}

-- TAG-PUSCH-CONFIG-STOP
-- ASN1STOP
```

### *SPS-Config*

Editor's Note: FFS: Relation between (UL-)SPS and "ULtransmissionWithoutGrant". Is it one feature with different configurations as the L1 parameters suggest? How is it modelled in MAC? What about DL?

Editor's Note: FFS: RAN1 indicated in the L1 table: "Note: Multiple configurations is possible, how many needs to be determined". RAN2 agreed that SPS can be used on Pcell and SCell... But each UE can use it on at most one serving cell of a cell group at a time. Are the "multiple configuration" meant for one carrier? Does the UE then use several SPS-RNTIs?

The *SPS-Config* IE is used to configure semi-persistent transmission according to two possible schemes. The actual uplink grant may either be configured via RRC (type1) or provided via the PDCCH (addressed to SPS-RNTI) (type2).

**_SPS-Config_ information element**

```
-- ASN1START
-- TAG-SPS-CONFIG-START

-- SPS may be configured on the PCell as well as on SCells. But it shall not be configured for more than
-- one serving cell of a cell group at once.
SPS-Config ::=                              SEQUENCE {
    -- FFS: Same SPS for UL and DL (like in LTE)? See also naming FFS above.
    -- sps-RNTI                                 BIT STRING (SIZE (16))                    OPTIONAL,

    -- FSS / TODO: ADD DL SPS!

    -- UL SPS configuration
    -- FFS CHECK: Add possibility to release UL SPS
    uplink                                      SEQUENCE {       periodicity                        TYPE_FFS!,
        powerControl                            TYPE_FFS!,

        -- Enable transformer precoder for type1 and type2. Absence indicates that it is disabled.
        -- Corresponds to L1 parameter 'UL-TWG-tp' (see 38.214, section FFS_Section)
        transformPrecoder                       ENUMERATED {enabled}
                    OPTIONAL,
        -- The number of HARQ processes configured. It applies for both Type 1 and Type 2
        -- Corresponds to L1 parameter 'UL-TWG-numbHARQproc' (see 38.214, section FFS_Section)
        nrofHARQ-processes                          INTEGER(1..FFS_Value)
                        OPTIONAL,

        -- If repetitions is used, this field indicates the redundancy version (RV) sequence to use.
        -- Corresponds to L1 parameter 'UL-TWG-RV-rep' (see 38.214, section FFS_Section)
        repK-RV                                     ENUMERATED {s1-0231, s2-0303, s3-0000}
                        OPTIONAL,
        -- Periodicity for UL transmission without UL grant for type 1 and type 2
        -- Corresponds to L1 parameter 'UL-TWG-periodicity' (see 38.321, section FFS_Section)
        -- The following periodicities are supported depending on the configured subcarrier spacing [ms]:
        --  15kHz: 2 symbols, 7 symbols, 1, 2, 5, 10, 20, 32, 40, 64, 80, 128, 160, 320, 640
        --  30kHz: 2 symbols, 7 symbols, 0.5, 1, 2, 5, 10, 20, 32, 40, 64, 80, 128, 160, 320, 640
        --  60kHz: 2 symbols, 7 symbols (6 symbols for ECP), 0.25,0.5,1,2,5,10,20,32, 40, 64, 80, 128, 160,
320, 640
        --  120kHz: 2 symbols, 7 symbols, 0.125,0.25,0.5,1,2,5,10,20, 32, 40, 64, 80, 128, 160, 320, 640
    OPTIONAL,
        --  2 symbols, 7 symbols, 0.125,0.25,0.5,1,2,5,10,20, 32, 40, 64, 80, 128, 160, 320, 640
        priodicity                                  ENUMERATED {sym2, sym7, ms0dot125, ms0dot25, ms0dot5, ms1,
ms2, ms5, ms10, ms20,
                                                                ms32, ms40, ms64, ms80, ms128, ms160,
ms320, ms640}               OPTIONAL,


        -- UL-SPS transmission with fully RRC-configured UL grant (Type1) (see 38.214, section x.x.x.x).
FFS_Ref
        -- If not provided or set to release, use UL-SPS transmission with UL grant configured by DCI
addressed to SPS-RNTI (Type2).
        rrcConfiguredUplinkGrant                CHOICE {
            setup                                       SEQUENCE {
                FFS: Merge the following two into one. Possibly don't use "periodicity" for
rrcConfiguredUplinkGrant
                timeDomainOffset                        TYPE_FFS!,
                timeDomainAllocation                    TYPE_FFS!,
                frequencyDomainAllocation               TYPE_FFS!,
                -- UE-specific DMRS configuration:
                dmrs                                    TYPE_FFS!,
                mcsAndTBS                                   TYPE_FFS!,
                --  The number or repetitions of K:
                repK                                    TYPE_FFS!           },
            release                             NULL
        }                                                                                   OPTIONAL,  -- Need M
```

```
    }                                                                                    OPTIONAL,  -- Need M
}

-- TAG-SPS-CONFIG-STOP
-- ASN1STOP
```

***SP-CSI report***

```
semiPersistentPUSCH                     SEQUENCE {
            -- Periodicity. Corresponds to L1 parameter 'Reportperiodicity-spCSI'. (see 38.214, section
FFS_Section)
            reportSlotConfig                        ENUMERATED {sl5, sl10, sl20, sl40, sl80, sl160, sl320},
            -- RNTI for SP CSI-RNTI, Corresponds to L1 parameter 'SPCSI-RNTI' (see 38.214, section
FFS_Section)
            -- FFS: RAN1 models different RNTIs as different Search Spaces with independent
configurations. Align the configuration
            -- of this one (e.g. group with monitoring periodicity, PDCCH candidate configuration, DCI-
Payload size...)?
            csi-RNTI                                RNTI-Value,
            -- Index of the p0-alpha set determining the power control for this CSI report transmission.
            -- Corresponds to L1 parameter 'SPCSI-p0alpha' (see 38.214, section FFS_Section)
            p0alpha                                 P0-PUSCH-AlphaSetId
        },
```

**Agreements on DCI contents and format**

Working assumption:

- For DL DCI,
  - The column "'Conf.?" indicates whether the field is present only if a certain feature is configured ("C") or always present
    - Note: if the field is configured to be present, the bitwidth for the field may or may not depend on the configuration (to be further discussed)
  - The column "Fallb.?" indicates whether the field is included in the fallback DCI or not (in the excel sheet the fallback format is listed in a separate tab)
  - Note: The column "Bits" is intended to define the bitwidth for the non-fallback DCI. For the case when the field is indicated as present in the fallback DCI, the bitwidth of the field in the fallback DCI may be the same or less that that of the non-fallback DCI (to be further discussed)
  - Note: there may be zero or more padding bits (to be further discussed)
  - Note: the table below is NOT intended to revert any previous agreements

| Field | Bits | Conf ? | Fallb ? | Description |
|---|---|---|---|---|
| Header | 1? | | F | At least to distinguish UL and DL with the same DCI size<br>FFS if more bits are needed |
| Carrier indicator | 0 or 3 | C | | |
| BWP indicator | 0, 1, 2 | C | | |
| Frequency-domain PDSCH resources | | [C] | F | VRBs, indicated using type 0 or type 1 resource allocation including the header bit to indicate resource allocation type in case of dynamic type0/1 selection for non-fallback<br><br>Fallback DCI only supports resource allocation type 1<br>**FFS the bitwidth is further dependent on BWP size** |
| Time-domain PDSCH resources | Up to 4 | **[C]** | F | Index into an RRC-configured table providing the set of OFDM symbols used for PDSCH transmission, the start slot, and the PDSCH mapping type<br><br>Note: not fully configurable entries for fallback DCI |
| VRB-to-PRB mapping | 1 | [C] | F | Flag to control VRB-to-PRB mapping (block interleaved or non-block interleaved). Only present/relevant for resource allocation type 1 |
| Reserved resource set on/off | 0, 1,2 | C | | Indicate whether reserved resources should be excluded form the PDSCH allocation. 1 bit per set, max 2 bits<br>FFS if partially needed in fallback |
| Bundling size indicator | 0, 1 | C | | Select from two RRC configured bundling sizes for PDSCH<br>FFS if partially needed in fallback |
| Modulation and coding scheme | 5 | | F | MCS |
| New data indicator | 1 | | F | |
| Redundancy version | 2 | | F | |
| Modulation and coding scheme, second CW | 5 | C | | |
| New data indicator, second CW | 1 | C | | |
| Redundancy version, second CW | 2 | C | | |
| HARQ process number | 3 or 4 | | F | HARQ process number, 3 or 4 bits (8 or 16 processes)<br>FFS: if configurable bit size (at least for non-fallback) or fixed |
| CBGFI | 0 or 1 | C | | CBG flush indication. Consists of 1 bit if CBG retransmission configured. |
| CBGTI | Up to 8 | C | | Indicates the CBG(s) (re)transmitted. Consists of N bits bitmap if CBG is configured. |
| TPC command for PUCCH | 2 | | F | Note: Check number of TPC bits with TPC session. |
| ARI (ACK/NAK Resource Index) | 2 | | F | FFS: size in case of fallback DCI? |
| HARQ timing indicator | 3 | | F | To indicate the timing (slot number) of the ACK relative to the PDSCH reception (K1)<br>Note: not fully configurable entries for fallback DCI |
| Downlink Assignment Index | | | | DAI (counter DAI and total DAI)<br>Note: Check outcome from HARQ codebook session. |
| Antenna port(s) | Up to [5]? | | | Antenna ports used (scheduled and co-scheduled) and the number of layers<br>FFS if (partially) needed in fallback |
| TCI (Transmission Configuration Indication) | 3 | | | 3 bits, fixed. Provides beam indication to indicate QCL assumption between DL RS antenna port(s) and DMRS antenna port(s) of DL data channel at least w.r.t. spatial QCL parameter<br>FFS if (partially) needed in fallback |

Working assumption:

- For UL DCI
  - The column "'Conf.?" indicates whether the field is present only if a certain feature is configured ("C") or always present
    - Note: if the field is configured to be present, the bitwidth for the field may or may not depend on the configuration (to be further discussed)
  - The column "Fallb.?" indicates whether the field is included in the fallback DCI or not (in the excel sheet the fallback format is listed in a separate tab)
  - Note: The column "Bits" is intended to define the bitwidth for the non-fallback DCI. For the case when the field is indicated as present in the fallback DCI, the bitwidth of the field in the fallback DCI may be the same or less that that of the non-fallback DCI (to be further discussed)

- Note: there may be zero or more padding bits (to be further discussed)
- Note: the table below is NOT intended to revert any previous agreements

| Field | Bits | Conf? | Fallb? | Description |
|---|---|---|---|---|
| Header | 1? | | F | At least to distinguish UL and DL with the same DCI size<br>FFS if more bits are needed |
| Carrier indicator | 0 or 3 | C | | |
| UL/SUL indicator | 1 | C | | To differentiate between UL and SUL |
| BWP indicator | 0, 1, 2 | C | | |
| Frequency-domain PUSCH resources | | [C] | F | VRBs, indicated using type 0 or type 1 resource allocation including the header bit to indicate resource allocation type in case of dynamic type0/1 selection for non-fallback<br><br>Fallback DCI only supports resource allocation type 1<br>**FFS the bitwidth is further dependent on BWP size** |
| Time-domain PUSCH resources | Up to 4 | [C] | F | Index into an RRC-configured table providing the set of OFDM symbols used for PUSCH transmission, the start slot, and the PUSCH mapping type<br><br>Note: not fully configurable entries for fallback DCI |
| VRB-to-PRB mapping | 1 | [C] | F? | Flag to control VRB-to-PRB mapping (block interleaved or non-block interleaved). Only present/relevant for resource allocation type 1<br><br>FFS if present in fallback and how to handle the relation to the FH flag |
| FH flag | 1 | [C] | F | To control uplink frequency hopping. Some resource allocation filed bits are interpreted differently in case of hopping.<br><br>Open issue: are interleaved VRB-to-PRB mapping and frequency hopping independently controlled or can the two fields be merged? |
| Modulation and coding scheme | 5 | | F | MCS |
| New data indicator | 1 | | F | |
| Redundancy version | 2 | | F | |
| HARQ process number | 3 or 4 | | F | HARQ process number, 3 or 4 bits |
| DAI | | | | Uplink DAI<br>Note: Check outcome from HARQ codebook session. |
| CBGTI | Up to 8 | C | | Indicates the CBG(s) (re)transmitted. Consists of N bits bitmap if CBG is configured. |
| TPC command for PUSCH | 2 | | F | |
| TRI/TPMI | [4] | C | | TPMI, and Transmission rank indicator (FFS: separate fields or jointly encoded) .<br><br>FFS: TPMI and antenna port fields not simultanosuly present.<br><br>FFS if (partially) present in fallback |
| SRI | | C | | The SRI field in UL grant is independently encoded from at least TPMI in the same UL grant.<br>The bitwidth of SRI field in UL grant is determined by N = ceil(log2(# of SRS resources in the set)).<br><br>FFS if (partially) present in fallback |
| Antenna ports | [5?] | C | | Antenna ports (scheduled and uplink DMRS CDM groups for rate matching), FFS on scrambling identity<br>FFS if (partially) present in fallback |
| DMRS-PTRS association | 2 | C | | To cover "For UL codebook-based transmission, when one PTRS port is configured, support gNB to indicate to UE in the UL grant which DMRS port is associated with the PTRS port". Not yet decided whether it will be a spearate field or integrated in some other fields.<br>FFS if (partially) present in fallback |
| SRS request | 4 | C | | To trigger an SRS transmission in the uplink.<br>Note: unclear if additional bits are needed in case of SUL operation |
| CSI request | 0–6 | C | | CSI measurement request and CSI report trigger for CSI on PUSCH |

**LTE special field for Semi-Persistent Scheduling Activation/Release PDCCH Validation**

LTE: Special fields for Semi-Persistent Scheduling Activation PDCCH Validation

| | DCI format 0 | DCI format 1/1A | DCI format 2/2A/2B/2C |
|---|---|---|---|
| TPC command for scheduled PUSCH | set to '00' | N/A | N/A |
| Cyclic shift DM RS | set to '000' | N/A | N/A |
| Modulation and coding scheme and redundancy version | MSB is set to '0' | N/A | N/A |
| HARQ process number | N/A | FDD: set to '000'<br>TDD: set to '0000' | FDD: set to '000'<br>TDD: set to '0000' |
| Modulation and coding scheme | N/A | MSB is set to '0' | For the enabled transport block:<br>MSB is set to '0' |
| Redundancy version | N/A | set to '00' | For the enabled transport block:<br>set to '00' |

LTE: Special fields for Semi-Persistent Scheduling Release PDCCH Validation

| | DCI format 0 | DCI format 1A |
|---|---|---|
| TPC command for scheduled PUSCH | set to '00' | N/A |
| Cyclic shift DM RS | set to '000' | N/A |
| Modulation and coding scheme and redundancy version | set to '11111' | N/A |
| Resource block assignment and hopping resource allocation | Set to all '1's | N/A |
| HARQ process number | N/A | FDD: set to '000'<br>TDD: set to '0000' |
| Modulation and coding scheme | N/A | set to '11111' |
| Redundancy version | N/A | set to '00' |
| Resource block assignment | N/A | Set to all '1's |

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*Technical Specification*

## 3rd Generation Partnership Project;
## Technical Specification Group Radio Access Network;
## Evolved Universal Terrestrial Radio Access (E-UTRA);
## Physical channels and modulation
## (Release 11)







**Petitioners' Exhibit 1024**
**Google et al. v. KT Corporation et al.**
**IPR2025-00291**

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# Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

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- x the first digit:
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  - 2 presented to TSG for approval;
  - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

# 1 Scope

The present document describes the physical channels for evolved UTRA.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.


[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description".

[3] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".

[4] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".

[5] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements".

[6] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

[7] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".

[8] 3GPP TS 36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".


# 3 Symbols and abbreviations

## 3.1 Symbols

For the purposes of the present document, the following symbols apply:

| | |
|---|---|
| $(k,l)$ | Resource element with frequency-domain index $k$ and time-domain index $l$ |
| $a_{k,l}^{(p)}$ | Value of resource element $(k,l)$ [for antenna port $p$] |
| $D$ | Matrix for supporting cyclic delay diversity |
| $D_{\mathrm{RA}}$ | Density of random access opportunities per radio frame |
| $f_0$ | Carrier frequency |

| | |
|---|---|
| $f_{\text{RA}}$ | PRACH resource frequency index within the considered time-domain location |
| $M_{\text{sc}}^{\text{PUSCH}}$ | Scheduled bandwidth for uplink transmission, expressed as a number of subcarriers |
| $M_{\text{RB}}^{\text{PUSCH}}$ | Scheduled bandwidth for uplink transmission, expressed as a number of resource blocks |
| $M_{\text{bit}}^{(q)}$ | Number of coded bits to transmit on a physical channel [for codeword $q$ ] |
| $M_{\text{symb}}^{(q)}$ | Number of modulation symbols to transmit on a physical channel [for codeword $q$ ] |
| $M_{\text{symb}}^{\text{layer}}$ | Number of modulation symbols to transmit per layer for a physical channel |
| $M_{\text{symb}}^{\text{ap}}$ | Number of modulation symbols to transmit per antenna port for a physical channel |
| $N$ | A constant equal to 2048 for $\Delta f = 15\,\text{kHz}$ and 4096 for $\Delta f = 7.5\,\text{kHz}$ |
| $N_{\text{CP},l}$ | Downlink cyclic prefix length for OFDM symbol $l$ in a slot |
| $N_{\text{CS}}$ | Cyclic shift value used for random access preamble generation |
| $N_{\text{cs}}^{(1)}$ | Number of cyclic shifts used for PUCCH formats 1/1a/1b in a resource block with a mix of formats 1/1a/1b and 2/2a/2b |
| $N_{\text{RB}}^{(2)}$ | Bandwidth available for use by PUCCH formats 2/2a/2b, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$ |
| $N_{\text{RB}}^{\text{HO}}$ | The offset used for PUSCH frequency hopping, expressed in number of resource blocks (set by higher layers) |
| $N_{\text{ID}}^{\text{cell}}$ | Physical layer cell identity |
| $N_{\text{ID}}^{\text{MBSFN}}$ | MBSFN area identity |
| $N_{\text{RB}}^{\text{DL}}$ | Downlink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$ |
| $N_{\text{RB}}^{\text{min, DL}}$ | Smallest downlink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$ |
| $N_{\text{RB}}^{\text{max, DL}}$ | Largest downlink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$ |
| $N_{\text{RB}}^{\text{UL}}$ | Uplink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$ |
| $N_{\text{RB}}^{\text{min, UL}}$ | Smallest uplink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$ |
| $N_{\text{RB}}^{\text{max, UL}}$ | Largest uplink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$ |
| $N_{\text{symb}}^{\text{DL}}$ | Number of OFDM symbols in a downlink slot |
| $N_{\text{symb}}^{\text{UL}}$ | Number of SC-FDMA symbols in an uplink slot |
| $N_{\text{sc}}^{\text{RB}}$ | Resource block size in the frequency domain, expressed as a number of subcarriers |
| $N_{\text{sb}}$ | Number of sub-bands for PUSCH frequency-hopping with predefined hopping pattern |
| $N_{\text{RB}}^{\text{sb}}$ | Size of each sub-band for PUSCH frequency-hopping with predefined hopping pattern, expressed as a number of resource blocks |
| $N_{\text{SP}}$ | Number of downlink to uplink switch points within the radio frame |
| $N_{\text{RS}}^{\text{PUCCH}}$ | Number of reference symbols per slot for PUCCH |
| $N_{\text{TA}}$ | Timing offset between uplink and downlink radio frames at the UE, expressed in units of $T_{\text{s}}$ |
| $N_{\text{TA offset}}$ | Fixed timing advance offset, expressed in units of $T_{\text{s}}$ |
| $n_{\text{PUCCH}}^{(1,\tilde{p})}$ | Resource index for PUCCH formats 1/1a/1b |
| $n_{\text{PUCCH}}^{(2,\tilde{p})}$ | Resource index for PUCCH formats 2/2a/2b |
| $n_{\text{PUCCH}}^{(3,\tilde{p})}$ | Resource index for PUCCH formats 3 |
| $n_{\text{PDCCH}}$ | Number of PDCCHs present in a subframe |
| $n_{\text{PRB}}$ | Physical resource block number |
| $n_{\text{PRB}}^{\text{RA}}$ | First physical resource block occupied by PRACH resource considered |
| $n_{\text{PRB offset}}^{\text{RA}}$ | First physical resource block available for PRACH |
| $n_{\text{VRB}}$ | Virtual resource block number |
| $n_{\text{RNTI}}$ | Radio network temporary identifier |
| $n_{\text{f}}$ | System frame number |

| | |
|---|---|
| $n_s$ | Slot number within a radio frame |
| $P$ | Number of antenna ports used for transmission of a channel |
| $p$ | Antenna port number |
| $q$ | Codeword number |
| $r_{RA}$ | Index for PRACH versions with same preamble format and PRACH density |
| $Q_m$ | Modulation order: 2 for QPSK, 4 for 16QAM and 6 for 64QAM transmissions |
| $s_l^{(p)}(t)$ | Time-continuous baseband signal for antenna port $p$ and OFDM symbol $l$ in a slot |
| $t_{RA}^{(0)}$ | Radio frame indicator index of PRACH opportunity |
| $t_{RA}^{(1)}$ | Half frame index of PRACH opportunity within the radio frame |
| $t_{RA}^{(2)}$ | Uplink subframe number for start of PRACH opportunity within the half frame |
| $T_f$ | Radio frame duration |
| $T_s$ | Basic time unit |
| $T_{slot}$ | Slot duration |
| $W$ | Precoding matrix for downlink spatial multiplexing |
| $\beta_{PRACH}$ | Amplitude scaling for PRACH |
| $\beta_{PUCCH}$ | Amplitude scaling for PUCCH |
| $\beta_{PUSCH}$ | Amplitude scaling for PUSCH |
| $\beta_{SRS}$ | Amplitude scaling for sounding reference symbols |
| $\Delta f$ | Subcarrier spacing |
| $\Delta f_{RA}$ | Subcarrier spacing for the random access preamble |
| $\upsilon$ | Number of transmission layers |

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

| | |
|---|---|
| CCE | Control Channel Element |
| CDD | Cyclic Delay Diversity |
| CRS | Cell-specific Reference Signal |
| CSI | Channel-State Information |
| DCI | Downlink Control Information |
| DM-RS | Demodulation Reference Signal |
| ECCE | Enhanced Control Channel Element |
| EPDCCH | Enhanced Physical Downlink Control CHannel |
| EREG | Enhanced Resource-Element Group |
| PBCH | Physical Broadcast CHannel |
| PCFICH | Physical Control Format Indicator CHannel |
| PDCCH | Physical Downlink Control CHannel |
| PDSCH | Physical Downlink Shared CHannel |
| PHICH | Physical Hybrid-ARQ Indicator CHannel |
| PMCH | Physical Multicast CHannel |
| PRACH | Physical Random Access CHannel |
| PRB | Physical Resource Block |
| PRS | Positioning Reference Signal |
| PUCCH | Physical Uplink Control CHannel |
| PUSCH | Physical Uplink Shared CHannel |
| REG | Resource-Element Group |
| SRS | Sounding Reference Signal |
| VRB | Virtual Resource Block |

# 4 Frame structure

Throughout this specification, unless otherwise noted, the size of various fields in the time domain is expressed as a number of time units $T_s = 1/(15000 \times 2048)$ seconds.

Downlink and uplink transmissions are organized into radio frames with $T_f = 307200 \times T_s = 10\,\text{ms}$ duration.
Two radio frame structures are supported:

- Type 1, applicable to FDD,
- Type 2, applicable to TDD.

Transmissions in multiple cells can be aggregated where up to four secondary cells can be used in addition to the primary cell. Unless otherwise noted, the description in this specification applies to each of the up to five serving cells. In case of multi-cell aggregation, the UE may assume the same frame structure is used in all the serving cells.

## 4.1 Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is $T_f = 307200 \cdot T_s = 10\,\text{ms}$ long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5\,\text{ms}$, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe $i$ consists of slots $2i$ and $2i+1$.

For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.

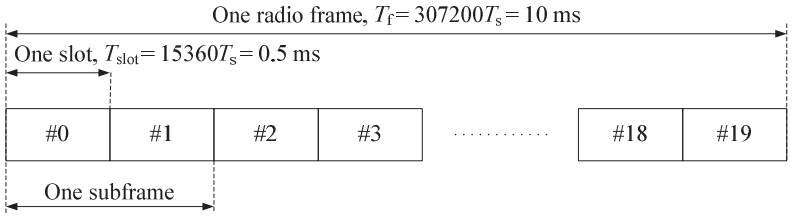



**Figure 4.1-1: Frame structure type 1**

# 4.2 Frame structure type 2

Frame structure type 2 is applicable to TDD. Each radio frame of length $T_f = 307200 \cdot T_s = 10\,\text{ms}$ consists of two half-frames of length $153600 \cdot T_s = 5\,\text{ms}$ each. Each half-frame consists of five subframes of length $30720 \cdot T_s = 1\,\text{ms}$.
The supported uplink-downlink configurations are listed in Table 4.2-2 where, for each subframe in a radio frame, "D" denotes the subframe is reserved for downlink transmissions, "U" denotes the subframe is reserved for uplink transmissions and "S" denotes a special subframe with the three fields DwPTS, GP and UpPTS.
The length of DwPTS and UpPTS is given by Table 4.2-1 subject to the total length of DwPTS, GP and UpPTS being equal to $30720 \cdot T_s = 1\,\text{ms}$. Each subframe $i$ is defined as two slots, $2i$ and $2i+1$ of length $T_{slot} = 15360 \cdot T_s = 0.5\,\text{ms}$ in each subframe.

Uplink-downlink configurations with both 5 ms and 10 ms downlink-to-uplink switch-point periodicity are supported.

In case of 5 ms downlink-to-uplink switch-point periodicity, the special subframe exists in both half-frames.

In case of 10 ms downlink-to-uplink switch-point periodicity, the special subframe exists in the first half-frame only.

Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following the special subframe are always reserved for uplink transmission.

In case multiple cells are aggregated, the UE may assume that the guard period of the special subframe in the different cells have an overlap of at least $1456 \cdot T_s$.

In case multiple cells with different uplink-downlink configurations are aggregated and the UE is not capable of simultaneous reception and transmission in the aggregated cells, the following constraints apply:

- if the subframe in the primary cell is a downlink subframe, the UE shall not transmit any signal or channel on a secondary cell in the same subframe
- if the subframe in the primary cell is an uplink subframe, the UE is not expected to receive any downlink transmissions on a secondary cell in the same subframe

- if the subframe in the primary cell is a special subframe and the same subframe in a secondary cell is a downlink subframe, the UE is not expected to receive PDSCH/EPDCCH/PMCH/PRS transmissions in the secondary cell in the same subframe, and the UE is not expected to receive any other signals on the secondary cell in OFDM symbols that overlaps with the guard period or UpPTS in the primary cell.

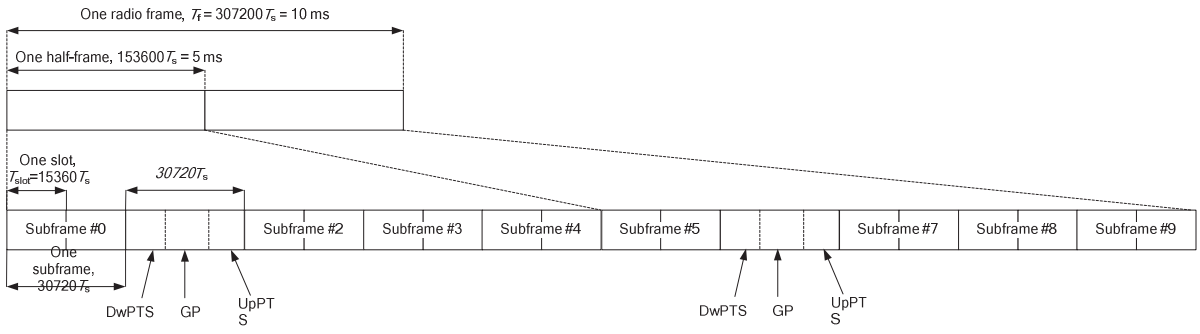



**Figure 4.2-1: Frame structure type 2 (for 5 ms switch-point periodicity)**

**Table 4.2-1: Configuration of special subframe (lengths of DwPTS/GP/UpPTS)**

| Special subframe configuration | Normal cyclic prefix in downlink | | | Extended cyclic prefix in downlink | | |
|---|---|---|---|---|---|---|
| | DwPTS | UpPTS | | DwPTS | UpPTS | |
| | | Normal cyclic prefix in uplink | Extended cyclic prefix in uplink | | Normal cyclic prefix in uplink | Extended cyclic prefix in uplink |
| 0 | $6592 \cdot T_s$ | $2192 \cdot T_s$ | $2560 \cdot T_s$ | $7680 \cdot T_s$ | $2192 \cdot T_s$ | $2560 \cdot T_s$ |
| 1 | $19760 \cdot T_s$ | | | $20480 \cdot T_s$ | | |
| 2 | $21952 \cdot T_s$ | | | $23040 \cdot T_s$ | | |
| 3 | $24144 \cdot T_s$ | | | $25600 \cdot T_s$ | | |
| 4 | $26336 \cdot T_s$ | | | $7680 \cdot T_s$ | $4384 \cdot T_s$ | $5120 \cdot T_s$ |
| 5 | $6592 \cdot T_s$ | $4384 \cdot T_s$ | $5120 \cdot T_s$ | $20480 \cdot T_s$ | | |
| 6 | $19760 \cdot T_s$ | | | $23040 \cdot T_s$ | | |
| 7 | $21952 \cdot T_s$ | | | $12800 \cdot T_s$ | | |
| 8 | $24144 \cdot T_s$ | | | - | - | - |
| 9 | $13168 \cdot T_s$ | | | - | - | - |

**Table 4.2-2: Uplink-downlink configurations**

| Uplink-downlink configuration | Downlink-to-Uplink Switch-point periodicity | Subframe number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 5 ms | D | S | U | U | U | D | S | U | U | U |
| 1 | 5 ms | D | S | U | U | D | D | S | U | U | D |
| 2 | 5 ms | D | S | U | D | D | D | S | U | D | D |
| 3 | 10 ms | D | S | U | U | U | D | D | D | D | D |
| 4 | 10 ms | D | S | U | U | D | D | D | D | D | D |
| 5 | 10 ms | D | S | U | D | D | D | D | D | D | D |
| 6 | 5 ms | D | S | U | U | U | D | S | U | U | D |

# 5 Uplink

## 5.1 Overview

The smallest resource unit for uplink transmissions is denoted a resource element and is defined in clause 5.2.2.

### 5.1.1 Physical channels

An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 3GPP TS 36.212 [3] and the present document 3GPP TS 36.211.
The following uplink physical channels are defined:

- Physical Uplink Shared Channel, PUSCH
- Physical Uplink Control Channel, PUCCH
- Physical Random Access Channel, PRACH

### 5.1.2 Physical signals

An uplink physical signal is used by the physical layer but does not carry information originating from higher layers.
The following uplink physical signals are defined:

- Reference signal

## 5.2 Slot structure and physical resources

### 5.2.1 Resource grid

The transmitted signal in each slot is described by one or several resource grids of $N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}$ subcarriers and $N_{\mathrm{symb}}^{\mathrm{UL}}$ SC-FDMA symbols. The resource grid is illustrated in Figure 5.2.1-1. The quantity $N_{\mathrm{RB}}^{\mathrm{UL}}$ depends on the uplink transmission bandwidth configured in the cell and shall fulfil

$$N_{\mathrm{RB}}^{\mathrm{min,UL}} \le N_{\mathrm{RB}}^{\mathrm{UL}} \le N_{\mathrm{RB}}^{\mathrm{max,UL}}$$

where $N_{\mathrm{RB}}^{\mathrm{min,UL}} = 6$ and $N_{\mathrm{RB}}^{\mathrm{max,UL}} = 110$ are the smallest and largest uplink bandwidths, respectively, supported by the current version of this specification. The set of allowed values for $N_{\mathrm{RB}}^{\mathrm{UL}}$ is given by 3GPP TS 36.101 [7].

The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by the higher layer parameter *UL-CyclicPrefixLength* and is given in Table 5.2.3-1.

An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. There is one resource grid per antenna port. The antenna ports used for transmission of a physical channel or signal depends on the number of antenna ports configured for the physical channel or signal as shown in Table 5.2.1-1. The index $\tilde{p}$ is used throughout clause 5 when a sequential numbering of the antenna ports is necessary.

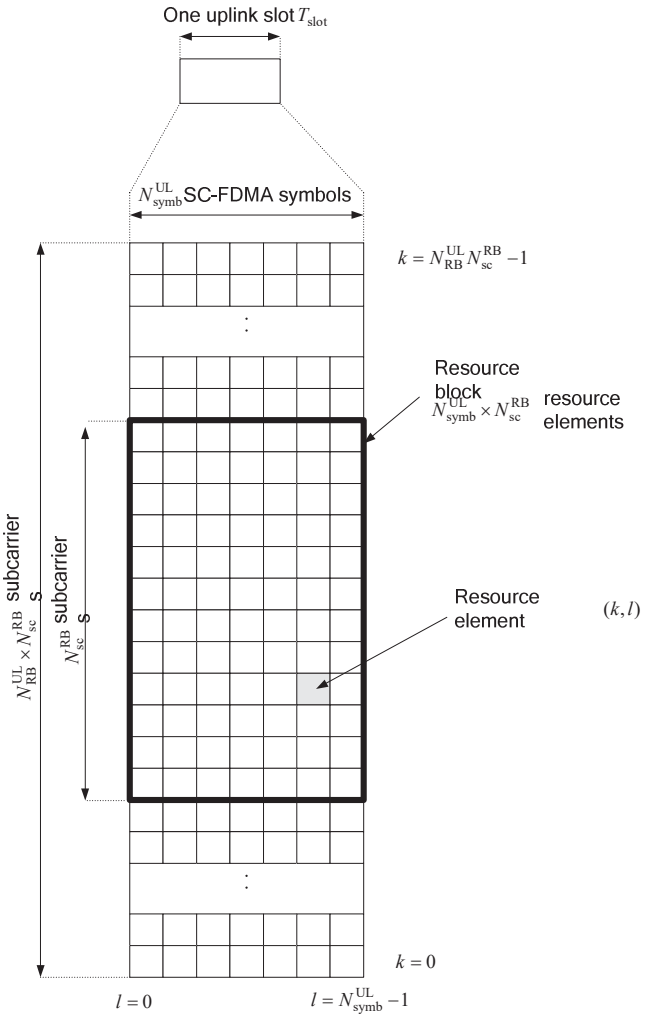



**Figure 5.2.1-1: Uplink resource grid**

**Table 5.2.1-1: Antenna ports used for different physical channels and signals**

| Physical channel or signal | Index $\tilde{p}$ | Antenna port number $p$ as a function of the number of antenna ports configured for the respective physical channel/signal | | |
|---|---|---|---|---|
| | | 1 | 2 | 4 |
| PUSCH | 0 | 10 | 20 | 40 |
| | 1 | - | 21 | 41 |
| | 2 | - | - | 42 |
| | 3 | - | - | 43 |
| SRS | 0 | 10 | 20 | 40 |
| | 1 | - | 21 | 41 |
| | 2 | - | - | 42 |
| | 3 | - | - | 43 |
| PUCCH | 0 | 100 | 200 | - |
| | 1 | - | 201 | - |

## 5.2.2 Resource elements

Each element in the resource grid is called a resource element and is uniquely defined by the index pair $(k,l)$ in a slot where $k = 0,...,N_{\text{RB}}^{\text{UL}}N_{\text{sc}}^{\text{RB}} - 1$ and $l = 0,...,N_{\text{symb}}^{\text{UL}} - 1$ are the indices in the frequency and time domains, respectively. Resource element $(k,l)$ on antenna port $p$ corresponds to the complex value $a_{k,l}^{(p)}$.
When there is no risk for confusion, or no particular antenna port is specified, the index $p$ may be dropped.
Quantities $a_{k,l}^{(p)}$ corresponding to resource elements not used for transmission of a physical channel or a physical signal in a slot shall be set to zero.

## 5.2.3 Resource blocks

A physical resource block is defined as $N_{\text{symb}}^{\text{UL}}$ consecutive SC-FDMA symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{UL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 5.2.3-1.
A physical resource block in the uplink thus consists of $N_{\text{symb}}^{\text{UL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

**Table 5.2.3-1: Resource block parameters**

| Configuration | $N_{\text{sc}}^{\text{RB}}$ | $N_{\text{symb}}^{\text{UL}}$ |
|---|---|---|
| Normal cyclic prefix | 12 | 7 |
| Extended cyclic prefix | 12 | 6 |

The relation between the physical resource block number $n_{\text{PRB}}$ in the frequency domain and resource elements $(k,l)$ in a slot is given by

$$n_{\text{PRB}} = \left\lfloor \frac{k}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$$

# 5.3 Physical uplink shared channel

The baseband signal representing the physical uplink shared channel is defined in terms of the following steps:

- scrambling
- modulation of scrambled bits to generate complex-valued symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- transform precoding to generate complex-valued symbols
- precoding of the complex-valued symbols
- mapping of precoded complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port

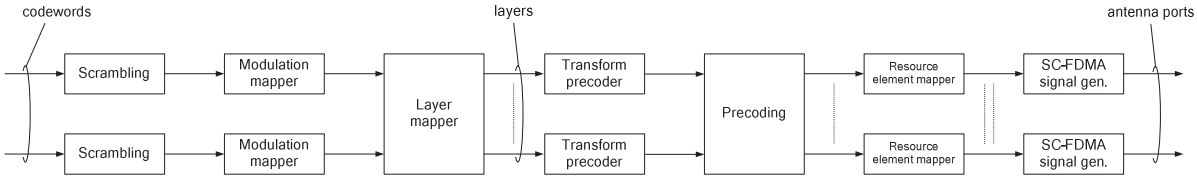



**Figure 5.3-1: Overview of uplink physical channel processing**

## 5.3.1 Scrambling

For each codeword $q$, the block of bits $b^{(q)}(0),...,b^{(q)}(M_{\text{bit}}^{(q)}-1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits transmitted in codeword $q$ on the physical uplink shared channel in one subframe, shall be scrambled with a UE-specific scrambling sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(\text{q})}-1)$ according to the following pseudo code

Set $i = 0$

while $i < M_{\text{bit}}^{(q)}$

if $b^{(q)}(i) = \text{x}$ // ACK/NACK or Rank Indication placeholder bits

$\tilde{b}^{(q)}(i) = 1$

else

if $b^{(q)}(i) = \text{y}$ // ACK/NACK or Rank Indication repetition placeholder bits

$\tilde{b}^{(q)}(i) = \tilde{b}^{(q)}(i-1)$

else // Data or channel quality coded bits, Rank Indication coded bits or ACK/NACK coded bits

$\tilde{b}^{(q)}(i) = \left(b^{(q)}(i) + c^{(q)}(i)\right) \bmod 2$

end if

end if

$i = i + 1$

end while

where x and y are tags defined in 3GPP TS 36.212 [3] clause 5.2.2.6 and where the scrambling sequence $c^{(q)}(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{14} + q \cdot 2^{13} + \lfloor n_s/2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{cell}}$ at the start of each subframe where $n_{\text{RNTI}}$ corresponds to the RNTI associated with the PUSCH transmission as described in clause 8 in 3GPP TS 36.213 [4].

Up to two codewords can be transmitted in one subframe, i.e., $q \in \{0,1\}$. In the case of single-codeword transmission, $q = 0$.

## 5.3.2 Modulation

For each codeword $q$, the block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(\text{q})} - 1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued symbols $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(q)} - 1)$. Table 5.3.2-1 specifies the modulation mappings applicable for the physical uplink shared channel.

**Table 5.3.2-1: Uplink modulation schemes**

| Physical channel | Modulation schemes |
|---|---|
| PUSCH | QPSK, 16QAM, 64QAM |

## 5.3.2A Layer mapping

The complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or two layers. Complex-valued modulation symbols $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(q)}-1)$ for codeword $q$ shall be mapped onto the layers $x(i)=\left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$, $i=0,1,...,M_{\text{symb}}^{\text{layer}}-1$ where $\upsilon$ is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.

### 5.3.2A.1 Layer mapping for transmission on a single antenna port

For transmission on a single antenna port, a single layer is used, $\upsilon=1$, and the mapping is defined by

$$x^{(0)}(i)=d^{(0)}(i)$$

with $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}$.

### 5.3.2A.2 Layer mapping for spatial multiplexing

For spatial multiplexing, the layer mapping shall be done according to Table 5.3.2A.2-1. The number of layers $\upsilon$ is less than or equal to the number of antenna ports $P$ used for transmission of the physical uplink shared channel.
The case of a single codeword mapped to multiple layers is only applicable when the number of antenna ports used for PUSCH is four.

**Table 5.3.2A.2-1: Codeword-to-layer mapping for spatial multiplexing**

| Number of layers | Number of codewords | Codeword-to-layer mapping $i=0,1,...,M_{\text{symb}}^{\text{layer}}-1$ | |
|---|---|---|---|
| 1 | 1 | $x^{(0)}(i)=d^{(0)}(i)$ | $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}$ |
| 2 | 1 | $x^{(0)}(i)=d^{(0)}(2i)$<br>$x^{(1)}(i)=d^{(0)}(2i+1)$ | $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}/2$ |
| 2 | 2 | $x^{(0)}(i)=d^{(0)}(i)$<br>$x^{(1)}(i)=d^{(1)}(i)$ | $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}=M_{\text{symb}}^{(1)}$ |
| 3 | 2 | $x^{(0)}(i)=d^{(0)}(i)$<br>$x^{(1)}(i)=d^{(1)}(2i)$<br>$x^{(2)}(i)=d^{(1)}(2i+1)$ | $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}=M_{\text{symb}}^{(1)}/2$ |
| 4 | 2 | $x^{(0)}(i)=d^{(0)}(2i)$<br>$x^{(1)}(i)=d^{(0)}(2i+1)$<br>$x^{(2)}(i)=d^{(1)}(2i)$<br>$x^{(3)}(i)=d^{(1)}(2i+1)$ | $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}/2=M_{\text{symb}}^{(1)}/2$ |

## 5.3.3 Transform precoding

For each layer $\lambda = 0,1,...,\upsilon - 1$ the block of complex-valued symbols $x^{(\lambda)}(0),...,x^{(\lambda)}(M_{\text{symb}}^{\text{layer}} - 1)$ is divided into $M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one SC-FDMA symbol. Transform precoding shall be applied according to

$$y^{(\lambda)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}}-1} x^{(\lambda)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUSCH}}}}$$
$$k = 0,...,M_{\text{sc}}^{\text{PUSCH}} - 1$$
$$l = 0,...,M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}} - 1$$

resulting in a block of complex-valued symbols $y^{(\lambda)}(0),...,y^{(\lambda)}(M_{\text{symb}}^{\text{layer}} - 1)$. The variable $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUSCH}}$ represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfil

$$M_{\text{RB}}^{\text{PUSCH}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5} \le N_{\text{RB}}^{\text{UL}}$$

where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers.

## 5.3.3A Precoding

The precoder takes as input a block of vectors $\left[y^{(0)}(i) \quad ... \quad y^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{layer}} - 1$ from the transform precoder and generates a block of vectors $\left[z^{(0)}(i) \quad \ldots \quad z^{(P-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$ to be mapped onto resource elements.

### 5.3.3A.1 Precoding for transmission on a single antenna port

For transmission on a single antenna port, precoding is defined by

$$z^{(0)}(i) = y^{(0)}(i)$$

where $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

### 5.3.3A.2 Precoding for spatial multiplexing

Precoding for spatial multiplexing is only used in combination with layer mapping for spatial multiplexing as described in clause 5.3.2A.2. Spatial multiplexing supports $P = 2$ or $P = 4$ antenna ports where the set of antenna ports used for spatial multiplexing is $p \in \{20,21\}$ and $p \in \{40,41,42,43\}$, respectively.

Precoding for spatial multiplexing is defined by

$$\begin{bmatrix} z^{(0)}(i) \\ \vdots \\ z^{(P-1)}(i) \end{bmatrix} = W \begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(\upsilon-1)}(i) \end{bmatrix}$$

where $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

The precoding matrix $W$ of size $P \times \upsilon$ is given by one of the entries in Table 5.3.3A.2-1 for $P = 2$ and by Tables 5.3.3A.2-2 through 5.3.3A.2-5 for $P = 4$ where the entries in each row are ordered from left to right in increasing order of codebook indices.

**Table 5.3.3A.2-1: Codebook for transmission on antenna ports $\{20,21\}$**

| Codebook index | Number of layers | |
|---|---|---|
| | $\upsilon = 1$ | $\upsilon = 2$ |
| 0 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$ | $\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$ |
| 1 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$ | - |
| 2 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$ | - |
| 3 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$ | - |
| 4 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\0\end{bmatrix}$ | - |
| 5 | $\frac{1}{\sqrt{2}}\begin{bmatrix}0\\1\end{bmatrix}$ | - |

**Table 5.3.3A.2-2: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon = 1$**

| Codebook index | Number of layers $\upsilon = 1$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 – 7 | $\frac{1}{2}\begin{bmatrix}1\\1\\1\\-1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\1\\j\\j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\1\\-1\\1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\1\\-j\\-j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\j\\1\\j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\j\\j\\1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\j\\-1\\-j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\j\\-j\\-1\end{bmatrix}$ |
| 8 – 15 | $\frac{1}{2}\begin{bmatrix}1\\-1\\1\\1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\-1\\j\\-j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\-1\\-1\\-1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\-1\\-j\\j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\-j\\1\\-j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\-j\\j\\-1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\-j\\-1\\j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\-j\\-j\\1\end{bmatrix}$ |
| 16 – 23 | $\frac{1}{2}\begin{bmatrix}1\\0\\1\\0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\0\\-1\\0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\0\\j\\0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1\\0\\-j\\0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}0\\1\\0\\1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}0\\1\\0\\-1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}0\\1\\0\\j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}0\\1\\0\\-j\end{bmatrix}$ |

**Table 5.3.3A.2-3: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon = 2$**

| Codebook index | Number of layers $\upsilon = 2$ | | | |
|---|---|---|---|---|
| 0 – 3 | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 1 & 0\\ 0 & 1\\ 0 & -j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 1 & 0\\ 0 & 1\\ 0 & j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ -j & 0\\ 0 & 1\\ 0 & 1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ -j & 0\\ 0 & 1\\ 0 & -1\end{bmatrix}$ |
| 4 – 7 | $\frac{1}{2}\begin{bmatrix}1 & 0\\ -1 & 0\\ 0 & 1\\ 0 & -j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ -1 & 0\\ 0 & 1\\ 0 & j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ j & 0\\ 0 & 1\\ 0 & 1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ j & 0\\ 0 & 1\\ 0 & -1\end{bmatrix}$ |
| 8 – 11 | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\\ 0 & 1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\\ 0 & -1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ -1 & 0\\ 0 & 1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ -1 & 0\\ 0 & -1\end{bmatrix}$ |
| 12 – 15 | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & 1\\ 1 & 0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & -1\\ 1 & 0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & 1\\ -1 & 0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & -1\\ -1 & 0\end{bmatrix}$ |

**Table 5.3.3A.2-4: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon = 3$**

| Codebook index | Number of layers $\upsilon = 3$ | | | |
|---|---|---|---|---|
| 0 – 3 | $\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ -1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ -1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$ |
| 4 – 7 | $\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\\ -1 & 0 & 0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ -1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$ |
| 8 – 11 | $\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\\ -1 & 0 & 0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\\ 1 & 0 & 0\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\\ -1 & 0 & 0\end{bmatrix}$ |

**Table 5.3.3A.2-5: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon = 4$**

| Codebook index | Number of layers $\upsilon = 4$ |
|---|---|
| 0 | $\frac{1}{2}\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$ |

### 5.3.4 Mapping to physical resources

For each antenna port $p$ used for transmission of the PUSCH in a subframe the block of complex-valued symbols $z^{(\tilde{p})}(0),...,z^{(\tilde{p})}(M^{\text{ap}}_{\text{symb}}-1)$ shall be multiplied with the amplitude scaling factor $\beta_{\text{PUSCH}}$ in order to conform to the transmit power $P_{\text{PUSCH}}$ specified in clause 5.1.1.1 in 3GPP TS 36.213 [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to physical resource blocks on antenna port $p$ and assigned for transmission of PUSCH. The relation between the index $\tilde{p}$ and the antenna port number $p$ is given by Table 5.2.1-1. The mapping to resource elements $(k,l)$ corresponding to the physical resource blocks assigned for transmission and

- not used for transmission of reference signals, and
- not part of the last SC-FDMA symbol in a subframe, if the UE transmits SRS in the same subframe, and
- not part of the last SC-FDMA symbol in a subframe configured with cell-specific SRS, if the PUSCH transmission partly or fully overlaps with the cell-specific SRS bandwidth, and
- not part of an SC-FDMA symbol reserved for possible SRS transmission in a UE-specific aperiodic SRS subframe, and
- not part of an SC-FDMA symbol reserved for possible SRS transmission in a UE-specific periodic SRS subframe in the same serving cell when the UE is configured with multiple TAGs

shall be in increasing order of first the index $k$, then the index $l$, starting with the first slot in the subframe.

If uplink frequency-hopping is disabled or the resource blocks allocated for PUSCH transmission are not contiguous in frequency, the set of physical resource blocks to be used for transmission is given by $n_{\text{PRB}} = n_{\text{VRB}}$ where $n_{\text{VRB}}$ is obtained from the uplink scheduling grant as described in clause 8.1 in 3GPP TS 36.213 [4].

If uplink frequency-hopping with type 1 PUSCH hopping is enabled, the set of physical resource blocks to be used for transmission is given by clause 8.4.1 in 3GPP TS 36.213 [4].

If uplink frequency-hopping with predefined hopping pattern is enabled, the set of physical resource blocks to be used for transmission in slot $n_{\text{s}}$ is given by the scheduling grant together with a predefined pattern according to

$$\tilde{n}_{\text{PRB}}(n_{\text{s}}) = \left(\tilde{n}_{\text{VRB}} + f_{\text{hop}}(i)\cdot N^{\text{sb}}_{\text{RB}} + \left(\left(N^{\text{sb}}_{\text{RB}}-1\right)-2\left(\tilde{n}_{\text{VRB}} \bmod N^{\text{sb}}_{\text{RB}}\right)\right)\cdot f_{\text{m}}(i)\right)\bmod(N^{\text{sb}}_{\text{RB}}\cdot N_{\text{sb}})$$

$$i = \begin{cases} \lfloor n_{\text{s}}/2 \rfloor & \text{inter-subframe hopping} \\ n_{\text{s}} & \text{intra and inter-subframe hopping} \end{cases}$$

$$n_{\text{PRB}}(n_{\text{s}}) = \begin{cases} \tilde{n}_{\text{PRB}}(n_{\text{s}}) & N_{sb}=1 \\ \tilde{n}_{\text{PRB}}(n_{\text{s}}) + \left\lceil N^{\text{HO}}_{\text{RB}}/2 \right\rceil & N_{sb}>1 \end{cases}$$

$$\tilde{n}_{\text{VRB}} = \begin{cases} n_{\text{VRB}} & N_{sb}=1 \\ n_{\text{VRB}} - \left\lceil N^{\text{HO}}_{\text{RB}}/2 \right\rceil & N_{sb}>1 \end{cases}$$

where $n_{\text{VRB}}$ is obtained from the scheduling grant as described in clause 8.1 in 3GPP TS 36.213 [4]. The parameter *pusch-HoppingOffset*, $N^{\text{HO}}_{\text{RB}}$, is provided by higher layers. The size $N^{\text{sb}}_{\text{RB}}$ of each sub-band is given by,

$$N^{\text{sb}}_{\text{RB}} = \begin{cases} N^{\text{UL}}_{\text{RB}} & N_{\text{sb}}=1 \\ \left\lfloor \left(N^{\text{UL}}_{\text{RB}} - N^{\text{HO}}_{\text{RB}} - N^{\text{HO}}_{\text{RB}} \bmod 2\right) / N_{\text{sb}} \right\rfloor & N_{\text{sb}}>1 \end{cases}$$

where the number of sub-bands $N_{\text{sb}}$ is given by higher layers. The function $f_{\text{m}}(i) \in \{0,1\}$ determines whether mirroring is used or not. The parameter *Hopping-mode* provided by higher layers determines if hopping is "inter-subframe" or "intra and inter-subframe".

The hopping function $f_{\text{hop}}(i)$ and the function $f_{\text{m}}(i)$ are given by

$$f_{\text{hop}}(i) = \begin{cases} 0 & N_{\text{sb}} = 1 \\ (f_{\text{hop}}(i-1) + \sum_{k=i\cdot 10+1}^{i\cdot 10+9} c(k) \times 2^{k-(i\cdot 10+1)}) \bmod N_{\text{sb}} & N_{\text{sb}} = 2 \\ (f_{\text{hop}}(i-1) + \left( \sum_{k=i\cdot 10+1}^{i\cdot 10+9} c(k) \times 2^{k-(i\cdot 10+1)} \right) \bmod (N_{\text{sb}} - 1) + 1) \bmod N_{\text{sb}} & N_{\text{sb}} > 2 \end{cases}$$

$$f_{\text{m}}(i) = \begin{cases} i \bmod 2 & N_{\text{sb}} = 1 \text{ and intra and inter} - \text{subframe hopping} \\ \text{CURRENT_TX_NB} \bmod 2 & N_{\text{sb}} = 1 \text{ and inter} - \text{subframe hopping} \\ c(i \cdot 10) & N_{\text{sb}} > 1 \end{cases}$$

where $f_{\text{hop}}(-1) = 0$ and the pseudo-random sequence $c(i)$ is given by clause 7.2 and CURRENT_TX_NB indicates the transmission number for the transport block transmitted in slot $n_{\text{s}}$ as defined in [8]. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = N_{\text{ID}}^{\text{cell}}$ for frame structure type 1 and $c_{\text{init}} = 2^9 \cdot (n_{\text{f}} \bmod 4) + N_{\text{ID}}^{\text{cell}}$ for frame structure type 2 at the start of each frame.

## 5.4 Physical uplink control channel

The physical uplink control channel, PUCCH, carries uplink control information. Simultaneous transmission of PUCCH and PUSCH from the same UE is supported if enabled by higher layers. For frame structure type 2, the PUCCH is not transmitted in the UpPTS field.

The physical uplink control channel supports multiple formats as shown in Table 5.4-1.
Formats 2a and 2b are supported for normal cyclic prefix only.

**Table 5.4-1: Supported PUCCH formats**

| PUCCH format | Modulation scheme | Number of bits per subframe, $M_{\text{bit}}$ |
|---|---|---|
| 1 | N/A | N/A |
| 1a | BPSK | 1 |
| 1b | QPSK | 2 |
| 2 | QPSK | 20 |
| 2a | QPSK+BPSK | 21 |
| 2b | QPSK+QPSK | 22 |
| 3 | QPSK | 48 |

All PUCCH formats use a cyclic shift, $n_{\text{cs}}^{\text{cell}}(n_{\text{s}}, l)$, which varies with the symbol number $l$ and the slot number $n_{\text{s}}$ according to

$$n_{\text{cs}}^{\text{cell}}(n_{\text{s}}, l) = \sum_{i=0}^{7} c(8N_{\text{symb}}^{\text{UL}} \cdot n_{\text{s}} + 8l + i) \cdot 2^i$$

where the pseudo-random sequence $c(i)$ is defined by clause 7.2. The pseudo-random sequence generator shall be initialized with $c_{\text{init}} = n_{\text{ID}}^{\text{RS}}$, where $n_{\text{ID}}^{\text{RS}}$ is given by clause 5.5.1.5 with $N_{\text{ID}}^{\text{cell}}$ corresponding to the primary cell, at the beginning of each radio frame.

The physical resources used for PUCCH depends on two parameters, $N_{\text{RB}}^{(2)}$ and $N_{\text{cs}}^{(1)}$, given by higher layers.
The variable $N_{\text{RB}}^{(2)} \geq 0$ denotes the bandwidth in terms of resource blocks that are available for use by PUCCH formats 2/2a/2b transmission in each slot. The variable $N_{\text{cs}}^{(1)}$ denotes the number of cyclic shift used for PUCCH formats 1/1a/1b in a resource block used for a mix of formats 1/1a/1b and 2/2a/2b. The value of $N_{\text{cs}}^{(1)}$ is an integer multiple of $\Delta_{\text{shift}}^{\text{PUCCH}}$ within the range of {0, 1, …, 7}, where $\Delta_{\text{shift}}^{\text{PUCCH}}$ is provided by higher layers. No mixed resource block is present if $N_{\text{cs}}^{(1)} = 0$. At most one resource block in each slot supports a mix of formats 1/1a/1b and 2/2a/2b.
Resources used for transmission of PUCCH formats 1/1a/1b, 2/2a/2b and 3 are represented by the non-negative indices $n_{\text{PUCCH}}^{(1,\tilde{p})}$, $n_{\text{PUCCH}}^{(2,\tilde{p})} < N_{\text{RB}}^{(2)} N_{\text{sc}}^{\text{RB}} + \left\lceil \frac{N_{\text{cs}}^{(1)}}{8} \right\rceil \cdot (N_{\text{sc}}^{\text{RB}} - N_{\text{cs}}^{(1)} - 2)$, and $n_{\text{PUCCH}}^{(3,\tilde{p})}$, respectively.

### 5.4.1 PUCCH formats 1, 1a and 1b

For PUCCH format 1, information is carried by the presence/absence of transmission of PUCCH from the UE.
In the remainder of this clause, $d(0) = 1$ shall be assumed for PUCCH format 1.

For PUCCH formats 1a and 1b, one or two explicit bits are transmitted, respectively. The block of bits $b(0),...,b(M_{\text{bit}} - 1)$ shall be modulated as described in Table 5.4.1-1, resulting in a complex-valued symbol $d(0)$.
The modulation schemes for the different PUCCH formats are given by Table 5.4-1.

The complex-valued symbol $d(0)$ shall be multiplied with a cyclically shifted length $N_{\text{seq}}^{\text{PUCCH}} = 12$ sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ for each of the $P$ antenna ports used for PUCCH transmission according to

$$y^{(\tilde{p})}(n) = \frac{1}{\sqrt{P}} d(0) \cdot r_{u,v}^{(\alpha_{\tilde{p}})}(n), \qquad n = 0,1,...,N_{\text{seq}}^{\text{PUCCH}} - 1$$

where $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is defined by clause 5.5.1 with $M_{\text{sc}}^{\text{RS}} = N_{\text{seq}}^{\text{PUCCH}}$. The antenna-port specific cyclic shift $\alpha_{\tilde{p}}$ varies between symbols and slots as defined below.

The block of complex-valued symbols $y^{(\tilde{p})}(0),...,y^{(\tilde{p})}(N_{\text{seq}}^{\text{PUCCH}}-1)$ shall be scrambled by $S(n_s)$ and block-wise spread with the antenna-port specific orthogonal sequence $w_{n_{\text{oc}}^{(\tilde{p})}}(i)$ according to

$$z^{(\tilde{p})}\left(m'\cdot N_{\text{SF}}^{\text{PUCCH}}\cdot N_{\text{seq}}^{\text{PUCCH}}+m\cdot N_{\text{seq}}^{\text{PUCCH}}+n\right)=S(n_{\text{s}})\cdot w_{n_{\text{oc}}^{(\tilde{p})}}(m)\cdot y^{(\tilde{p})}(n)$$

where

$$\begin{aligned}m&=0,...,N_{\text{SF}}^{\text{PUCCH}}-1\\ n&=0,...,N_{\text{seq}}^{\text{PUCCH}}-1\\ m'&=0,1\end{aligned}$$

and

$$S(n_{\text{s}})=\begin{cases}1 & \text{if } n'_{\tilde{p}}(n_{\text{s}})\bmod 2=0\\ e^{j\pi/2} & \text{otherwise}\end{cases}$$

with $N_{\text{SF}}^{\text{PUCCH}}=4$ for both slots of normal PUCCH formats 1/1a/1b, and $N_{\text{SF}}^{\text{PUCCH}}=4$ for the first slot and $N_{\text{SF}}^{\text{PUCCH}}=3$ for the second slot of shortened PUCCH formats 1/1a/1b. The sequence $w_{n_{\text{oc}}^{(\tilde{p})}}(i)$ is given by Table 5.4.1-2 and Table 5.4.1-3 and $n'_{\tilde{p}}(n_{\text{s}})$ is defined below.

Resources used for transmission of PUCCH format 1, 1a and 1b are identified by a resource index $n_{\text{PUCCH}}^{(1,\tilde{p})}$ from which the orthogonal sequence index $n_{\text{oc}}^{(\tilde{p})}(n_{\text{s}})$ and the cyclic shift $\alpha_{\tilde{p}}(n_{\text{s}},l)$ are determined according to

$$n_{\text{oc}}^{(\tilde{p})}(n_{\text{s}})=\begin{cases}\left\lfloor n'_{\tilde{p}}(n_{\text{s}})\cdot\Delta_{\text{shift}}^{\text{PUCCH}}/N'\right\rfloor & \text{for normal cyclic prefix}\\ 2\cdot\left\lfloor n'_{\tilde{p}}(n_{\text{s}})\cdot\Delta_{\text{shift}}^{\text{PUCCH}}/N'\right\rfloor & \text{for extended cyclic prefix}\end{cases}$$

$$\alpha_{\tilde{p}}(n_{\text{s}},l)=2\pi\cdot n_{\text{cs}}^{(\tilde{p})}(n_{\text{s}},l)/N_{\text{sc}}^{\text{RB}}$$

$$n_{\text{cs}}^{(\tilde{p})}(n_{\text{s}},l)=\begin{cases}\left[n_{\text{cs}}^{\text{cell}}(n_{\text{s}},l)+\left(n'_{\tilde{p}}(n_{\text{s}})\cdot\Delta_{\text{shift}}^{\text{PUCCH}}+\left(n_{\text{oc}}^{(\tilde{p})}(n_{\text{s}})\bmod\Delta_{\text{shift}}^{\text{PUCCH}}\right)\right)\bmod N'\right]\bmod N_{\text{sc}}^{\text{RB}} & \text{for normal cyclic prefix}\\ \left[n_{\text{cs}}^{\text{cell}}(n_{\text{s}},l)+\left(n'_{\tilde{p}}(n_{\text{s}})\cdot\Delta_{\text{shift}}^{\text{PUCCH}}+n_{\text{oc}}^{(\tilde{p})}(n_{\text{s}})/2\right)\bmod N'\right]\bmod N_{\text{sc}}^{\text{RB}} & \text{for extended cyclic prefix}\end{cases}$$

where

$$N'=\begin{cases}N_{\text{cs}}^{(1)} & \text{if } n_{\text{PUCCH}}^{(1,\tilde{p})}<c\cdot N_{\text{cs}}^{(1)}/\Delta_{\text{shift}}^{\text{PUCCH}}\\ N_{\text{sc}}^{\text{RB}} & \text{otherwise}\end{cases}$$

$$c=\begin{cases}3 & \text{normal cyclic prefix}\\ 2 & \text{extended cyclic prefix}\end{cases}$$

The resource indices within the two resource blocks in the two slots of a subframe to which the PUCCH is mapped are given by

$$n'_{\tilde{p}}(n_{\text{s}})=\begin{cases}n_{\text{PUCCH}}^{(1,\tilde{p})} & \text{if } n_{\text{PUCCH}}^{(1,\tilde{p})}<c\cdot N_{\text{cs}}^{(1)}/\Delta_{\text{shift}}^{\text{PUCCH}}\\ \left(n_{\text{PUCCH}}^{(1,\tilde{p})}-c\cdot N_{\text{cs}}^{(1)}/\Delta_{\text{shift}}^{\text{PUCCH}}\right)\bmod\left(c\cdot N_{\text{sc}}^{\text{RB}}/\Delta_{\text{shift}}^{\text{PUCCH}}\right) & \text{otherwise}\end{cases}$$

for $n_{\text{s}}\bmod 2=0$ and by

$$n'_{\tilde{p}}(n_s)=\begin{cases}\left[c\left(n'_{\tilde{p}}(n_s-1)+1\right)\right] \bmod\left(cN_{sc}^{RB}/\Delta_{shift}^{PUCCH}+1\right)-1 & n_{PUCCH}^{(1,\tilde{p})}\geq c\cdot N_{cs}^{(1)}/\Delta_{shift}^{PUCCH}\\ \left\lfloor h_{\tilde{p}}/c\right\rfloor+\left(h_{\tilde{p}} \bmod c\right)N'/\Delta_{shift}^{PUCCH} & \text{otherwise}\end{cases}$$

for $n_s \bmod 2=1$, where $h_{\tilde{p}}=\left(n'_{\tilde{p}}(n_s-1)+d\right)\bmod\left(cN'/\Delta_{shift}^{PUCCH}\right)$, with $d=2$ for normal CP and $d=0$ for extended CP.

The parameter *deltaPUCCH-Shift* $\Delta_{shift}^{PUCCH}$ is provided by higher layers.

**Table 5.4.1-1: Modulation symbol $d(0)$ for PUCCH formats 1a and 1b**

| PUCCH format | $b(0),...,b(M_{bit}-1)$ | $d(0)$ |
|---|---|---|
| 1a | 0 | 1 |
| | 1 | $-1$ |
| 1b | 00 | 1 |
| | 01 | $-j$ |
| | 10 | $j$ |
| | 11 | $-1$ |

**Table 5.4.1-2: Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{SF}^{PUCCH}-1)\right]$ for $N_{SF}^{PUCCH}=4$**

| Sequence index $n_{oc}^{(\tilde{p})}(n_s)$ | Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{SF}^{PUCCH}-1)\right]$ |
|---|---|
| 0 | $[+1 \quad +1 \quad +1 \quad +1]$ |
| 1 | $[+1 \quad -1 \quad +1 \quad -1]$ |
| 2 | $[+1 \quad -1 \quad -1 \quad +1]$ |

**Table 5.4.1-3: Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{SF}^{PUCCH}-1)\right]$ for $N_{SF}^{PUCCH}=3$**

| Sequence index $n_{oc}^{(\tilde{p})}(n_s)$ | Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{SF}^{PUCCH}-1)\right]$ |
|---|---|
| **0** | $[1 \quad 1 \quad 1]$ |
| **1** | $\left[1 \quad e^{j2\pi/3} \quad e^{j4\pi/3}\right]$ |
| **2** | $\left[1 \quad e^{j4\pi/3} \quad e^{j2\pi/3}\right]$ |

## 5.4.2 PUCCH formats 2, 2a and 2b

The block of bits $b(0),...,b(19)$ shall be scrambled with a UE-specific scrambling sequence, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(19)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = \left(\lfloor n_s/2 \rfloor + 1\right) \cdot \left(2N_{\text{ID}}^{\text{cell}} + 1\right) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where $n_{\text{RNTI}}$ is C-RNTI.

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(19)$ shall be QPSK modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(9)$.

Each complex-valued symbol $d(0),...,d(9)$ shall be multiplied with a cyclically shifted length $N_{\text{seq}}^{\text{PUCCH}} = 12$ sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ for each of the $P$ antenna ports used for PUCCH transmission according to

$$z^{(\tilde{p})}(N_{\text{seq}}^{\text{PUCCH}} \cdot n + i) = \frac{1}{\sqrt{P}} d(n) \cdot r_{u,v}^{(\alpha_{\tilde{p}})}(i)$$
$$n = 0,1,...,9$$
$$i = 0,1,...,N_{\text{sc}}^{\text{RB}} - 1$$

where $r_{u,v}^{(\alpha_{\tilde{p}})}(i)$ is defined by clause 5.5.1 with $M_{\text{sc}}^{\text{RS}} = N_{\text{seq}}^{\text{PUCCH}}$.

Resources used for transmission of PUCCH formats 2/2a/2b are identified by a resource index $n_{\text{PUCCH}}^{(2,\tilde{p})}$ from which the cyclic shift $\alpha_{\tilde{p}}(n_s, l)$ is determined according to

$$\alpha_{\tilde{p}}(n_s, l) = 2\pi \cdot n_{\text{cs}}^{(\tilde{p})}(n_s, l) \big/ N_{\text{sc}}^{\text{RB}}$$

where

$$n_{\text{cs}}^{(\tilde{p})}(n_s, l) = \left(n_{\text{cs}}^{\text{cell}}(n_s, l) + n'_{\tilde{p}}(n_s)\right) \bmod N_{\text{sc}}^{\text{RB}}$$

and

$$n'_{\tilde{p}}(n_s) = \begin{cases} n_{\text{PUCCH}}^{(2,\tilde{p})} \bmod N_{\text{sc}}^{\text{RB}} & \text{if } n_{\text{PUCCH}}^{(2,\tilde{p})} < N_{\text{sc}}^{\text{RB}} N_{\text{RB}}^{(2)} \\ \left(n_{\text{PUCCH}}^{(2,\tilde{p})} + N_{\text{cs}}^{(1)} + 1\right) \bmod N_{\text{sc}}^{\text{RB}} & \text{otherwise} \end{cases}$$

for $n_s \bmod 2 = 0$ and by

$$n'_{\tilde{p}}(n_s) = \begin{cases} \left[N_{\text{sc}}^{\text{RB}}\left(n'_{\tilde{p}}(n_s - 1) + 1\right)\right] \bmod\left(N_{\text{sc}}^{\text{RB}} + 1\right) - 1 & \text{if } n_{\text{PUCCH}}^{(2,\tilde{p})} < N_{\text{sc}}^{\text{RB}} N_{\text{RB}}^{(2)} \\ \left(N_{\text{sc}}^{\text{RB}} - 2 - n_{\text{PUCCH}}^{(2,\tilde{p})}\right) \bmod N_{\text{sc}}^{\text{RB}} & \text{otherwise} \end{cases}$$

for $n_s \bmod 2 = 1$.

For PUCCH formats 2a and 2b, supported for normal cyclic prefix only, the bit(s) $b(20),...,b(M_{\text{bit}} - 1)$ shall be modulated as described in Table 5.4.2-1 resulting in a single modulation symbol $d(10)$ used in the generation of the reference-signal for PUCCH format 2a and 2b as described in clause 5.5.2.2.1.

**Table 5.4.2-1: Modulation symbol $d(10)$ for PUCCH formats 2a and 2b**

| PUCCH format | $b(20),...,b(M_{\text{bit}}-1)$ | $d(10)$ |
|---|---|---|
| 2a | 0 | 1 |
| | 1 | $-1$ |
| 2b | 00 | 1 |
| | 01 | $-j$ |
| | 10 | $j$ |
| | 11 | $-1$ |

## 5.4.2A PUCCH format 3

The block of bits $b(0),...,b(M_{\text{bit}}-1)$ shall be scrambled with a UE-specific scrambling sequence, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ according to

$$\tilde{b}(i) = \left(b(i)+c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = \left(\lfloor n_s/2 \rfloor + 1\right)\cdot\left(2N_{\text{ID}}^{\text{cell}}+1\right)\cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where $n_{\text{RNTI}}$ is the C-RNTI.

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ shall be QPSK modulated as described in Subclause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ where $M_{\text{symb}} = M_{\text{bit}}/2 = 2N_{\text{sc}}^{\text{RB}}$.

The complex-valued symbols $d(0),...,d(M_{\text{symb}}-1)$ shall be block-wise spread with the orthogonal sequences $w_{n_{oc,0}^{(\tilde{p})}}(i)$ and $w_{n_{oc,1}^{(\tilde{p})}}(i)$ resulting in $N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}}$ sets of $N_{\text{sc}}^{\text{RB}}$ values each according to

$$y_n^{(\tilde{p})}(i) = \begin{cases} w_{n_{oc,0}^{(\tilde{p})}}(\bar{n}) \cdot e^{j\pi\lfloor n_{\text{cs}}^{\text{cell}}(n_s,l)/64 \rfloor/2} \cdot d(i) & n < N_{\text{SF},0}^{\text{PUCCH}} \\ w_{n_{oc,1}^{(\tilde{p})}}(\bar{n}) \cdot e^{j\pi\lfloor n_{\text{cs}}^{\text{cell}}(n_s,l)/64 \rfloor/2} \cdot d(N_{\text{sc}}^{\text{RB}}+i) & \text{otherwise} \end{cases}$$

$$\bar{n} = n \bmod N_{\text{SF},0}^{\text{PUCCH}}$$

$$n = 0,..., N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}} - 1$$

$$i = 0,1,..., N_{\text{sc}}^{\text{RB}} - 1$$

where $N_{\text{SF},0}^{\text{PUCCH}} = N_{\text{SF},1}^{\text{PUCCH}} = 5$ for both slots in a subframe using normal PUCCH format 3 and $N_{\text{SF},0}^{\text{PUCCH}} = 5$, $N_{\text{SF},1}^{\text{PUCCH}} = 4$ holds for the first and second slot, respectively, in a subframe using shortened PUCCH format 3. The orthogonal sequences $w_{n_{oc,0}^{(\tilde{p})}}(i)$ and $w_{n_{oc,1}^{(\tilde{p})}}(i)$ are given by Table 5.4.2A-1. Resources used for transmission of PUCCH formats 3 are identified by a resource index $n_{\text{PUCCH}}^{(3,\tilde{p})}$ from which the quantities $n_{\text{oc},0}^{(\tilde{p})}$ and $n_{\text{oc},1}^{(\tilde{p})}$ are derived according to

$$n_{\text{oc},0}^{(\tilde{p})} = n_{\text{PUCCH}}^{(3,\tilde{p})} \bmod N_{\text{SF},1}^{\text{PUCCH}}$$

$$n_{\text{oc},1}^{(\tilde{p})} = \begin{cases} \left(3n_{\text{oc},0}^{(\tilde{p})}\right) \bmod N_{\text{SF},1}^{\text{PUCCH}} & \text{if } N_{\text{SF},1}^{\text{PUCCH}} = 5 \\ n_{\text{oc},0}^{(\tilde{p})} \bmod N_{\text{SF},1}^{\text{PUCCH}} & \text{otherwise} \end{cases}$$

Each set of complex-valued symbols shall be cyclically shifted according to

$$\tilde{y}_n^{(\tilde{p})}(i) = y_n^{(\tilde{p})}\left(\left(i + n_{\text{cs}}^{\text{cell}}(n_s,l)\right) \bmod N_{\text{sc}}^{\text{RB}}\right)$$

where $n_{\text{cs}}^{\text{cell}}(n_s,l)$ is given by Subclause 5.4, $n_s$ is the slot number within a radio frame and $l$ is the SC-FDMA symbol number within a slot.

The shifted sets of complex-valued symbols shall be transform precoded according to

$$z^{(\tilde{p})}(n \cdot N_{\text{sc}}^{\text{RB}} + k) = \frac{1}{\sqrt{P}} \frac{1}{\sqrt{N_{\text{sc}}^{\text{RB}}}} \sum_{i=0}^{N_{\text{sc}}^{\text{RB}}-1} \tilde{y}_n^{(\tilde{p})}(i) e^{-j\frac{2\pi ik}{N_{\text{sc}}^{\text{RB}}}}$$

$$k = 0,\ldots, N_{\text{sc}}^{\text{RB}} - 1$$

$$n = 0,\ldots, N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}} - 1$$

where $P$ is the number of antenna ports used for PUCCH transmission, resulting in a block of complex-valued symbols $z^{(\tilde{p})}(0),\ldots, z^{(\tilde{p})}\left(\left(N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}}\right)N_{\text{sc}}^{\text{RB}} - 1\right)$.

**Table 5.4.2A-1: The orthogonal sequence $w_{n_{\text{oc}}}(i)$**

| Sequence index $n_{\text{oc}}$ | Orthogonal sequence $\left[w_{n_{\text{oc}}}(0) \quad \cdots \quad w_{n_{\text{oc}}}(N_{\text{SF}}^{\text{PUCCH}} - 1)\right]$ | |
|---|---|---|
| | $N_{\text{SF}}^{\text{PUCCH}} = 5$ | $N_{\text{SF}}^{\text{PUCCH}} = 4$ |
| 0 | $\left[1 \quad 1 \quad 1 \quad 1 \quad 1\right]$ | $\left[+1 \quad +1 \quad +1 \quad +1\right]$ |
| 1 | $\left[1 \quad e^{j2\pi/5} \quad e^{j4\pi/5} \quad e^{j6\pi/5} \quad e^{j8\pi/5}\right]$ | $\left[+1 \quad -1 \quad +1 \quad -1\right]$ |
| 2 | $\left[1 \quad e^{j4\pi/5} \quad e^{j8\pi/5} \quad e^{j2\pi/5} \quad e^{j6\pi/5}\right]$ | $\left[+1 \quad +1 \quad -1 \quad -1\right]$ |
| 3 | $\left[1 \quad e^{j6\pi/5} \quad e^{j2\pi/5} \quad e^{j8\pi/5} \quad e^{j4\pi/5}\right]$ | $\left[+1 \quad -1 \quad -1 \quad +1\right]$ |
| 4 | $\left[1 \quad e^{j8\pi/5} \quad e^{j6\pi/5} \quad e^{j4\pi/5} \quad e^{j2\pi/5}\right]$ | - |

## 5.4.3 Mapping to physical resources

The block of complex-valued symbols $z^{(\tilde{p})}(i)$ shall be multiplied with the amplitude scaling factor $\beta_{\text{PUCCH}}$ in order to conform to the transmit power $P_{\text{PUCCH}}$ specified in Subclause 5.1.2.1 in 3GPP TS 36.213 [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to resource elements. PUCCH uses one resource block in each of the two slots in a subframe. Within the physical resource block used for transmission, the mapping of $z^{(\tilde{p})}(i)$ to resource elements $(k,l)$ on antenna port $p$ and not used for transmission of reference signals shall be in increasing order of first $k$, then $l$ and finally the slot number, starting with the first slot in the subframe. The relation between the index $\tilde{p}$ and the antenna port number $p$ is given by Table 5.2.1-1.

The physical resource blocks to be used for transmission of PUCCH in slot $n_s$ are given by

$$n_{\text{PRB}} = \begin{cases} \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m+n_s \bmod 2) \bmod 2 = 0 \\ N_{\text{RB}}^{\text{UL}} - 1 - \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m+n_s \bmod 2) \bmod 2 = 1 \end{cases}$$

where the variable $m$ depends on the PUCCH format. For formats 1, 1a and 1b

$$m = \begin{cases} N_{\text{RB}}^{(2)} & \text{if } n_{\text{PUCCH}}^{(1,\tilde{p})} < c \cdot N_{\text{cs}}^{(1)} / \Delta_{\text{shift}}^{\text{PUCCH}} \\ \left\lfloor \frac{n_{\text{PUCCH}}^{(1,\tilde{p})} - c \cdot N_{\text{cs}}^{(1)} / \Delta_{\text{shift}}^{\text{PUCCH}}}{c \cdot N_{\text{sc}}^{\text{RB}} / \Delta_{\text{shift}}^{\text{PUCCH}}} \right\rfloor + N_{\text{RB}}^{(2)} + \left\lceil \frac{N_{\text{cs}}^{(1)}}{8} \right\rceil & \text{otherwise} \end{cases}$$

$$c = \begin{cases} 3 & \text{normal cyclic prefix} \\ 2 & \text{extended cyclic prefix} \end{cases}$$

and for formats 2, 2a and 2b

$$m = \left\lfloor n_{\text{PUCCH}}^{(2,\tilde{p})} / N_{\text{sc}}^{\text{RB}} \right\rfloor$$

and for format 3

$$m = \left\lfloor n_{\text{PUCCH}}^{(3,\tilde{p})} / N_{\text{SF},0}^{\text{PUCCH}} \right\rfloor$$

Mapping of modulation symbols for the physical uplink control channel is illustrated in Figure 5.4.3-1.

In case of simultaneous transmission of sounding reference signal and PUCCH format 1, 1a, 1b or 3 when there is one serving cell configured, a shortened PUCCH format shall be used where the last SC-FDMA symbol in the second slot of a subframe shall be left empty.

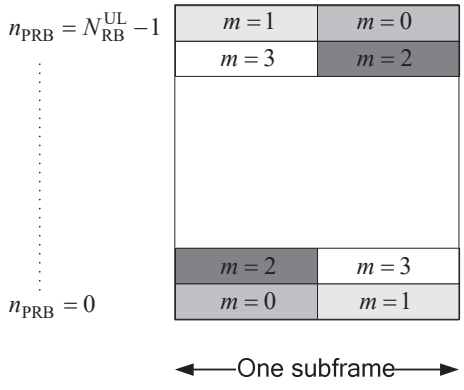



**Figure 5.4.3-1: Mapping to physical resource blocks for PUCCH**

# 5.5 Reference signals

Two types of uplink reference signals are supported:

- Demodulation reference signal, associated with transmission of PUSCH or PUCCH
- Sounding reference signal, not associated with transmission of PUSCH or PUCCH

The same set of base sequences is used for demodulation and sounding reference signals.

## 5.5.1 Generation of the reference signal sequence

Reference signal sequence $r_{u,v}^{(\alpha)}(n)$ is defined by a cyclic shift $\alpha$ of a base sequence $\bar{r}_{u,v}(n)$ according to

$$r_{u,v}^{(\alpha)}(n) = e^{j\alpha n}\bar{r}_{u,v}(n), \quad 0 \le n < M_{\text{sc}}^{\text{RS}}$$

where $M_{\text{sc}}^{\text{RS}} = mN_{\text{sc}}^{\text{RB}}$ is the length of the reference signal sequence and $1 \le m \le N_{\text{RB}}^{\max,\text{UL}}$. Multiple reference signal sequences are defined from a single base sequence through different values of $\alpha$.

Base sequences $\bar{r}_{u,v}(n)$ are divided into groups, where $u \in \{0,1,...,29\}$ is the group number and $v$ is the base sequence number within the group, such that each group contains one base sequence ( $v = 0$ ) of each length $M_{\text{sc}}^{\text{RS}} = mN_{\text{sc}}^{\text{RB}}$, $1 \le m \le 5$ and two base sequences ( $v = 0,1$ ) of each length $M_{\text{sc}}^{\text{RS}} = mN_{\text{sc}}^{\text{RB}}$, $6 \le m \le N_{\text{RB}}^{\max,\text{UL}}$. The sequence group number $u$ and the number $v$ within the group may vary in time as described in clauses 5.5.1.3 and 5.5.1.4, respectively. The definition of the base sequence $\bar{r}_{u,v}(0),...,\bar{r}_{u,v}(M_{\text{sc}}^{\text{RS}}-1)$ depends on the sequence length $M_{\text{sc}}^{\text{RS}}$.

### 5.5.1.1 Base sequences of length $3N_{\text{sc}}^{\text{RB}}$ or larger

For $M_{\text{sc}}^{\text{RS}} \ge 3N_{\text{sc}}^{\text{RB}}$, the base sequence $\bar{r}_{u,v}(0),...,\bar{r}_{u,v}(M_{\text{sc}}^{\text{RS}}-1)$ is given by

$$\bar{r}_{u,v}(n) = x_q(n \bmod N_{\text{ZC}}^{\text{RS}}), \quad 0 \le n < M_{\text{sc}}^{\text{RS}}$$

where the $q^{\text{th}}$ root Zadoff-Chu sequence is defined by

$$x_q(m) = e^{-j\frac{\pi q m(m+1)}{N_{\text{ZC}}^{\text{RS}}}}, \quad 0 \le m \le N_{\text{ZC}}^{\text{RS}}-1$$

with $q$ given by

$$q = \lfloor \bar{q} + 1/2 \rfloor + v \cdot (-1)^{\lfloor 2\bar{q} \rfloor}$$
$$\bar{q} = N_{\text{ZC}}^{\text{RS}} \cdot (u+1)/31$$

The length $N_{\text{ZC}}^{\text{RS}}$ of the Zadoff-Chu sequence is given by the largest prime number such that $N_{\text{ZC}}^{\text{RS}} < M_{\text{sc}}^{\text{RS}}$.

### 5.5.1.2 Base sequences of length less than $3N_{sc}^{RB}$

For $M_{sc}^{RS} = N_{sc}^{RB}$ and $M_{sc}^{RS} = 2N_{sc}^{RB}$, base sequence is given by

$$\bar{r}_{u,v}(n) = e^{j\varphi(n)\pi/4}, \quad 0 \le n \le M_{sc}^{RS} - 1$$

where the value of $\varphi(n)$ is given by Table 5.5.1.2-1 and Table 5.5.1.2-2 for $M_{sc}^{RS} = N_{sc}^{RB}$ and $M_{sc}^{RS} = 2N_{sc}^{RB}$, respectively.

**Table 5.5.1.2-1: Definition of $\varphi(n)$ for $M_{sc}^{RS} = N_{sc}^{RB}$.**

| $u$ | $\varphi(0),...,\varphi(11)$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -1 | 1 | 3 | -3 | 3 | 3 | 1 | 1 | 3 | 1 | -3 | 3 |
| 1 | 1 | 1 | 3 | 3 | 3 | -1 | 1 | -3 | -3 | 1 | -3 | 3 |
| 2 | 1 | 1 | -3 | -3 | -3 | -1 | -3 | -3 | 1 | -3 | 1 | -1 |
| 3 | -1 | 1 | 1 | 1 | 1 | -1 | -3 | -3 | 1 | -3 | 3 | -1 |
| 4 | -1 | 3 | 1 | -1 | 1 | -1 | -3 | -1 | 1 | -1 | 1 | 3 |
| 5 | 1 | -3 | 3 | -1 | -1 | 1 | 1 | -1 | -1 | 3 | -3 | 1 |
| 6 | -1 | 3 | -3 | -3 | -3 | 3 | 1 | -1 | 3 | 3 | -3 | 1 |
| 7 | -3 | -1 | -1 | -1 | 1 | -3 | 3 | -1 | 1 | -3 | 3 | 1 |
| 8 | 1 | -3 | 3 | 1 | -1 | -1 | -1 | 1 | 1 | 3 | -1 | 1 |
| 9 | 1 | -3 | -1 | 3 | 3 | -1 | -3 | 1 | 1 | 1 | 1 | 1 |
| 10 | -1 | 3 | -1 | 1 | 1 | -3 | -3 | -1 | -3 | -3 | 3 | -1 |
| 11 | 3 | 1 | -1 | -1 | 3 | 3 | -3 | 1 | 3 | 1 | 3 | 3 |
| 12 | 1 | -3 | 1 | 1 | -3 | 1 | 1 | 1 | -3 | -3 | -3 | 1 |
| 13 | 3 | 3 | -3 | 3 | -3 | 1 | 1 | 3 | -1 | -3 | 3 | 3 |
| 14 | -3 | 1 | -1 | -3 | -1 | 3 | 1 | 3 | 3 | 3 | -1 | 1 |
| 15 | 3 | -1 | 1 | -3 | -1 | -1 | 1 | 1 | 3 | 1 | -1 | -3 |
| 16 | 1 | 3 | 1 | -1 | 1 | 3 | 3 | 3 | -1 | -1 | 3 | -1 |
| 17 | -3 | 1 | 1 | 3 | -3 | 3 | -3 | -3 | 3 | 1 | 3 | -1 |
| 18 | -3 | 3 | 1 | 1 | -3 | 1 | -3 | -3 | -1 | -1 | 1 | -3 |
| 19 | -1 | 3 | 1 | 3 | 1 | -1 | -1 | 3 | -3 | -1 | -3 | -1 |
| 20 | -1 | -3 | 1 | 1 | 1 | 1 | 3 | 1 | -1 | 1 | -3 | -1 |
| 21 | -1 | 3 | -1 | 1 | -3 | -3 | -3 | -3 | -3 | 1 | -1 | -3 |
| 22 | 1 | 1 | -3 | -3 | -3 | -3 | -1 | 3 | -3 | 1 | -3 | 3 |
| 23 | 1 | 1 | -1 | -3 | -1 | -3 | 1 | -1 | 1 | 3 | -1 | 1 |
| 24 | 1 | 1 | 3 | 1 | 3 | 3 | -1 | 1 | -1 | -3 | -3 | 1 |
| 25 | 1 | -3 | 3 | 3 | 1 | 3 | 3 | 1 | -3 | -1 | -1 | 3 |
| 26 | 1 | 3 | -3 | -3 | 3 | -3 | 1 | -1 | -1 | 3 | -1 | -3 |
| 27 | -3 | -1 | -3 | -1 | -3 | 3 | 1 | -1 | 1 | 3 | -3 | -3 |
| 28 | -1 | 3 | -3 | 3 | -1 | 3 | 3 | -3 | 3 | 3 | -1 | -1 |
| 29 | 3 | -3 | -3 | -1 | -1 | -3 | -1 | 3 | -3 | 3 | 1 | -1 |

**Table 5.5.1.2-2: Definition of $\varphi(n)$ for $M_{sc}^{RS} = 2N_{sc}^{RB}$**

| $u$ | $\varphi(0),...,\varphi(23)$ | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -1 | 3 | 1 | -3 | 3 | -1 | 1 | 3 | -3 | 3 | 1 | 3 | -3 | 3 | 1 | 1 | -1 | 1 | 3 | -3 | 3 | -3 | -1 | -3 |
| 1 | -3 | 3 | -3 | -3 | -3 | 1 | -3 | -3 | 3 | -1 | 1 | 1 | 1 | 3 | 1 | -1 | 3 | -3 | -3 | 1 | 3 | 1 | 1 | -3 |
| 2 | 3 | -1 | 3 | 3 | 1 | 1 | -3 | 3 | 3 | 3 | 3 | 1 | -1 | 3 | -1 | 1 | 1 | -1 | -3 | -1 | -1 | 1 | 3 | 3 |
| 3 | -1 | -3 | 1 | 1 | 3 | -3 | 1 | 1 | -3 | -1 | -1 | 1 | 3 | 1 | 3 | 1 | -1 | 3 | 1 | 1 | -3 | -1 | -3 | -1 |
| 4 | -1 | -1 | -1 | -3 | -3 | -1 | 1 | 1 | 3 | 3 | -1 | 3 | -1 | 1 | -1 | -3 | 1 | -1 | -3 | -3 | 1 | -3 | -1 | -1 |
| 5 | -3 | 1 | 1 | 3 | -1 | 1 | 3 | 1 | -3 | 1 | -3 | 1 | 1 | -1 | -1 | 3 | -1 | -3 | 3 | -3 | -3 | -3 | 1 | 1 |
| 6 | 1 | 1 | -1 | -1 | 3 | -3 | -3 | 3 | -3 | 1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 | -3 | -1 | 1 | -1 | 3 | -1 | -3 |
| 7 | -3 | 3 | 3 | -1 | -1 | -3 | -1 | 3 | 1 | 3 | 1 | 3 | 1 | 1 | -1 | 3 | 1 | -1 | 1 | 3 | -3 | -1 | -1 | 1 |
| 8 | -3 | 1 | 3 | -3 | 1 | -1 | -3 | 3 | -3 | 3 | -1 | -1 | -1 | -1 | 1 | -3 | -3 | -3 | 1 | -3 | -3 | -3 | 1 | -3 |
| 9 | 1 | 1 | -3 | 3 | 3 | -1 | -3 | -1 | 3 | -3 | 3 | 3 | 3 | -1 | 1 | 1 | -3 | 1 | -1 | 1 | 1 | -3 | 1 | 1 |
| 10 | -1 | 1 | -3 | -3 | 3 | -1 | 3 | -1 | -1 | -3 | -3 | -3 | -1 | -3 | -3 | 1 | -1 | 1 | 3 | 3 | -1 | 1 | -1 | 3 |
| 11 | 1 | 3 | 3 | -3 | -3 | 1 | 3 | 1 | -1 | -3 | -3 | -3 | 3 | 3 | -3 | 3 | 3 | -1 | -3 | 3 | -1 | 1 | -3 | 1 |
| 12 | 1 | 3 | 3 | 1 | 1 | 1 | -1 | -1 | 1 | -3 | 3 | -1 | 1 | 1 | -3 | 3 | 3 | -1 | -3 | 3 | -3 | -1 | -3 | -1 |
| 13 | 3 | -1 | -1 | -1 | -1 | -3 | -1 | 3 | 3 | 1 | -1 | 1 | 3 | 3 | 3 | -1 | 1 | 1 | -3 | 1 | 3 | -1 | -3 | 3 |
| 14 | -3 | -3 | 3 | 1 | 3 | 1 | -3 | 3 | 1 | 3 | 1 | 1 | 3 | 3 | -1 | -1 | -3 | 1 | -3 | -1 | 3 | 1 | 1 | 3 |
| 15 | -1 | -1 | 1 | -3 | 1 | 3 | -3 | 1 | -1 | -3 | -1 | 3 | 1 | 3 | 1 | -1 | -3 | -3 | -1 | -1 | -3 | -3 | -3 | -1 |
| 16 | -1 | -3 | 3 | -1 | -1 | -1 | -1 | 1 | 1 | -3 | 3 | 1 | 3 | 3 | 1 | -1 | 1 | -3 | 1 | -3 | 1 | 1 | -3 | -1 |
| 17 | 1 | 3 | -1 | 3 | 3 | -1 | -3 | 1 | -1 | -3 | 3 | 3 | 3 | -1 | 1 | 1 | 3 | -1 | -3 | -1 | 3 | -1 | -1 | -1 |
| 18 | 1 | 1 | 1 | 1 | 1 | -1 | 3 | -1 | -3 | 1 | 1 | 3 | -3 | 1 | -3 | -1 | 1 | 1 | -3 | -3 | 3 | 1 | 1 | -3 |
| 19 | 1 | 3 | 3 | 1 | -1 | -3 | 3 | -1 | 3 | 3 | 3 | -3 | 1 | -1 | 1 | -1 | -3 | -1 | 1 | 3 | -1 | 3 | -3 | -3 |
| 20 | -1 | -3 | 3 | -3 | -3 | -3 | -1 | -1 | -3 | -1 | -3 | 3 | 1 | 3 | -3 | -1 | 3 | -1 | 1 | -1 | 3 | -3 | 1 | -1 |
| 21 | -3 | -3 | 1 | 1 | -1 | 1 | -1 | 1 | -1 | 3 | 1 | -3 | -1 | 1 | -1 | 1 | -1 | -1 | 3 | 3 | -3 | -1 | 1 | -3 |
| 22 | -3 | -1 | -3 | 3 | 1 | -1 | -3 | -1 | -3 | -3 | 3 | -3 | 3 | -3 | -1 | 1 | 3 | 1 | -3 | 1 | 3 | 3 | -1 | -3 |
| 23 | -1 | -1 | -1 | -1 | 3 | 3 | 3 | 1 | 3 | 3 | -3 | 1 | 3 | -1 | 3 | -1 | 3 | 3 | -3 | 3 | 1 | -1 | 3 | 3 |
| 24 | 1 | -1 | 3 | 3 | -1 | -3 | 3 | -3 | -1 | -1 | 3 | -1 | 3 | -1 | -1 | 1 | 1 | 1 | 1 | -1 | -1 | -3 | -1 | 3 |
| 25 | 1 | -1 | 1 | -1 | 3 | -1 | 3 | 1 | 1 | -1 | -1 | -3 | 1 | 1 | -3 | 1 | 3 | -3 | 1 | 1 | -3 | -3 | -1 | -1 |
| 26 | -3 | -1 | 1 | 3 | 1 | 1 | -3 | -1 | -1 | -3 | 3 | -3 | 3 | 1 | -3 | 3 | -3 | 1 | -1 | 1 | -3 | 1 | 1 | 1 |
| 27 | -1 | -3 | 3 | 3 | 1 | 1 | 3 | -1 | -3 | -1 | -1 | -1 | 3 | 1 | -3 | -3 | -1 | 3 | -3 | -1 | -3 | -1 | -3 | -1 |
| 28 | -1 | -3 | -1 | -1 | 1 | -3 | -1 | -1 | 1 | -1 | -3 | 1 | 1 | -3 | 1 | -3 | -3 | 3 | 1 | 1 | -1 | 3 | -1 | -1 |
| 29 | 1 | 1 | -1 | -1 | -3 | -1 | 3 | -1 | 3 | -1 | 1 | 3 | 1 | -1 | 3 | 1 | 3 | -3 | -3 | 1 | -1 | -1 | 1 | 3 |

### 5.5.1.3 Group hopping

The sequence-group number $u$ in slot $n_s$ is defined by a group hopping pattern $f_{gh}(n_s)$ and a sequence-shift pattern $f_{ss}$ according to

$$u = \left(f_{gh}(n_s) + f_{ss}\right) \bmod 30$$

There are 17 different hopping patterns and 30 different sequence-shift patterns. Sequence-group hopping can be enabled or disabled by means of the cell-specific parameter *Group-hopping-enabled* provided by higher layers. Sequence-group hopping for PUSCH can be disabled for a certain UE through the higher-layer parameter *Disable-sequence-group-hopping* despite being enabled on a cell basis unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure.

The group-hopping pattern $f_{gh}(n_s)$ may be different for PUSCH, PUCCH and SRS and is given by

$$f_{gh}(n_s) = \begin{cases} 0 & \text{if group hopping is disabled} \\ \left(\sum_{i=0}^{7} c(8n_s + i) \cdot 2^i\right) \bmod 30 & \text{if group hopping is enabled} \end{cases}$$

where the pseudo-random sequence $c(i)$ is defined by clause 7.2. The pseudo-random sequence generator shall be initialized with $c_{init} = \left\lfloor \frac{n_{ID}^{RS}}{30} \right\rfloor$ at the beginning of each radio frame where $n_{ID}^{RS}$ is given by clause 5.5.1.5.

The sequence-shift pattern $f_{ss}$ definition differs between PUCCH, PUSCH and SRS.

For PUCCH, the sequence-shift pattern $f_{ss}^{PUCCH}$ is given by $f_{ss}^{PUCCH} = n_{ID}^{RS} \bmod 30$ where $n_{ID}^{RS}$ is given by clause 5.5.1.5.

For PUSCH, the sequence-shift pattern $f_{ss}^{PUSCH}$ is given by $f_{ss}^{PUSCH} = \left(N_{ID}^{cell} + \Delta_{ss}\right) \bmod 30$, where $\Delta_{ss} \in \{0,1,...,29\}$ is configured by higher layers, if no value for $n_{ID}^{PUSCH}$ is provided by higher layers or if the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, otherwise it is given by $f_{ss}^{PUSCH} = n_{ID}^{RS} \bmod 30$ with $n_{ID}^{RS}$ given by clause 5.5.1.5.

For SRS, the sequence-shift pattern $f_{ss}^{SRS}$ is given by $f_{ss}^{SRS} = n_{ID}^{RS} \bmod 30$ where $n_{ID}^{RS}$ is given by clause 5.5.1.5.

### 5.5.1.4 Sequence hopping

Sequence hopping only applies for reference-signals of length $M_{sc}^{RS} \geq 6N_{sc}^{RB}$.

For reference-signals of length $M_{sc}^{RS} < 6N_{sc}^{RB}$, the base sequence number $v$ within the base sequence group is given by $v = 0$.

For reference-signals of length $M_{sc}^{RS} \geq 6N_{sc}^{RB}$, the base sequence number $v$ within the base sequence group in slot $n_s$ is defined by

$$v = \begin{cases} c(n_s) & \text{if group hopping is disabled and sequence hopping is enabled} \\ 0 & \text{otherwise} \end{cases}$$

where the pseudo-random sequence $c(i)$ is given by clause 7.2. The parameter *Sequence-hopping-enabled* provided by higher layers determines if sequence hopping is enabled or not. Sequence hopping for PUSCH can be disabled for a certain UE through the higher-layer parameter *Disable-sequence-group-hopping* despite being enabled on a cell basis unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure.

For PUSCH, the pseudo-random sequence generator shall be initialized with $c_{init} = \left\lfloor \frac{n_{ID}^{RS}}{30} \right\rfloor \cdot 2^5 + f_{ss}^{PUSCH}$ at the beginning of each radio frame where $n_{ID}^{RS}$ is given by clause 5.5.1.5.

For SRS, the pseudo-random sequence generator shall be initialized with $c_{init} = \left\lfloor \frac{n_{ID}^{RS}}{30} \right\rfloor \cdot 2^5 + \left(n_{ID}^{RS} + \Delta_{ss}\right) \bmod 30$ at the beginning of each radio frame where $n_{ID}^{RS}$ is given by clause 5.5.1.5 and $\Delta_{ss}$ is given by clause 5.5.1.3.

### 5.5.1.5 Determining virtual cell identity for sequence generation

The definition of $n_{ID}^{RS}$ depends on the type of transmission.

Transmissions associated with PUSCH:

- $n_{ID}^{RS} = N_{ID}^{cell}$ if no value for $n_{ID}^{PUSCH}$ is configured by higher layers or if the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure,
- $n_{ID}^{RS} = n_{ID}^{PUSCH}$ otherwise.

Transmissions associated with PUCCH:

- $n_{ID}^{RS} = N_{ID}^{cell}$ if no value for $n_{ID}^{PUCCH}$ is configured by higher layers,
- $n_{ID}^{RS} = n_{ID}^{PUCCH}$ otherwise.

Sounding reference signals:

- $n_{ID}^{RS} = N_{ID}^{cell}$.

## 5.5.2 Demodulation reference signal

### 5.5.2.1 Demodulation reference signal for PUSCH

#### 5.5.2.1.1 Reference signal sequence

The PUSCH demodulation reference signal sequence $r_{\text{PUSCH}}^{(\lambda)}(\cdot)$ associated with layer $\lambda \in \{0,1,...,\upsilon-1\}$ is defined by

$$r_{\text{PUSCH}}^{(\lambda)}\left(m \cdot M_{\text{sc}}^{\text{RS}} + n\right) = w^{(\lambda)}(m) r_{u,v}^{(\alpha_\lambda)}(n)$$

where

$$m = 0,1$$
$$n = 0,...,M_{\text{sc}}^{\text{RS}} - 1$$

and

$$M_{\text{sc}}^{\text{RS}} = M_{\text{sc}}^{\text{PUSCH}}$$

Subclause 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),...,r_{u,v}^{(\alpha_\lambda)}(M_{\text{sc}}^{\text{RS}}-1)$. The orthogonal sequence $w^{(\lambda)}(m)$ is given by $\left[w^{\lambda}(0) \quad w^{\lambda}(1)\right] = \left[1 \quad 1\right]$ for DCI format 0 if the higher-layer parameter *Activate-DMRS-with OCC* is not set or if the temporary C-RNTI was used to transmit the most recent uplink-related DCI for the transport block associated with the corresponding PUSCH transmission, otherwise it is given by Table 5.5.2.1.1-1 using the cyclic shift field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission.

The cyclic shift $\alpha_\lambda$ in a slot $n_{\text{s}}$ is given as $\alpha_\lambda = 2\pi n_{\text{cs},\lambda}/12$ with

$$n_{\text{cs},\lambda} = \left(n_{\text{DMRS}}^{(1)} + n_{\text{DMRS},\lambda}^{(2)} + n_{\text{PN}}(n_{\text{s}})\right) \bmod 12$$

where the values of $n_{\text{DMRS}}^{(1)}$ is given by Table 5.5.2.1.1-2 according to the parameter *cyclicShift* provided by higher layers, $n_{\text{DMRS},\lambda}^{(2)}$ is given by the cyclic shift for DMRS field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission where the value of $n_{\text{DMRS},\lambda}^{(2)}$ is given in Table 5.5.2.1.1-1.

The first row of Table 5.5.2.1.1-1 shall be used to obtain $n_{\text{DMRS},0}^{(2)}$ and $w^{(\lambda)}(m)$ if there is no uplink-related DCI for the same transport block associated with the corresponding PUSCH transmission, and

- if the initial PUSCH for the same transport block is semi-persistently scheduled, or
- if the initial PUSCH for the same transport block is scheduled by the random access response grant.

The quantity $n_{\text{PN}}(n_{\text{s}})$ is given by

$$n_{\text{PN}}(n_{\text{s}}) = \sum_{i=0}^{7} c(8N_{\text{symb}}^{\text{UL}} \cdot n_{\text{s}} + i) \cdot 2^i$$

where the pseudo-random sequence $c(i)$ is defined by clause 7.2. The application of $c(i)$ is cell-specific. The pseudo-random sequence generator shall be initialized with $c_{\text{init}}$ at the beginning of each radio frame. The quantity $c_{\text{init}}$ is given by $c_{\text{init}} = \left\lfloor \frac{N_{\text{ID}}^{\text{cell}}}{30} \right\rfloor \cdot 2^5 + \left(\left(N_{\text{ID}}^{\text{cell}} + \Delta_{\text{ss}}\right) \bmod 30\right)$ if no value for $N_{\text{ID}}^{\text{csh_DMRS}}$ is configured by higher layers or the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block

as part of the contention based random access procedure, otherwise it is given by

$$c_{\text{init}} = \left\lfloor \frac{N_{\text{ID}}^{\text{csh_DMRS}}}{30} \right\rfloor \cdot 2^5 + \left(N_{\text{ID}}^{\text{csh_DMRS}} \bmod 30\right).$$

The vector of reference signals shall be precoded according to

$$\begin{bmatrix} \tilde{r}_{\text{PUSCH}}^{(0)} \\ \vdots \\ \tilde{r}_{\text{PUSCH}}^{(P-1)} \end{bmatrix} = W \begin{bmatrix} r_{\text{PUSCH}}^{(0)} \\ \vdots \\ r_{\text{PUSCH}}^{(\upsilon-1)} \end{bmatrix}$$

where $P$ is the number of antenna ports used for PUSCH transmission.

For PUSCH transmission using a single antenna port, $P=1$, $W=1$ and $\upsilon=1$.

For spatial multiplexing, $P=2$ or $P=4$ and the precoding matrix $W$ shall be identical to the precoding matrix used in clause 5.3.3A.2 for precoding of the PUSCH in the same subframe.

**Table 5.5.2.1.1-1: Mapping of Cyclic Shift Field in uplink-related DCI format to $n_{\text{DMRS},\lambda}^{(2)}$ and $\left[w^{(\lambda)}(0) \quad w^{(\lambda)}(1)\right]$**

| Cyclic Shift Field in uplink-related DCI format [3] | $n_{\text{DMRS},\lambda}^{(2)}$ | | | | $\left[w^{(\lambda)}(0) \quad w^{(\lambda)}(1)\right]$ | | | |
|---|---|---|---|---|---|---|---|---|
| | $\lambda=0$ | $\lambda=1$ | $\lambda=2$ | $\lambda=3$ | $\lambda=0$ | $\lambda=1$ | $\lambda=2$ | $\lambda=3$ |
| 000 | 0 | 6 | 3 | 9 | [1 1] | [1 1] | [1 −1] | [1 −1] |
| 001 | 6 | 0 | 9 | 3 | [1 −1] | [1 −1] | [1 1] | [1 1] |
| 010 | 3 | 9 | 6 | 0 | [1 −1] | [1 −1] | [1 1] | [1 1] |
| 011 | 4 | 10 | 7 | 1 | [1 1] | [1 1] | [1 1] | [1 1] |
| 100 | 2 | 8 | 5 | 11 | [1 1] | [1 1] | [1 1] | [1 1] |
| 101 | 8 | 2 | 11 | 5 | [1 −1] | [1 −1] | [1 −1] | [1 −1] |
| 110 | 10 | 4 | 1 | 7 | [1 −1] | [1 −1] | [1 −1] | [1 −1] |
| 111 | 9 | 3 | 0 | 6 | [1 1] | [1 1] | [1 −1] | [1 −1] |

**Table 5.5.2.1.1-2: Mapping of *cyclicShift* to $n_{\text{DMRS}}^{(1)}$ values**

| cyclicShift | $n_{\text{DMRS}}^{(1)}$ |
|---|---|
| 0 | 0 |
| 1 | 2 |
| 2 | 3 |
| 3 | 4 |
| 4 | 6 |
| 5 | 8 |
| 6 | 9 |
| 7 | 10 |

#### 5.5.2.1.2 Mapping to physical resources

For each antenna port used for transmission of the PUSCH, the sequence $\tilde{r}_{\text{PUSCH}}^{(\tilde{p})}(\cdot)$ shall be multiplied with the amplitude scaling factor $\beta_{\text{PUSCH}}$ and mapped in sequence starting with $\tilde{r}_{\text{PUSCH}}^{(\tilde{p})}(0)$ to the resource blocks.
The set of physical resource blocks used in the mapping process and the relation between the index $\tilde{p}$ and the antenna port number $p$ shall be identical to the corresponding PUSCH transmission as defined in clause 5.3.4.
The mapping to resource elements $(k,l)$, with $l=3$ for normal cyclic prefix and $l=2$ for extended cyclic prefix, in the subframe shall be in increasing order of first $k$, then the slot number.

### 5.5.2.2 Demodulation reference signal for PUCCH

#### 5.5.2.2.1 Reference signal sequence

The PUCCH demodulation reference signal sequence $r_{\text{PUCCH}}^{(\tilde{p})}(\cdot)$ is defined by

$$r_{\text{PUCCH}}^{(\tilde{p})}\left(m' N_{\text{RS}}^{\text{PUCCH}} M_{\text{sc}}^{\text{RS}} + mM_{\text{sc}}^{\text{RS}} + n\right) = \frac{1}{\sqrt{P}} \overline{w}^{(\tilde{p})}(m) z(m) r_{u,v}^{(\alpha_{\tilde{p}})}(n)$$

where

$$\begin{aligned} m &= 0,\ldots, N_{\text{RS}}^{\text{PUCCH}} - 1 \\ n &= 0,\ldots, M_{\text{sc}}^{\text{RS}} - 1 \\ m' &= 0,1 \end{aligned}$$

and $P$ is the number of antenna ports used for PUCCH transmission. For PUCCH formats 2a and 2b, $z(m)$ equals $d(10)$ for $m=1$, where $d(10)$ is defined in clause 5.4.2. For all other cases, $z(m)=1$.

The sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is given by clause 5.5.1 with $M_{\text{sc}}^{\text{RS}}=12$ where the expression for the cyclic shift $\alpha_{\tilde{p}}$ is determined by the PUCCH format.

For PUCCH formats 1, 1a and 1b, $\alpha_{\tilde{p}}(n_{\text{s}},l)$ is given by

$$\overline{n}_{\text{oc}}^{(\tilde{p})}(n_{\text{s}}) = \left\lfloor n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta_{\text{shift}}^{\text{PUCCH}} \big/ N' \right\rfloor$$

$$\alpha_{\tilde{p}}(n_{\text{s}},l) = 2\pi \cdot \overline{n}_{\text{cs}}^{(\tilde{p})}(n_{\text{s}},l) \big/ N_{\text{sc}}^{\text{RB}}$$

$$\overline{n}_{\text{cs}}^{(\tilde{p})}(n_{\text{s}},l) = \begin{cases} \left[n_{\text{cs}}^{\text{cell}}(n_{\text{s}},l) + \left(n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta_{\text{shift}}^{\text{PUCCH}} + \left(\overline{n}_{\text{oc}}^{(\tilde{p})}(n_{\text{s}}) \bmod \Delta_{\text{shift}}^{\text{PUCCH}}\right)\right) \bmod N'\right] \bmod N_{\text{sc}}^{\text{RB}} & \text{for normal cyclic prefix} \\ \left[n_{\text{cs}}^{\text{cell}}(n_{\text{s}},l) + \left(n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta_{\text{shift}}^{\text{PUCCH}} + \overline{n}_{\text{oc}}^{(\tilde{p})}(n_{\text{s}})\right) \bmod N'\right] \bmod N_{\text{sc}}^{\text{RB}} & \text{for extended cyclic prefix} \end{cases}$$

where $n'_{\tilde{p}}(n_{\text{s}})$, $N'$, $\Delta_{\text{shift}}^{\text{PUCCH}}$ and $n_{\text{cs}}^{\text{cell}}(n_s,l)$ are defined by clause 5.4.1. The number of reference symbols per slot $N_{\text{RS}}^{\text{PUCCH}}$ and the sequence $\overline{w}(n)$ are given by Table 5.5.2.2.1-1 and 5.5.2.2.1-2, respectively.

For PUCCH formats 2, 2a and 2b, $\alpha_{\tilde{p}}(n_{\text{s}},l)$ is defined by clause 5.4.2. The number of reference symbols per slot $N_{\text{RS}}^{\text{PUCCH}}$ and the sequence $\overline{w}^{(\tilde{p})}(n)$ are given by Table 5.5.2.2.1-1 and 5.5.2.2.1-3, respectively.

For PUCCH format 3, $\alpha_{\tilde{p}}(n_{\text{s}},l)$ is given by

$$\alpha_{\tilde{p}}(n_{\text{s}},l) = 2\pi \cdot n_{\text{cs}}^{(\tilde{p})}(n_{\text{s}},l) \big/ N_{\text{sc}}^{\text{RB}}$$

$$n_{\text{cs}}^{(\tilde{p})}(n_{\text{s}},l) = \left(n_{\text{cs}}^{\text{cell}}(n_{\text{s}},l) + n'_{\tilde{p}}(n_{\text{s}})\right) \bmod N_{\text{sc}}^{\text{RB}}$$

where $n'_{\tilde{p}}(n_s)$ is given by Table 5.5.2.2.1-4 and $n_{oc,0}^{(\tilde{p})}$ and $n_{oc,1}^{(\tilde{p})}$ for the first and second slot in a subframe, respectively, are obtained from clause 5.4.2A. The number of reference symbols per slot $N_{RS}^{PUCCH}$ and the sequence $\overline{w}(n)$ are given by Table 5.5.2.2.1-1 and 5.5.2.2.1-3, respectively.

**Table 5.5.2.2.1-1: Number of PUCCH demodulation reference symbols per slot $N_{RS}^{PUCCH}$**

| PUCCH format | Normal cyclic prefix | Extended cyclic prefix |
|---|---|---|
| 1, 1a, 1b | 3 | 2 |
| 2, 3 | 2 | 1 |
| 2a, 2b | 2 | N/A |

**Table 5.5.2.2.1-2: Orthogonal sequences $\left[\overline{w}^{(\tilde{p})}(0) \quad \cdots \quad \overline{w}^{(\tilde{p})}(N_{RS}^{PUCCH}-1)\right]$ for PUCCH formats 1, 1a and 1b**

| Sequence index $\overline{n}_{oc}^{(\tilde{p})}(n_s)$ | Normal cyclic prefix | Extended cyclic prefix |
|---|---|---|
| 0 | $\left[1 \quad 1 \quad 1\right]$ | $\left[1 \quad 1\right]$ |
| 1 | $\left[1 \quad e^{j2\pi/3} \quad e^{j4\pi/3}\right]$ | $\left[1 \quad -1\right]$ |
| 2 | $\left[1 \quad e^{j4\pi/3} \quad e^{j2\pi/3}\right]$ | N/A |

**Table 5.5.2.2.1-3: Orthogonal sequences $\left[\overline{w}^{(\tilde{p})}(0) \quad \cdots \quad \overline{w}^{(\tilde{p})}(N_{RS}^{PUCCH}-1)\right]$ for PUCCH formats 2, 2a, 2b and 3.**

| Normal cyclic prefix | Extended cyclic prefix |
|---|---|
| $\left[1 \quad 1\right]$ | $\left[1\right]$ |

**Table 5.5.2.2.1-4: Relation between $n_{oc}^{(\tilde{p})}$ and $n'_{\tilde{p}}(n_s)$ for PUCCH format 3.**

| $n_{oc}^{(\tilde{p})}$ | $n'_{\tilde{p}}(n_s)$ | |
|---|---|---|
| | $N_{SF,1}=5$ | $N_{SF,1}=4$ |
| 0 | 0 | 0 |
| 1 | 3 | 3 |
| 2 | 6 | 6 |
| 3 | 8 | 9 |
| 4 | 10 | N/A |

### 5.5.2.2.2 Mapping to physical resources

The sequence $r_{PUCCH}^{(\tilde{p})}(\cdot)$ shall be multiplied with the amplitude scaling factor $\beta_{PUCCH}$ and mapped in sequence starting with $r_{PUCCH}^{(\tilde{p})}(0)$ to resource elements $(k,l)$ on antenna port $p$. The mapping shall be in increasing order of first $k$, then $l$ and finally the slot number. The set of values for $k$ and the relation between the index $\tilde{p}$ and the antenna port number $p$ shall be identical to the values used for the corresponding PUCCH transmission. The values of the symbol index $l$ in a slot are given by Table 5.5.2.2.2-1.

**Table 5.5.2.2.2-1: Demodulation reference signal location for different PUCCH formats.**

| PUCCH format | Set of values for $l$ | |
|---|---|---|
| | Normal cyclic prefix | Extended cyclic prefix |
| 1, 1a, 1b | 2, 3, 4 | 2, 3 |
| 2, 3 | 1, 5 | 3 |
| 2a, 2b | 1, 5 | N/A |

## 5.5.3 Sounding reference signal

### 5.5.3.1 Sequence generation

The sounding reference signal sequence $r_{\text{SRS}}^{(\tilde{p})}(n) = r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is defined by clause 5.5.1, where $u$ is the sequence-group number defined in clause 5.5.1.3 and $v$ is the base sequence number defined in clause 5.5.1.4. The cyclic shift $\alpha_{\tilde{p}}$ of the sounding reference signal is given as

$$\alpha_{\tilde{p}} = 2\pi \frac{n_{\text{SRS}}^{\text{cs},\tilde{p}}}{8}$$

$$n_{\text{SRS}}^{\text{cs},\tilde{p}} = \left( n_{\text{SRS}}^{\text{cs}} + \frac{8\tilde{p}}{N_{\text{ap}}} \right) \bmod 8,$$

$$\tilde{p} \in \{0,1,...,N_{\text{ap}}-1\}$$

where $n_{\text{SRS}}^{\text{cs}} = \{0,1,2,3,4,5,6,7\}$ is configured separately for periodic and each configuration of aperiodic sounding by the higher-layer parameters *cyclicShift* and *cyclicShift-ap*, respectively, for each UE and $N_{\text{ap}}$ is the number of antenna ports used for sounding reference signal transmission.

### 5.5.3.2 Mapping to physical resources

The sequence shall be multiplied with the amplitude scaling factor $\beta_{\text{SRS}}$ in order to conform to the transmit power $P_{\text{SRS}}$ specified in clause 5.1.3.1 in 3GPP TS 36.213 [4], and mapped in sequence starting with $r_{\text{SRS}}^{(\tilde{p})}(0)$ to resource elements $(k,l)$ on antenna port $p$ according to

$$a_{2k'+k_0^{(p)},l}^{(p)} = \begin{cases} \frac{1}{\sqrt{N_{\text{ap}}}} \beta_{\text{SRS}} r_{SRS}^{(\tilde{p})}(k') & k' = 0,1,\ldots,M_{\text{sc},b}^{\text{RS}}-1 \\ 0 & \text{otherwise} \end{cases}$$

where $N_{\text{ap}}$ is the number of antenna ports used for sounding reference signal transmission and the relation between the index $\tilde{p}$ and the antenna port $p$ is given by Table 5.2.1-1. The set of antenna ports used for sounding reference signal transmission is configured independently for periodic and each configuration of aperiodic sounding. The quantity $k_0^{(p)}$ is the frequency-domain starting position of the sounding reference signal and for $b = B_{\text{SRS}}$ and $M_{\text{sc},b}^{\text{RS}}$ is the length of the sounding reference signal sequence defined as

$$M_{\text{sc},b}^{\text{RS}} = m_{\text{SRS},b} N_{\text{sc}}^{\text{RB}} / 2$$

where $m_{\text{SRS},b}$ is given by Table 5.5.3.2-1 through Table 5.5.3.2-4 for each uplink bandwidth $N_{\text{RB}}^{\text{UL}}$. The cell-specific parameter *srs-BandwidthConfig,* $C_{\text{SRS}} \in \{0,1,2,3,4,5,6,7\}$ and the UE-specific parameter *srs-Bandwidth,* $B_{\text{SRS}} \in \{0,1,2,3\}$ are given by higher layers. For UpPTS, $m_{\text{SRS},0}$ shall be reconfigured to $m_{\text{SRS},0}^{\max} = \max_{c \in C} \left\{ m_{\text{SRS},0}^{c} \right\} \le \left( N_{\text{RB}}^{\text{UL}} - 6N_{\text{RA}} \right)$ if this reconfiguration is enabled by the cell-specific parameter *srsMaxUpPts* given by higher layers, otherwise if the reconfiguration is disabled $m_{\text{SRS},0}^{\max} = m_{\text{SRS},0}$,where $c$ is a SRS BW configuration and $C_{\text{SRS}}$ is the set of SRS BW configurations from the Tables 5.5.3.2-1 to 5.5.3.2-4 for each uplink bandwidth $N_{\text{RB}}^{\text{UL}}$, $N_{\text{RA}}$ is the number of format 4 PRACH in the addressed UpPTS and derived from Table 5.7.1-4.

The frequency-domain starting position $k_0^{(p)}$ is defined by

$$k_0^{(p)} = \bar{k}_0^{(p)} + \sum_{b=0}^{B_{\text{SRS}}} 2M_{\text{sc},b}^{\text{RS}} n_b$$

where for normal uplink subframes $\bar{k}_0^{(p)}$ is defined by

$$\bar{k}_0^{(p)} = \left(\left\lfloor N_{\mathrm{RB}}^{\mathrm{UL}} / 2 \right\rfloor - m_{\mathrm{SRS},0}/2\right) N_{\mathrm{SC}}^{\mathrm{RB}} + k_{\mathrm{TC}}^{(p)}$$

and for UpPTS by

$$\bar{k}_0^{(p)} = \begin{cases} (N_{\mathrm{RB}}^{\mathrm{UL}} - m_{\mathrm{SRS},0}^{\max}) N_{\mathrm{sc}}^{\mathrm{RB}} + k_{\mathrm{TC}}^{(p)} & \text{if } \left((n_{\mathrm{f}} \bmod 2)\cdot(2 - N_{\mathrm{SP}}) + n_{\mathrm{hf}}\right) \bmod 2 = 0 \\ k_{\mathrm{TC}}^{(p)} & \text{otherwise} \end{cases}$$

The quantity $k_{\mathrm{TC}}^{(p)} \in \{0,1\}$ is given by

$$k_{\mathrm{TC}}^{(p)} = \begin{cases} 1 - \bar{k}_{\mathrm{TC}} & \text{if } n_{\mathrm{SRS}}^{\mathrm{cs}} \in \{4,5,6,7\} \text{ and } \tilde{p} \in \{1,3\} \text{ and } N_{\mathrm{ap}} = 4 \\ \bar{k}_{\mathrm{TC}} & \text{otherwise} \end{cases}$$

where the relation between the index $\tilde{p}$ and the antenna port $p$ is given by Table 5.2.1-1, $\bar{k}_{\mathrm{TC}} \in \{0,1\}$ is given by the UE-specific parameter *transmissionComb* or *transmissionComb-ap* for periodic and each configuration of aperiodic transmission, respectively, provided by higher layers for the UE, and $n_b$ is frequency position index. The variable $n_{\mathrm{hf}}$ is equal to 0 for UpPTS in the first half frame and equal to 1 for UpPTS in the second half frame of a radio frame.

The frequency hopping of the sounding reference signal is configured by the parameter $b_{\mathrm{hop}} \in \{0,1,2,3\}$, provided by higher-layer parameter *srs-HoppingBandwidth.* Frequency hopping is not supported for aperiodic transmission.. If frequency hopping of the sounding reference signal is not enabled (i.e., $b_{\mathrm{hop}} \geq B_{\mathrm{SRS}}$), the frequency position index $n_b$ remains constant (unless re-configured) and is defined by $n_{\mathrm{b}} = \lfloor 4n_{\mathrm{RRC}}/m_{\mathrm{SRS},b} \rfloor \bmod N_{\mathrm{b}}$ where the parameter $n_{\mathrm{RRC}}$ is given by higher-layer parameters *freqDomainPosition* and *freqDomainPosition-ap* for periodic and each configuration of aperiodic transmission, respectively. If frequency hopping of the sounding reference signal is enabled (i.e., $b_{\mathrm{hop}} < B_{\mathrm{SRS}}$), the frequency position indexes $n_b$ are defined by

$$n_b = \begin{cases} \lfloor 4n_{\mathrm{RRC}}/m_{\mathrm{SRS},b} \rfloor \bmod N_b & b \leq b_{\mathrm{hop}} \\ \left\{F_b(n_{\mathrm{SRS}}) + \lfloor 4n_{\mathrm{RRC}}/m_{\mathrm{SRS},b} \rfloor\right\} \bmod N_b & \text{otherwise} \end{cases}$$

where $N_b$ is given by Table 5.5.3.2-1 through Table 5.5.3.2-4 for each uplink bandwidth $N_{\mathrm{RB}}^{\mathrm{UL}}$,

$$F_b(n_{\mathrm{SRS}}) = \begin{cases} (N_b/2)\left\lfloor \dfrac{n_{\mathrm{SRS}} \bmod \Pi_{b'=b_{\mathrm{hop}}}^{b} N_{b'}}{\Pi_{b'=b_{\mathrm{hop}}}^{b-1} N_{b'}} \right\rfloor + \left\lfloor \dfrac{n_{\mathrm{SRS}} \bmod \Pi_{b'=b_{\mathrm{hop}}}^{b} N_{b'}}{2\Pi_{b'=b_{\mathrm{hop}}}^{b-1} N_{b'}} \right\rfloor & \text{if } N_b \text{ even} \\ \lfloor N_b/2 \rfloor \left\lfloor n_{\mathrm{SRS}} / \Pi_{b'=b_{\mathrm{hop}}}^{b-1} N_{b'} \right\rfloor & \text{if } N_b \text{ odd} \end{cases}$$

where $N_{b_{\mathrm{hop}}} = 1$ regardless of the $N_b$ value on Table 5.5.3.2-1 through Table 5.5.3.2-4, and

$$n_{\mathrm{SRS}} = \begin{cases} 2N_{\mathrm{SP}} n_{\mathrm{f}} + 2(N_{\mathrm{SP}} - 1)\left\lfloor \dfrac{n_{\mathrm{s}}}{10} \right\rfloor + \left\lfloor \dfrac{T_{\mathrm{offset}}}{T_{\mathrm{offset_max}}} \right\rfloor, & \text{for 2 ms SRS periodicity of frame structure type 2} \\ \left\lfloor (n_{\mathrm{f}} \times 10 + \lfloor n_{\mathrm{s}}/2 \rfloor)/T_{\mathrm{SRS}} \right\rfloor, & \text{otherwise} \end{cases}$$

counts the number of UE-specific SRS transmissions, where $T_{\mathrm{SRS}}$ is UE-specific periodicity of SRS transmission defined in clause 8.2 of 3GPP TS 36.213 [4], $T_{\mathrm{offset}}$ is SRS subframe offset defined in Table 8.2-2 of 3GPP TS 36.213 [4] and $T_{\mathrm{offset_max}}$ is the maximum value of $T_{\mathrm{offset}}$ for a certain configuration of SRS subframe offset.

For all subframes other than special subframes, the sounding reference signal shall be transmitted in the last symbol of the subframe.

**Table 5.5.3.2-1: $m_{\mathrm{SRS},b}$ and $N_b$, $b = 0,1,2,3$, values for the uplink bandwidth of $6 \le N_{\mathrm{RB}}^{\mathrm{UL}} \le 40$**

| SRS bandwidth configuration $C_{\mathrm{SRS}}$ | SRS-Bandwidth $B_{\mathrm{SRS}} = 0$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 1$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 2$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 3$ | |
|---|---|---|---|---|---|---|---|---|
| | $m_{\mathrm{SRS},0}$ | $N_0$ | $m_{\mathrm{SRS},1}$ | $N_1$ | $m_{\mathrm{SRS},2}$ | $N_2$ | $m_{\mathrm{SRS},3}$ | $N_3$ |
| 0 | 36 | 1 | 12 | 3 | 4 | 3 | 4 | 1 |
| 1 | 32 | 1 | 16 | 2 | 8 | 2 | 4 | 2 |
| 2 | 24 | 1 | 4 | 6 | 4 | 1 | 4 | 1 |
| 3 | 20 | 1 | 4 | 5 | 4 | 1 | 4 | 1 |
| 4 | 16 | 1 | 4 | 4 | 4 | 1 | 4 | 1 |
| 5 | 12 | 1 | 4 | 3 | 4 | 1 | 4 | 1 |
| 6 | 8 | 1 | 4 | 2 | 4 | 1 | 4 | 1 |
| 7 | 4 | 1 | 4 | 1 | 4 | 1 | 4 | 1 |

**Table 5.5.3.2-2: $m_{\mathrm{SRS},b}$ and $N_b$, $b = 0,1,2,3$, values for the uplink bandwidth of $40 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 60$**

| SRS bandwidth configuration $C_{\mathrm{SRS}}$ | SRS-Bandwidth $B_{\mathrm{SRS}} = 0$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 1$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 2$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 3$ | |
|---|---|---|---|---|---|---|---|---|
| | $m_{\mathrm{SRS},0}$ | $N_0$ | $m_{\mathrm{SRS},1}$ | $N_1$ | $m_{\mathrm{SRS},2}$ | $N_2$ | $m_{\mathrm{SRS},3}$ | $N_3$ |
| 0 | 48 | 1 | 24 | 2 | 12 | 2 | 4 | 3 |
| 1 | 48 | 1 | 16 | 3 | 8 | 2 | 4 | 2 |
| 2 | 40 | 1 | 20 | 2 | 4 | 5 | 4 | 1 |
| 3 | 36 | 1 | 12 | 3 | 4 | 3 | 4 | 1 |
| 4 | 32 | 1 | 16 | 2 | 8 | 2 | 4 | 2 |
| 5 | 24 | 1 | 4 | 6 | 4 | 1 | 4 | 1 |
| 6 | 20 | 1 | 4 | 5 | 4 | 1 | 4 | 1 |
| 7 | 16 | 1 | 4 | 4 | 4 | 1 | 4 | 1 |

**Table 5.5.3.2-3: $m_{\mathrm{SRS},b}$ and $N_b$, $b = 0,1,2,3$, values for the uplink bandwidth of $60 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 80$**

| SRS bandwidth configuration $C_{\mathrm{SRS}}$ | SRS-Bandwidth $B_{\mathrm{SRS}} = 0$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 1$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 2$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 3$ | |
|---|---|---|---|---|---|---|---|---|
| | $m_{\mathrm{SRS},0}$ | $N_0$ | $m_{\mathrm{SRS},1}$ | $N_1$ | $m_{\mathrm{SRS},2}$ | $N_2$ | $m_{\mathrm{SRS},3}$ | $N_3$ |
| 0 | 72 | 1 | 24 | 3 | 12 | 2 | 4 | 3 |
| 1 | 64 | 1 | 32 | 2 | 16 | 2 | 4 | 4 |
| 2 | 60 | 1 | 20 | 3 | 4 | 5 | 4 | 1 |
| 3 | 48 | 1 | 24 | 2 | 12 | 2 | 4 | 3 |
| 4 | 48 | 1 | 16 | 3 | 8 | 2 | 4 | 2 |
| 5 | 40 | 1 | 20 | 2 | 4 | 5 | 4 | 1 |
| 6 | 36 | 1 | 12 | 3 | 4 | 3 | 4 | 1 |
| 7 | 32 | 1 | 16 | 2 | 8 | 2 | 4 | 2 |

**Table 5.5.3.2-4: $m_{\mathrm{SRS},b}$ and $N_b$, $b = 0,1,2,3$, values for the uplink bandwidth of $80 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 110$**

| SRS bandwidth configuration $C_{\mathrm{SRS}}$ | SRS-Bandwidth $B_{\mathrm{SRS}} = 0$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 1$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 2$ | | SRS-Bandwidth $B_{\mathrm{SRS}} = 3$ | |
|---|---|---|---|---|---|---|---|---|
| | $m_{\mathrm{SRS},0}$ | $N_0$ | $m_{\mathrm{SRS},1}$ | $N_1$ | $m_{\mathrm{SRS},2}$ | $N_2$ | $m_{\mathrm{SRS},3}$ | $N_3$ |
| 0 | 96 | 1 | 48 | 2 | 24 | 2 | 4 | 6 |
| 1 | 96 | 1 | 32 | 3 | 16 | 2 | 4 | 4 |
| 2 | 80 | 1 | 40 | 2 | 20 | 2 | 4 | 5 |
| 3 | 72 | 1 | 24 | 3 | 12 | 2 | 4 | 3 |
| 4 | 64 | 1 | 32 | 2 | 16 | 2 | 4 | 4 |
| 5 | 60 | 1 | 20 | 3 | 4 | 5 | 4 | 1 |
| 6 | 48 | 1 | 24 | 2 | 12 | 2 | 4 | 3 |
| 7 | 48 | 1 | 16 | 3 | 8 | 2 | 4 | 2 |

### 5.5.3.3 Sounding reference signal subframe configuration

The cell-specific subframe configuration period $T_{SFC}$ and the cell-specific subframe offset $\Delta_{SFC}$ for the transmission of sounding reference signals are listed in Tables 5.5.3.3-1 and 5.5.3.3-2, for frame structures type 1 and 2 respectively, where the parameter *srs-SubframeConfig* is provided by higher layers. Sounding reference signal subframes are the subframes satisfying $\lfloor n_s / 2 \rfloor \bmod T_{SFC} \in \Delta_{SFC}$. For frame structure type 2, sounding reference signal is transmitted only in configured UL subframes or UpPTS.

**Table 5.5.3.3-1: Frame structure type 1 sounding reference signal subframe configuration**

| srs-SubframeConfig | Binary | Configuration Period $T_{SFC}$ (subframes) | Transmission offset $\Delta_{SFC}$ (subframes) |
|---|---|---|---|
| 0 | 0000 | 1 | {0} |
| 1 | 0001 | 2 | {0} |
| 2 | 0010 | 2 | {1} |
| 3 | 0011 | 5 | {0} |
| 4 | 0100 | 5 | {1} |
| 5 | 0101 | 5 | {2} |
| 6 | 0110 | 5 | {3} |
| 7 | 0111 | 5 | {0,1} |
| 8 | 1000 | 5 | {2,3} |
| 9 | 1001 | 10 | {0} |
| 10 | 1010 | 10 | {1} |
| 11 | 1011 | 10 | {2} |
| 12 | 1100 | 10 | {3} |
| 13 | 1101 | 10 | {0,1,2,3,4,6,8} |
| 14 | 1110 | 10 | {0,1,2,3,4,5,6,8} |
| 15 | 1111 | reserved | reserved |

**Table 5.5.3.3-2: Frame structure type 2 sounding reference signal subframe configuration**

| srs-SubframeConfig | Binary | Configuration Period $T_{SFC}$ (subframes) | Transmission offset $\Delta_{SFC}$ (subframes) |
|---|---|---|---|
| 0 | 0000 | 5 | {1} |
| 1 | 0001 | 5 | {1, 2} |
| 2 | 0010 | 5 | {1, 3} |
| 3 | 0011 | 5 | {1, 4} |
| 4 | 0100 | 5 | {1, 2, 3} |
| 5 | 0101 | 5 | {1, 2, 4} |
| 6 | 0110 | 5 | {1, 3, 4} |
| 7 | 0111 | 5 | {1, 2, 3, 4} |
| 8 | 1000 | 10 | {1, 2, 6} |
| 9 | 1001 | 10 | {1, 3, 6} |
| 10 | 1010 | 10 | {1, 6, 7} |
| 11 | 1011 | 10 | {1, 2, 6, 8} |
| 12 | 1100 | 10 | {1, 3, 6, 9} |
| 13 | 1101 | 10 | {1, 4, 6, 7} |
| 14 | 1110 | reserved | reserved |
| 15 | 1111 | reserved | reserved |

## 5.6 SC-FDMA baseband signal generation

This clause applies to all uplink physical signals and physical channels except the physical random access channel.

The time-continuous signal $s_l^{(p)}(t)$ for antenna port $p$ in SC-FDMA symbol $l$ in an uplink slot is defined by

$$s_l^{(p)}(t) = \sum_{k=-\lfloor N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \rfloor}^{\lceil N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \rceil - 1} a_{k^{(-)},l}^{(p)} \cdot e^{j2\pi(k+1/2)\Delta f\left(t - N_{\mathrm{CP},l} T_{\mathrm{s}}\right)}$$

for $0 \le t < (N_{\mathrm{CP},l} + N) \times T_{\mathrm{s}}$ where $k^{(-)} = k + \lfloor N_{RB}^{UL} N_{sc}^{RB}/2 \rfloor$, $N = 2048$, $\Delta f = 15\,\mathrm{kHz}$ and $a_{k,l}^{(p)}$ is the content of resource element $(k,l)$ on antenna port $p$.

The SC-FDMA symbols in a slot shall be transmitted in increasing order of $l$, starting with $l = 0$, where SC-FDMA symbol $l > 0$ starts at time $\sum_{l'=0}^{l-1} (N_{\mathrm{CP},l'} + N) T_{\mathrm{s}}$ within the slot.

Table 5.6-1 lists the values of $N_{\mathrm{CP},l}$ that shall be used.

**Table 5.6-1: SC-FDMA parameters**

| Configuration | Cyclic prefix length $N_{\mathrm{CP},l}$ |
|---|---|
| Normal cyclic prefix | 160 for $l = 0$<br>144 for $l = 1,2,...,6$ |
| Extended cyclic prefix | 512 for $l = 0,1,...,5$ |

# 5.7 Physical random access channel

## 5.7.1 Time and frequency structure

The physical layer random access preamble, illustrated in Figure 5.7.1-1, consists of a cyclic prefix of length $T_{CP}$ and a sequence part of length $T_{SEQ}$. The parameter values are listed in Table 5.7.1-1 and depend on the frame structure and the random access configuration. Higher layers control the preamble format.

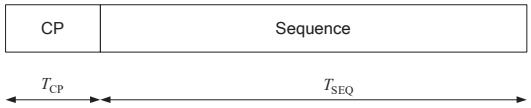



**Figure 5.7.1-1: Random access preamble format**

**Table 5.7.1-1: Random access preamble parameters**

| Preamble format | $T_{CP}$ | $T_{SEQ}$ |
|---|---|---|
| 0 | $3168 \cdot T_s$ | $24576 \cdot T_s$ |
| 1 | $21024 \cdot T_s$ | $24576 \cdot T_s$ |
| 2 | $6240 \cdot T_s$ | $2 \cdot 24576 \cdot T_s$ |
| 3 | $21024 \cdot T_s$ | $2 \cdot 24576 \cdot T_s$ |
| 4 (see Note) | $448 \cdot T_s$ | $4096 \cdot T_s$ |
| NOTE: Frame structure type 2 and special subframe configurations with UpPTS lengths $4384 \cdot T_s$ and $5120 \cdot T_s$ only. | | |

The transmission of a random access preamble, if triggered by the MAC layer, is restricted to certain time and frequency resources. These resources are enumerated in increasing order of the subframe number within the radio frame and the physical resource blocks in the frequency domain such that index 0 correspond to the lowest numbered physical resource block and subframe within the radio frame. PRACH resources within the radio frame are indicated by a PRACH Resource Index, where the indexing is in the order of appearance in Table 5.7.1-2 and Table 5.7.1-4.

For frame structure type 1 with preamble format 0-3, there is at most one random access resource per subframe. Table 5.7.1-2 lists the preamble formats according to Table 5.7.1-1 and the subframes in which random access preamble transmission is allowed for a given configuration in frame structure type 1. The parameter *prach-ConfigurationIndex* is given by higher layers. The start of the random access preamble shall be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{TA} = 0$, where $N_{TA}$ is defined in clause 8.1. For PRACH configurations 0, 1, 2, 15, 16, 17, 18, 31, 32, 33, 34, 47, 48, 49, 50 and 63 the UE may for handover purposes assume an absolute value of the relative time difference between radio frame $i$ in the current cell and the target cell of less than $153600 \cdot T_s$.

The first physical resource block $n_{PRB}^{RA}$ allocated to the PRACH opportunity considered for preamble formats 0, 1, 2 and 3 is defined as $n_{PRB}^{RA} = n_{PRB\,offset}^{RA}$, where the parameter *prach-FrequencyOffset,* $n_{PRBoffset}^{RA}$ is expressed as a physical resource block number configured by higher layers and fulfilling $0 \le n_{PRBoffset}^{RA} \le N_{RB}^{UL} - 6$.

**Table 5.7.1-2: Frame structure type 1 random access configuration for preamble formats 0-3**

| PRACH Configuration Index | Preamble Format | System frame number | Subframe number | PRACH Configuration Index | Preamble Format | System frame number | Subframe number |
|---|---|---|---|---|---|---|---|
| 0 | 0 | Even | 1 | 32 | 2 | Even | 1 |
| 1 | 0 | Even | 4 | 33 | 2 | Even | 4 |
| 2 | 0 | Even | 7 | 34 | 2 | Even | 7 |
| 3 | 0 | Any | 1 | 35 | 2 | Any | 1 |
| 4 | 0 | Any | 4 | 36 | 2 | Any | 4 |
| 5 | 0 | Any | 7 | 37 | 2 | Any | 7 |
| 6 | 0 | Any | 1, 6 | 38 | 2 | Any | 1, 6 |
| 7 | 0 | Any | 2 ,7 | 39 | 2 | Any | 2 ,7 |
| 8 | 0 | Any | 3, 8 | 40 | 2 | Any | 3, 8 |
| 9 | 0 | Any | 1, 4, 7 | 41 | 2 | Any | 1, 4, 7 |
| 10 | 0 | Any | 2, 5, 8 | 42 | 2 | Any | 2, 5, 8 |
| 11 | 0 | Any | 3, 6, 9 | 43 | 2 | Any | 3, 6, 9 |
| 12 | 0 | Any | 0, 2, 4, 6, 8 | 44 | 2 | Any | 0, 2, 4, 6, 8 |
| 13 | 0 | Any | 1, 3, 5, 7, 9 | 45 | 2 | Any | 1, 3, 5, 7, 9 |
| 14 | 0 | Any | 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 | 46 | N/A | N/A | N/A |
| 15 | 0 | Even | 9 | 47 | 2 | Even | 9 |
| 16 | 1 | Even | 1 | 48 | 3 | Even | 1 |
| 17 | 1 | Even | 4 | 49 | 3 | Even | 4 |
| 18 | 1 | Even | 7 | 50 | 3 | Even | 7 |
| 19 | 1 | Any | 1 | 51 | 3 | Any | 1 |
| 20 | 1 | Any | 4 | 52 | 3 | Any | 4 |
| 21 | 1 | Any | 7 | 53 | 3 | Any | 7 |
| 22 | 1 | Any | 1, 6 | 54 | 3 | Any | 1, 6 |
| 23 | 1 | Any | 2 ,7 | 55 | 3 | Any | 2 ,7 |
| 24 | 1 | Any | 3, 8 | 56 | 3 | Any | 3, 8 |
| 25 | 1 | Any | 1, 4, 7 | 57 | 3 | Any | 1, 4, 7 |
| 26 | 1 | Any | 2, 5, 8 | 58 | 3 | Any | 2, 5, 8 |
| 27 | 1 | Any | 3, 6, 9 | 59 | 3 | Any | 3, 6, 9 |
| 28 | 1 | Any | 0, 2, 4, 6, 8 | 60 | N/A | N/A | N/A |
| 29 | 1 | Any | 1, 3, 5, 7, 9 | 61 | N/A | N/A | N/A |
| 30 | N/A | N/A | N/A | 62 | N/A | N/A | N/A |
| 31 | 1 | Even | 9 | 63 | 3 | Even | 9 |

For frame structure type 2 with preamble formats 0-4, there might be multiple random access resources in an UL subframe (or UpPTS for preamble format 4) depending on the UL/DL configuration [see table 4.2-2]. Table 5.7.1-3 lists PRACH configurations allowed for frame structure type 2 where the configuration index corresponds to a certain combination of preamble format, PRACH density value, $D_{\mathrm{RA}}$ and version index, $r_{\mathrm{RA}}$.

The parameter *prach-ConfigurationIndex* is given by higher layers. For frame structure type 2 with PRACH configuration 0, 1, 2, 20, 21, 22, 30, 31, 32, 40, 41, 42, 48, 49, 50, or with PRACH configuration 51, 53, 54, 55, 56, 57 in UL/DL configuration 3, 4, 5, the UE may for handover purposes assume an absolute value of the relative time difference between radio frame $i$ in the current cell and the target cell is less than $153600 \cdot T_{\mathrm{s}}$.

**Table 5.7.1-3: Frame structure type 2 random access configurations for preamble formats 0-4**

| PRACH configuration Index | Preamble Format | Density Per 10 ms $D_{\mathrm{RA}}$ | Version $r_{\mathrm{RA}}$ | PRACH configuration Index | Preamble Format | Density Per 10 ms $D_{\mathrm{RA}}$ | Version $r_{\mathrm{RA}}$ |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0.5 | 0 | 32 | 2 | 0.5 | 2 |
| 1 | 0 | 0.5 | 1 | 33 | 2 | 1 | 0 |
| 2 | 0 | 0.5 | 2 | 34 | 2 | 1 | 1 |
| 3 | 0 | 1 | 0 | 35 | 2 | 2 | 0 |
| 4 | 0 | 1 | 1 | 36 | 2 | 3 | 0 |
| 5 | 0 | 1 | 2 | 37 | 2 | 4 | 0 |
| 6 | 0 | 2 | 0 | 38 | 2 | 5 | 0 |
| 7 | 0 | 2 | 1 | 39 | 2 | 6 | 0 |
| 8 | 0 | 2 | 2 | 40 | 3 | 0.5 | 0 |
| 9 | 0 | 3 | 0 | 41 | 3 | 0.5 | 1 |
| 10 | 0 | 3 | 1 | 42 | 3 | 0.5 | 2 |
| 11 | 0 | 3 | 2 | 43 | 3 | 1 | 0 |
| 12 | 0 | 4 | 0 | 44 | 3 | 1 | 1 |
| 13 | 0 | 4 | 1 | 45 | 3 | 2 | 0 |
| 14 | 0 | 4 | 2 | 46 | 3 | 3 | 0 |
| 15 | 0 | 5 | 0 | 47 | 3 | 4 | 0 |
| 16 | 0 | 5 | 1 | 48 | 4 | 0.5 | 0 |
| 17 | 0 | 5 | 2 | 49 | 4 | 0.5 | 1 |
| 18 | 0 | 6 | 0 | 50 | 4 | 0.5 | 2 |
| 19 | 0 | 6 | 1 | 51 | 4 | 1 | 0 |
| 20 | 1 | 0.5 | 0 | 52 | 4 | 1 | 1 |
| 21 | 1 | 0.5 | 1 | 53 | 4 | 2 | 0 |
| 22 | 1 | 0.5 | 2 | 54 | 4 | 3 | 0 |
| 23 | 1 | 1 | 0 | 55 | 4 | 4 | 0 |
| 24 | 1 | 1 | 1 | 56 | 4 | 5 | 0 |
| 25 | 1 | 2 | 0 | 57 | 4 | 6 | 0 |
| 26 | 1 | 3 | 0 | 58 | N/A | N/A | N/A |
| 27 | 1 | 4 | 0 | 59 | N/A | N/A | N/A |
| 28 | 1 | 5 | 0 | 60 | N/A | N/A | N/A |
| 29 | 1 | 6 | 0 | 61 | N/A | N/A | N/A |
| 30 | 2 | 0.5 | 0 | 62 | N/A | N/A | N/A |
| 31 | 2 | 0.5 | 1 | 63 | N/A | N/A | N/A |

Table 5.7.1-4 lists the mapping to physical resources for the different random access opportunities needed for a certain PRACH density value, $D_{\mathrm{RA}}$. Each quadruple of the format $(f_{\mathrm{RA}}, t_{\mathrm{RA}}^{(0)}, t_{\mathrm{RA}}^{(1)}, t_{\mathrm{RA}}^{(2)})$ indicates the location of a specific random access resource, where $f_{\mathrm{RA}}$ is a frequency resource index within the considered time instance, $t_{\mathrm{RA}}^{(0)} = 0,1,2$ indicates whether the resource is reoccurring in all radio frames, in even radio frames, or in odd radio frames, respectively, $t_{\mathrm{RA}}^{(1)} = 0,1$ indicates whether the random access resource is located in first half frame or in second half frame, respectively, and where $t_{\mathrm{RA}}^{(2)}$ is the uplink subframe number where the preamble starts, counting from 0 at the first uplink subframe between 2 consecutive downlink-to-uplink switch points, with the exception of preamble format 4 where $t_{\mathrm{RA}}^{(2)}$ is denoted as (*). The start of the random access preamble formats 0-3 shall be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{\mathrm{TA}} = 0$ and the random access preamble format 4 shall start $4832 \cdot T_{\mathrm{s}}$ before the end of the UpPTS at the UE, where the UpPTS is referenced to the UE's uplink frame timing assuming $N_{\mathrm{TA}} = 0$.

The random access opportunities for each PRACH configuration shall be allocated in time first and then in frequency if and only if time multiplexing is not sufficient to hold all opportunities of a PRACH configuration needed for a certain density value $D_{\mathrm{RA}}$ without overlap in time. For preamble format 0-3, the frequency multiplexing shall be done according to

$$n_{\mathrm{PRB}}^{\mathrm{RA}} = \begin{cases} n_{\mathrm{PRB\,offset}}^{\mathrm{RA}} + 6\left\lfloor \frac{f_{\mathrm{RA}}}{2} \right\rfloor, & \text{if } f_{\mathrm{RA}} \bmod 2 = 0 \\ N_{\mathrm{RB}}^{\mathrm{UL}} - 6 - n_{\mathrm{PRB\,offset}}^{\mathrm{RA}} - 6\left\lfloor \frac{f_{\mathrm{RA}}}{2} \right\rfloor, & \text{otherwise} \end{cases}$$

where $N_{\mathrm{RB}}^{\mathrm{UL}}$ is the number of uplink resource blocks, $n_{\mathrm{PRB}}^{\mathrm{RA}}$ is the first physical resource block allocated to the PRACH opportunity considered and where the parameter *prach-FrequencyOffset,* $n_{\mathrm{PRB\,offset}}^{\mathrm{RA}}$ is the first physical resource block available for PRACH expressed as a physical resource block number configured by higher layers and fulfilling $0 \le n_{\mathrm{PRBoffset}}^{\mathrm{RA}} \le N_{\mathrm{RB}}^{\mathrm{UL}} - 6$.

For preamble format 4, the frequency multiplexing shall be done according to

$$n_{\mathrm{PRB}}^{\mathrm{RA}} = \begin{cases} 6 f_{\mathrm{RA}}, & \text{if } \left((n_{\mathrm{f}} \bmod 2) \times (2 - N_{\mathrm{SP}}) + t_{\mathrm{RA}}^{(1)}\right) \bmod 2 = 0 \\ N_{\mathrm{RB}}^{\mathrm{UL}} - 6(f_{\mathrm{RA}} + 1), & \text{otherwise} \end{cases}$$

where $n_{\mathrm{f}}$ is the system frame number and where $N_{\mathrm{SP}}$ is the number of DL to UL switch points within the radio frame.

Each random access preamble occupies a bandwidth corresponding to 6 consecutive resource blocks for both frame structures.

**Table 5.7.1-4: Frame structure type 2 random access preamble mapping in time and frequency**

| PRACH configuration Index (See Table 5.7.1-3) | UL/DL configuration (See Table 4.2-2) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| 0 | (0,1,0,2) | (0,1,0,1) | (0,1,0,0) | (0,1,0,2) | (0,1,0,1) | (0,1,0,0) | (0,1,0,2) |
| 1 | (0,2,0,2) | (0,2,0,1) | (0,2,0,0) | (0,2,0,2) | (0,2,0,1) | (0,2,0,0) | (0,2,0,2) |
| 2 | (0,1,1,2) | (0,1,1,1) | (0,1,1,0) | (0,1,0,1) | (0,1,0,0) | N/A | (0,1,1,1) |
| 3 | (0,0,0,2) | (0,0,0,1) | (0,0,0,0) | (0,0,0,2) | (0,0,0,1) | (0,0,0,0) | (0,0,0,2) |
| 4 | (0,0,1,2) | (0,0,1,1) | (0,0,1,0) | (0,0,0,1) | (0,0,0,0) | N/A | (0,0,1,1) |
| 5 | (0,0,0,1) | (0,0,0,0) | N/A | (0,0,0,0) | N/A | N/A | (0,0,0,1) |
| 6 | (0,0,0,2)<br>(0,0,1,2) | (0,0,0,1)<br>(0,0,1,1) | (0,0,0,0)<br>(0,0,1,0) | (0,0,0,1)<br>(0,0,0,2) | (0,0,0,0)<br>(0,0,0,1) | (0,0,0,0)<br>(1,0,0,0) | (0,0,0,2)<br>(0,0,1,1) |
| 7 | (0,0,0,1)<br>(0,0,1,1) | (0,0,0,0)<br>(0,0,1,0) | N/A | (0,0,0,0)<br>(0,0,0,2) | N/A | N/A | (0,0,0,1)<br>(0,0,1,0) |
| 8 | (0,0,0,0)<br>(0,0,1,0) | N/A | N/A | (0,0,0,0)<br>(0,0,0,1) | N/A | N/A | (0,0,0,0)<br>(0,0,1,1) |
| 9 | (0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,2) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,1,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2) | (0,0,0,0)<br>(0,0,0,1)<br>(1,0,0,1) | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0) | (0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,1) |
| 10 | (0,0,0,0)<br>(0,0,1,0)<br>(0,0,1,1) | (0,0,0,1)<br>(0,0,1,0)<br>(0,0,1,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,1,0) | N/A | (0,0,0,0)<br>(0,0,0,1)<br>(1,0,0,0) | N/A | (0,0,0,0)<br>(0,0,0,2)<br>(0,0,1,0) |
| 11 | N/A | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,1,0) | N/A | N/A | N/A | N/A | (0,0,0,1)<br>(0,0,1,0)<br>(0,0,1,1) |
| 12 | (0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,1)<br>(0,0,1,2) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,1,0)<br>(0,0,1,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0)<br>(1,0,1,0) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(1,0,0,2) | (0,0,0,0)<br>(0,0,0,1)<br>(1,0,0,0)<br>(1,0,0,1) | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0)<br>(3,0,0,0) | (0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,0)<br>(0,0,1,1) |
| 13 | (0,0,0,0)<br>(0,0,0,2)<br>(0,0,1,0)<br>(0,0,1,2) | N/A | N/A | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(1,0,0,1) | N/A | N/A | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,1) |
| 14 | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,1,0)<br>(0,0,1,1) | N/A | N/A | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(1,0,0,0) | N/A | N/A | (0,0,0,0)<br>(0,0,0,2)<br>(0,0,1,0)<br>(0,0,1,1) |
| 15 | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,1)<br>(0,0,1,2) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,1,0)<br>(0,0,1,1)<br>(1,0,0,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0)<br>(1,0,1,0)<br>(2,0,0,0) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(1,0,0,1)<br>(1,0,0,2) | (0,0,0,0)<br>(0,0,0,1)<br>(1,0,0,0)<br>(1,0,0,1)<br>(2,0,0,1) | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0)<br>(3,0,0,0)<br>(4,0,0,0) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,0)<br>(0,0,1,1) |
| 16 | (0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,0)<br>(0,0,1,1)<br>(0,0,1,2) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,1,0)<br>(0,0,1,1)<br>(1,0,1,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0)<br>(1,0,1,0)<br>(2,0,1,0) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(1,0,0,0)<br>(1,0,0,2) | (0,0,0,0)<br>(0,0,0,1)<br>(1,0,0,0)<br>(1,0,0,1)<br>(2,0,0,0) | N/A | N/A |
| 17 | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,0)<br>(0,0,1,2) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,1,0)<br>(0,0,1,1)<br>(1,0,0,0) | N/A | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(1,0,0,0)<br>(1,0,0,1) | N/A | N/A | N/A |
| 18 | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,0)<br>(0,0,1,1)<br>(0,0,1,2) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,1,0)<br>(0,0,1,1)<br>(1,0,0,1)<br>(1,0,1,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0)<br>(1,0,1,0)<br>(2,0,0,0)<br>(2,0,1,0) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(1,0,0,0)<br>(1,0,0,1)<br>(1,0,0,2) | (0,0,0,0)<br>(0,0,0,1)<br>(1,0,0,0)<br>(1,0,0,1)<br>(2,0,0,0)<br>(2,0,0,1) | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0)<br>(3,0,0,0)<br>(4,0,0,0)<br>(5,0,0,0) | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,0)<br>(0,0,1,1)<br>(1,0,0,2) |
| 19 | N/A | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,1,0)<br>(0,0,1,1)<br>(1,0,0,0)<br>(1,0,1,0) | N/A | N/A | N/A | N/A | (0,0,0,0)<br>(0,0,0,1)<br>(0,0,0,2)<br>(0,0,1,0)<br>(0,0,1,1)<br>(1,0,1,1) |
| 20 / 30 | (0,1,0,1) | (0,1,0,0) | N/A | (0,1,0,1) | (0,1,0,0) | N/A | (0,1,0,1) |
| 21 / 31 | (0,2,0,1) | (0,2,0,0) | N/A | (0,2,0,1) | (0,2,0,0) | N/A | (0,2,0,1) |
| 22 / 32 | (0,1,1,1) | (0,1,1,0) | N/A | N/A | N/A | N/A | (0,1,1,0) |
| 23 / 33 | (0,0,0,1) | (0,0,0,0) | N/A | (0,0,0,1) | (0,0,0,0) | N/A | (0,0,0,1) |
| 24 / 34 | (0,0,1,1) | (0,0,1,0) | N/A | N/A | N/A | N/A | (0,0,1,0) |
| 25 / 35 | (0,0,0,1)<br>(0,0,1,1) | (0,0,0,0)<br>(0,0,1,0) | N/A | (0,0,0,1)<br>(1,0,0,1) | (0,0,0,0)<br>(1,0,0,0) | N/A | (0,0,0,1)<br>(0,0,1,0) |
| 26 / 36 | (0,0,0,1)<br>(0,0,1,1)<br>(1,0,0,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0) | N/A | (0,0,0,1)<br>(1,0,0,1)<br>(2,0,0,1) | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0) | N/A | (0,0,0,1)<br>(0,0,1,0)<br>(1,0,0,1) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 27 / 37 | (0,0,0,1)<br>(0,0,1,1)<br>(1,0,0,1)<br>(1,0,1,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0)<br>(1,0,1,0) | N/A | (0,0,0,1)<br>(1,0,0,1)<br>(2,0,0,1)<br>(3,0,0,1) | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0)<br>(3,0,0,0) | N/A | (0,0,0,1)<br>(0,0,1,0)<br>(1,0,0,1)<br>(1,0,1,0) |
| 28 / 38 | (0,0,0,1)<br>(0,0,1,1)<br>(1,0,0,1)<br>(1,0,1,1)<br>(2,0,0,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0)<br>(1,0,1,0)<br>(2,0,0,0) | N/A | (0,0,0,1)<br>(1,0,0,1)<br>(2,0,0,1)<br>(3,0,0,1)<br>(4,0,0,1) | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0)<br>(3,0,0,0)<br>(4,0,0,0) | N/A | (0,0,0,1)<br>(0,0,1,0)<br>(1,0,0,1)<br>(1,0,1,0)<br>(2,0,0,1) |
| 29 /39 | (0,0,0,1)<br>(0,0,1,1)<br>(1,0,0,1)<br>(1,0,1,1)<br>(2,0,0,1)<br>(2,0,1,1) | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0)<br>(1,0,1,0)<br>(2,0,0,0)<br>(2,0,1,0) | N/A | (0,0,0,1)<br>(1,0,0,1)<br>(2,0,0,1)<br>(3,0,0,1)<br>(4,0,0,1)<br>(5,0,0,1) | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0)<br>(3,0,0,0)<br>(4,0,0,0)<br>(5,0,0,0) | N/A | (0,0,0,1)<br>(0,0,1,0)<br>(1,0,0,1)<br>(1,0,1,0)<br>(2,0,0,1)<br>(2,0,1,0) |
| 40 | (0,1,0,0) | N/A | N/A | (0,1,0,0) | N/A | N/A | (0,1,0,0) |
| 41 | (0,2,0,0) | N/A | N/A | (0,2,0,0) | N/A | N/A | (0,2,0,0) |
| 42 | (0,1,1,0) | N/A | N/A | N/A | N/A | N/A | N/A |
| 43 | (0,0,0,0) | N/A | N/A | (0,0,0,0) | N/A | N/A | (0,0,0,0) |
| 44 | (0,0,1,0) | N/A | N/A | N/A | N/A | N/A | N/A |
| 45 | (0,0,0,0)<br>(0,0,1,0) | N/A | N/A | (0,0,0,0)<br>(1,0,0,0) | N/A | N/A | (0,0,0,0)<br>(1,0,0,0) |
| 46 | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0) | N/A | N/A | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0) | N/A | N/A | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0) |
| 47 | (0,0,0,0)<br>(0,0,1,0)<br>(1,0,0,0)<br>(1,0,1,0) | N/A | N/A | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0)<br>(3,0,0,0) | N/A | N/A | (0,0,0,0)<br>(1,0,0,0)<br>(2,0,0,0)<br>(3,0,0,0) |
| 48 | (0,1,0,*) | (0,1,0,*) | (0,1,0,*) | (0,1,0,*) | (0,1,0,*) | (0,1,0,*) | (0,1,0,*) |
| 49 | (0,2,0,*) | (0,2,0,*) | (0,2,0,*) | (0,2,0,*) | (0,2,0,*) | (0,2,0,*) | (0,2,0,*) |
| 50 | (0,1,1,*) | (0,1,1,*) | (0,1,1,*) | N/A | N/A | N/A | (0,1,1,*) |
| 51 | (0,0,0,*) | (0,0,0,*) | (0,0,0,*) | (0,0,0,*) | (0,0,0,*) | (0,0,0,*) | (0,0,0,*) |
| 52 | (0,0,1,*) | (0,0,1,*) | (0,0,1,*) | N/A | N/A | N/A | (0,0,1,*) |
| 53 | (0,0,0,*)<br>(0,0,1,*) | (0,0,0,*)<br>(0,0,1,*) | (0,0,0,*)<br>(0,0,1,*) | (0,0,0,*)<br>(1,0,0,*) | (0,0,0,*)<br>(1,0,0,*) | (0,0,0,*)<br>(1,0,0,*) | (0,0,0,*)<br>(0,0,1,*) |
| 54 | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*) |
| 55 | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*)<br>(3,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*)<br>(3,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*)<br>(3,0,0,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*) |
| 56 | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*)<br>(2,0,0,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*)<br>(2,0,0,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*)<br>(2,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*)<br>(3,0,0,*)<br>(4,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*)<br>(3,0,0,*)<br>(4,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*)<br>(3,0,0,*)<br>(4,0,0,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*)<br>(2,0,0,*) |
| 57 | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*)<br>(2,0,0,*)<br>(2,0,1,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*)<br>(2,0,0,*)<br>(2,0,1,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*)<br>(2,0,0,*)<br>(2,0,1,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*)<br>(3,0,0,*)<br>(4,0,0,*)<br>(5,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*)<br>(3,0,0,*)<br>(4,0,0,*)<br>(5,0,0,*) | (0,0,0,*)<br>(1,0,0,*)<br>(2,0,0,*)<br>(3,0,0,*)<br>(4,0,0,*)<br>(5,0,0,*) | (0,0,0,*)<br>(0,0,1,*)<br>(1,0,0,*)<br>(1,0,1,*)<br>(2,0,0,*)<br>(2,0,1,*) |
| 58 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 59 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 60 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 61 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 62 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 63 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| NOTE: * UpPTS | | | | | | | |

## 5.7.2 Preamble sequence generation

The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network configures the set of preamble sequences the UE is allowed to use.

There are 64 preambles available in each cell. The set of 64 preamble sequences in a cell is found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index RACH_ROOT_SEQUENCE, where RACH_ROOT_SEQUENCE is broadcasted as part of the System Information. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found.
The logical root sequence order is cyclic: the logical index 0 is consecutive to 837. The relation between a logical root sequence index and physical root sequence index $u$ is given by Tables 5.7.2-4 and 5.7.2-5 for preamble formats 0 – 3 and 4, respectively.

The $u^{\text{th}}$ root Zadoff-Chu sequence is defined by

$$x_u(n) = e^{-j\frac{\pi un(n+1)}{N_{\text{ZC}}}}, \quad 0 \le n \le N_{\text{ZC}} - 1$$

where the length $N_{\text{ZC}}$ of the Zadoff-Chu sequence is given by Table 5.7.2-1. From the $u^{\text{th}}$ root Zadoff-Chu sequence, random access preambles with zero correlation zones of length $N_{\text{CS}} - 1$ are defined by cyclic shifts according to

$$x_{u,v}(n) = x_u((n + C_v) \bmod N_{\text{ZC}})$$

where the cyclic shift is given by

$$C_v = \begin{cases} vN_{\text{CS}} & v = 0,1,\ldots,\lfloor N_{\text{ZC}}/N_{\text{CS}} \rfloor - 1, N_{\text{CS}} \neq 0 \quad \text{for unrestricted sets} \\ 0 & N_{\text{CS}} = 0 \quad \text{for unrestricted sets} \\ d_{\text{start}} \lfloor v/n_{\text{shift}}^{\text{RA}} \rfloor + (v \bmod n_{\text{shift}}^{\text{RA}}) N_{\text{CS}} & v = 0,1,\ldots,n_{\text{shift}}^{\text{RA}} n_{\text{group}}^{\text{RA}} + \bar{n}_{\text{shift}}^{\text{RA}} - 1 \quad \text{for restricted sets} \end{cases}$$

and $N_{\text{CS}}$ is given by Tables 5.7.2-2 and 5.7.2-3 for preamble formats 0-3 and 4, respectively, where the parameter *zeroCorrelationZoneConfig* is provided by higher layers. The parameter *High-speed-flag* provided by higher layers determines if unrestricted set or restricted set shall be used.

The variable $d_u$ is the cyclic shift corresponding to a Doppler shift of magnitude $1/T_{\text{SEQ}}$ and is given by

$$d_u = \begin{cases} p & 0 \le p < N_{\text{ZC}}/2 \\ N_{\text{ZC}} - p & \text{otherwise} \end{cases}$$

where $p$ is the smallest non-negative integer that fulfils $(pu) \bmod N_{\text{ZC}} = 1$. The parameters for restricted sets of cyclic shifts depend on $d_u$. For $N_{\text{CS}} \le d_u < N_{\text{ZC}}/3$, the parameters are given by

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor d_u / N_{\text{CS}} \rfloor \\ d_{\text{start}} &= 2d_u + n_{\text{shift}}^{\text{RA}} N_{\text{CS}} \\ n_{\text{group}}^{\text{RA}} &= \lfloor N_{\text{ZC}} / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \max\left(\left\lfloor (N_{\text{ZC}} - 2d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{\text{CS}} \right\rfloor, 0\right) \end{aligned}$$

For $N_{\text{ZC}}/3 \le d_u \le (N_{\text{ZC}} - N_{\text{CS}})/2$, the parameters are given by

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor (N_{\text{ZC}} - 2d_u)/N_{\text{CS}} \rfloor \\ d_{\text{start}} &= N_{\text{ZC}} - 2d_u + n_{\text{shift}}^{\text{RA}} N_{\text{CS}} \\ n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \min\left(\max\left(\left\lfloor (d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{\text{CS}} \right\rfloor, 0\right), n_{\text{shift}}^{\text{RA}}\right) \end{aligned}$$

For all other values of $d_u$, there are no cyclic shifts in the restricted set.

**Table 5.7.2-1: Random access preamble sequence length**

| Preamble format | $N_{ZC}$ |
|---|---|
| 0 – 3 | 839 |
| 4 | 139 |

**Table 5.7.2-2: $N_{CS}$ for preamble generation (preamble formats 0-3)**

| *zeroCorrelationZoneConfig* | $N_{CS}$ value | |
|---|---|---|
| | Unrestricted set | Restricted set |
| 0 | 0 | 15 |
| 1 | 13 | 18 |
| 2 | 15 | 22 |
| 3 | 18 | 26 |
| 4 | 22 | 32 |
| 5 | 26 | 38 |
| 6 | 32 | 46 |
| 7 | 38 | 55 |
| 8 | 46 | 68 |
| 9 | 59 | 82 |
| 10 | 76 | 100 |
| 11 | 93 | 128 |
| 12 | 119 | 158 |
| 13 | 167 | 202 |
| 14 | 279 | 237 |
| 15 | 419 | - |

**Table 5.7.2-3: $N_{CS}$ for preamble generation (preamble format 4)**

| *zeroCorrelationZoneConfig* | $N_{CS}$ value |
|---|---|
| 0 | 2 |
| 1 | 4 |
| 2 | 6 |
| 3 | 8 |
| 4 | 10 |
| 5 | 12 |
| 6 | 15 |
| 7 | N/A |
| 8 | N/A |
| 9 | N/A |
| 10 | N/A |
| 11 | N/A |
| 12 | N/A |
| 13 | N/A |
| 14 | N/A |
| 15 | N/A |

**Table 5.7.2-4: Root Zadoff-Chu sequence order for preamble formats 0 – 3**

| Logical root sequence number | Physical root sequence number $u$ (in increasing order of the corresponding logical sequence number) |
|---|---|
| 0–23 | 129, 710, 140, 699, 120, 719, 210, 629, 168, 671, 84, 755, 105, 734, 93, 746, 70, 769, 60, 779<br>2, 837, 1, 838 |
| 24–29 | 56, 783, 112, 727, 148, 691 |
| 30–35 | 80, 759, 42, 797, 40, 799 |
| 36–41 | 35, 804, 73, 766, 146, 693 |
| 42–51 | 31, 808, 28, 811, 30, 809, 27, 812, 29, 810 |
| 52–63 | 24, 815, 48, 791, 68, 771, 74, 765, 178, 661, 136, 703 |
| 64–75 | 86, 753, 78, 761, 43, 796, 39, 800, 20, 819, 21, 818 |
| 76–89 | 95, 744, 202, 637, 190, 649, 181, 658, 137, 702, 125, 714, 151, 688 |
| 90–115 | 217, 622, 128, 711, 142, 697, 122, 717, 203, 636, 118, 721, 110, 729, 89, 750, 103, 736, 61, 778, 55, 784, 15, 824, 14, 825 |
| 116–135 | 12, 827, 23, 816, 34, 805, 37, 802, 46, 793, 207, 632, 179, 660, 145, 694, 130, 709, 223, 616 |
| 136–167 | 228, 611, 227, 612, 132, 707, 133, 706, 143, 696, 135, 704, 161, 678, 201, 638, 173, 666, 106, 733, 83, 756, 91, 748, 66, 773, 53, 786, 10, 829, 9, 830 |
| 168–203 | 7, 832, 8, 831, 16, 823, 47, 792, 64, 775, 57, 782, 104, 735, 101, 738, 108, 731, 208, 631, 184, 655, 197, 642, 191, 648, 121, 718, 141, 698, 149, 690, 216, 623, 218, 621 |
| 204–263 | 152, 687, 144, 695, 134, 705, 138, 701, 199, 640, 162, 677, 176, 663, 119, 720, 158, 681, 164, 675, 174, 665, 171, 668, 170, 669, 87, 752, 169, 670, 88, 751, 107, 732, 81, 758, 82, 757, 100, 739, 98, 741, 71, 768, 59, 780, 65, 774, 50, 789, 49, 790, 26, 813, 17, 822, 13, 826, 6, 833 |
| 264–327 | 5, 834, 33, 806, 51, 788, 75, 764, 99, 740, 96, 743, 97, 742, 166, 673, 172, 667, 175, 664, 187, 652, 163, 676, 185, 654, 200, 639, 114, 725, 189, 650, 115, 724, 194, 645, 195, 644, 192, 647, 182, 657, 157, 682, 156, 683, 211, 628, 154, 685, 123, 716, 139, 700, 212, 627, 153, 686, 213, 626, 215, 624, 150, 689 |
| 328–383 | 225, 614, 224, 615, 221, 618, 220, 619, 127, 712, 147, 692, 124, 715, 193, 646, 205, 634, 206, 633, 116, 723, 160, 679, 186, 653, 167, 672, 79, 760, 85, 754, 77, 762, 92, 747, 58, 781, 62, 777, 69, 770, 54, 785, 36, 803, 32, 807, 25, 814, 18, 821, 11, 828, 4, 835 |
| 384–455 | 3, 836, 19, 820, 22, 817, 41, 798, 38, 801, 44, 795, 52, 787, 45, 794, 63, 776, 67, 772, 72<br>767, 76, 763, 94, 745, 102, 737, 90, 749, 109, 730, 165, 674, 111, 728, 209, 630, 204, 635, 117, 722, 188, 651, 159, 680, 198, 641, 113, 726, 183, 656, 180, 659, 177, 662, 196, 643, 155, 684, 214, 625, 126, 713, 131, 708, 219, 620, 222, 617, 226, 613 |
| 456–513 | 230, 609, 232, 607, 262, 577, 252, 587, 418, 421, 416, 423, 413, 426, 411, 428, 376, 463, 395, 444, 283, 556, 285, 554, 379, 460, 390, 449, 363, 476, 384, 455, 388, 451, 386, 453, 361, 478, 387, 452, 360, 479, 310, 529, 354, 485, 328, 511, 315, 524, 337, 502, 349, 490, 335, 504, 324, 515 |
| 514–561 | 323, 516, 320, 519, 334, 505, 359, 480, 295, 544, 385, 454, 292, 547, 291, 548, 381, 458, 399, 440, 380, 459, 397, 442, 369, 470, 377, 462, 410, 429, 407, 432, 281, 558, 414, 425, 247, 592, 277, 562, 271, 568, 272, 567, 264, 575, 259, 580 |
| 562–629 | 237, 602, 239, 600, 244, 595, 243, 596, 275, 564, 278, 561, 250, 589, 246, 593, 417, 422, 248, 591, 394, 445, 393, 446, 370, 469, 365, 474, 300, 539, 299, 540, 364, 475, 362, 477, 298, 541, 312, 527, 313, 526, 314, 525, 353, 486, 352, 487, 343, 496, 327, 512, 350, 489, 326, 513, 319, 520, 332, 507, 333, 506, 348, 491, 347, 492, 322, 517 |
| 630–659 | 330, 509, 338, 501, 341, 498, 340, 499, 342, 497, 301, 538, 366, 473, 401, 438, 371, 468, 408, 431, 375, 464, 249, 590, 269, 570, 238, 601, 234, 605 |
| 660–707 | 257, 582, 273, 566, 255, 584, 254, 585, 245, 594, 251, 588, 412, 427, 372, 467, 282, 557, 403, 436, 396, 443, 392, 447, 391, 448, 382, 457, 389, 450, 294, 545, 297, 542, 311, 528, 344, 495, 345, 494, 318, 521, 331, 508, 325, 514, 321, 518 |
| 708–729 | 346, 493, 339, 500, 351, 488, 306, 533, 289, 550, 400, 439, 378, 461, 374, 465, 415, 424, 270, 569, 241, 598 |
| 730–751 | 231, 608, 260, 579, 268, 571, 276, 563, 409, 430, 398, 441, 290, 549, 304, 535, 308, 531, 358, 481, 316, 523 |
| 752–765 | 293, 546, 288, 551, 284, 555, 368, 471, 253, 586, 256, 583, 263, 576 |
| 766–777 | 242, 597, 274, 565, 402, 437, 383, 456, 357, 482, 329, 510 |
| 778–789 | 317, 522, 307, 532, 286, 553, 287, 552, 266, 573, 261, 578 |
| 790–795 | 236, 603, 303, 536, 356, 483 |
| 796–803 | 355, 484, 405, 434, 404, 435, 406, 433 |
| 804–809 | 235, 604, 267, 572, 302, 537 |
| 810–815 | 309, 530, 265, 574, 233, 606 |
| 816–819 | 367, 472, 296, 543 |
| 820–837 | 336, 503, 305, 534, 373, 466, 280, 559, 279, 560, 419, 420, 240, 599, 258, 581, 229, 610 |

**Table 5.7.2-5: Root Zadoff-Chu sequence order for preamble format 4**

| Logical root sequence number | Physical root sequence number $u$ (in increasing order of the corresponding logical sequence number) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 – 19 | 1 | 138 | 2 | 137 | 3 | 136 | 4 | 135 | 5 | 134 | 6 | 133 | 7 | 132 | 8 | 131 | 9 | 130 | 10 | 129 |
| 20 – 39 | 11 | 128 | 12 | 127 | 13 | 126 | 14 | 125 | 15 | 124 | 16 | 123 | 17 | 122 | 18 | 121 | 19 | 120 | 20 | 119 |
| 40 – 59 | 21 | 118 | 22 | 117 | 23 | 116 | 24 | 115 | 25 | 114 | 26 | 113 | 27 | 112 | 28 | 111 | 29 | 110 | 30 | 109 |
| 60 – 79 | 31 | 108 | 32 | 107 | 33 | 106 | 34 | 105 | 35 | 104 | 36 | 103 | 37 | 102 | 38 | 101 | 39 | 100 | 40 | 99 |
| 80 – 99 | 41 | 98 | 42 | 97 | 43 | 96 | 44 | 95 | 45 | 94 | 46 | 93 | 47 | 92 | 48 | 91 | 49 | 90 | 50 | 89 |
| 100 – 119 | 51 | 88 | 52 | 87 | 53 | 86 | 54 | 85 | 55 | 84 | 56 | 83 | 57 | 82 | 58 | 81 | 59 | 80 | 60 | 79 |
| 120 – 137 | 61 | 78 | 62 | 77 | 63 | 76 | 64 | 75 | 65 | 74 | 66 | 73 | 67 | 72 | 68 | 71 | 69 | 70 | - | - |
| 138 – 837 | N/A | | | | | | | | | | | | | | | | | | | |

## 5.7.3 Baseband signal generation

The time-continuous random access signal $s(t)$ is defined by

$$s(t) = \beta_{\text{PRACH}} \sum_{k=0}^{N_{ZC}-1} \sum_{n=0}^{N_{ZC}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{ZC}}} \cdot e^{j2\pi\left(k+\varphi+K\left(k_0+\frac{1}{2}\right)\right)\Delta f_{\text{RA}}\left(t-T_{\text{CP}}\right)}$$

where $0 \le t < T_{\text{SEQ}} + T_{\text{CP}}$, $\beta_{\text{PRACH}}$ is an amplitude scaling factor in order to conform to the transmit power $P_{\text{PRACH}}$ specified in clause 6.1 in 3GPP TS 36.213 [4], and $k_0 = n_{\text{PRB}}^{\text{RA}} N_{\text{sc}}^{\text{RB}} - N_{\text{RB}}^{\text{UL}} N_{\text{sc}}^{\text{RB}} / 2$. The location in the frequency domain is controlled by the parameter $n_{\text{PRB}}^{\text{RA}}$ is derived from clause 5.7.1. The factor $K = \Delta f / \Delta f_{\text{RA}}$ accounts for the difference in subcarrier spacing between the random access preamble and uplink data transmission. The variable $\Delta f_{\text{RA}}$, the subcarrier spacing for the random access preamble, and the variable $\varphi$, a fixed offset determining the frequency-domain location of the random access preamble within the physical resource blocks, are both given by Table 5.7.3-1.

**Table 5.7.3-1: Random access baseband parameters**

| Preamble format | $\Delta f_{\text{RA}}$ | $\varphi$ |
|---|---|---|
| 0 – 3 | 1250 Hz | 7 |
| 4 | 7500 Hz | 2 |

## 5.8 Modulation and upconversion

Modulation and upconversion to the carrier frequency of the complex-valued SC-FDMA baseband signal for each antenna port or the complex-valued PRACH baseband signal is shown in Figure 5.8-1. The filtering required prior to transmission is defined by the requirements in 3GPP TS 36.101 [7].

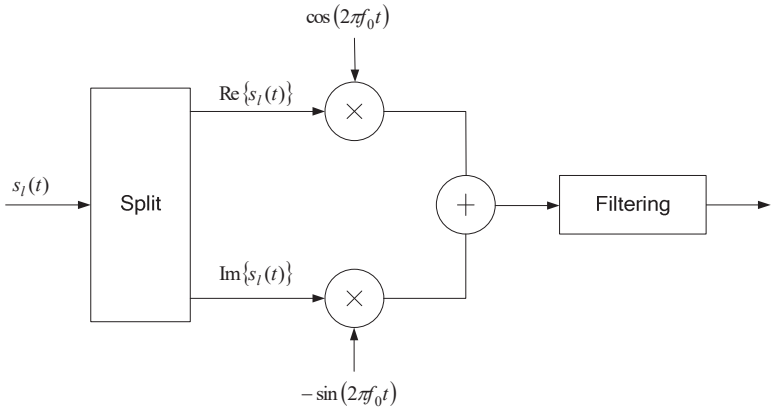



**Figure 5.8-1: Uplink modulation**

# 6 Downlink

## 6.1 Overview

The smallest time-frequency unit for downlink transmission is denoted a resource element and is defined in clause 6.2.2.

A subset of the downlink subframes in a radio frame on a carrier supporting PDSCH transmission can be configured as MBSFN subframes by higher layers. Each MBSFN subframe is divided into a non-MBSFN region and an MBSFN region.

- The non-MBSFN region spans the first one or two OFDM symbols in an MBSFN subframe where the length of the non-MBSFN region is given according to Subclause 6.7.
- The MBSFN region in an MBSFN subframe is defined as the OFDM symbols not used for the non-MBSFN region.

Unless otherwise specified, transmission in each downlink subframe shall use the same cyclic prefix length as used for downlink subframe #0.

### 6.1.1 Physical channels

A downlink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 3GPP TS 36.212 [3] and the present document 3GPP TS 36.211.
The following downlink physical channels are defined:

- Physical Downlink Shared Channel, PDSCH
- Physical Broadcast Channel, PBCH
- Physical Multicast Channel, PMCH
- Physical Control Format Indicator Channel, PCFICH
- Physical Downlink Control Channel, PDCCH
- Physical Hybrid ARQ Indicator Channel, PHICH
- Enhanced Physical Downlink Control Channel, EPDCCH

### 6.1.2 Physical signals

A downlink physical signal corresponds to a set of resource elements used by the physical layer but does not carry information originating from higher layers. The following downlink physical signals are defined:

- Reference signal
- Synchronization signal

# 6.2 Slot structure and physical resource elements

## 6.2.1 Resource grid

The transmitted signal in each slot is described by one or several resource grids of $N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}$ subcarriers and $N_{\mathrm{symb}}^{\mathrm{DL}}$ OFDM symbols. The resource grid structure is illustrated in Figure 6.2.2-1. The quantity $N_{\mathrm{RB}}^{\mathrm{DL}}$ depends on the downlink transmission bandwidth configured in the cell and shall fulfil

$$N_{\mathrm{RB}}^{\mathrm{min,DL}} \le N_{\mathrm{RB}}^{\mathrm{DL}} \le N_{\mathrm{RB}}^{\mathrm{max,DL}}$$

where $N_{\mathrm{RB}}^{\mathrm{min,DL}} = 6$ and $N_{\mathrm{RB}}^{\mathrm{max,DL}} = 110$ are the smallest and largest downlink bandwidths, respectively, supported by the current version of this specification.

The set of allowed values for $N_{\mathrm{RB}}^{\mathrm{DL}}$ is given by 3GPP TS 36.104 [6]. The number of OFDM symbols in a slot depends on the cyclic prefix length and subcarrier spacing configured and is given in Table 6.2.3-1.

An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. There is one resource grid per antenna port. The set of antenna ports supported depends on the reference signal configuration in the cell:

- Cell-specific reference signals support a configuration of one, two, or four antenna ports and are transmitted on antenna ports $p = 0$, $p \in \{0,1\}$, and $p \in \{0,1,2,3\}$, respectively.
- MBSFN reference signals are transmitted on antenna port $p = 4$.
- UE-specific reference signals associated with PDSCH are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$, or one or several of $p \in \{7,8,9,10,11,12,13,14\}$.
- Demodulation reference signals associated with EPDCCH are transmitted on one or several of $p \in \{107,108,109,110\}$.
- Positioning reference signals are transmitted on antenna port $p = 6$.
- CSI reference signals support a configuration of one, two, four or eight antenna ports and are transmitted on antenna ports $p = 15$, $p = 15,16$, $p = 15,...,18$ and $p = 15,...,22$, respectively.

Two antenna ports are said to be quasi co-located if the large-scale properties of the channel over which a symbol on one antenna port is conveyed can be inferred from the channel over which a symbol on the other antenna port is conveyed. The large-scale properties include one or more of delay spread, Doppler spread, Doppler shift, average gain, and average delay.

## 6.2.2 Resource elements

Each element in the resource grid for antenna port $p$ is called a resource element and is uniquely identified by the index pair $(k,l)$ in a slot where $k = 0,...,N_{RB}^{DL}N_{sc}^{RB} - 1$ and $l = 0,...,N_{symb}^{DL} - 1$ are the indices in the frequency and time domains, respectively. Resource element $(k,l)$ on antenna port $p$ corresponds to the complex value $a_{k,l}^{(p)}$.
When there is no risk for confusion, or no particular antenna port is specified, the index $p$ may be dropped.

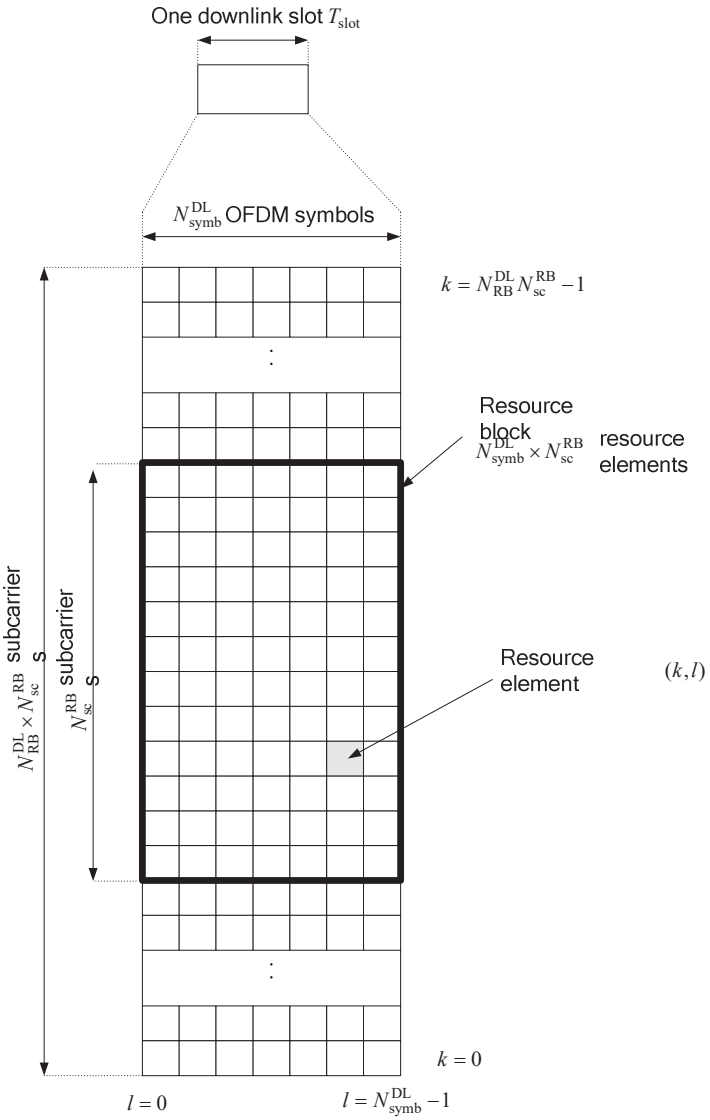



**Figure 6.2.2-1: Downlink resource grid**

## 6.2.3 Resource blocks

Resource blocks are used to describe the mapping of certain physical channels to resource elements. Physical and virtual resource blocks are defined.

A physical resource block is defined as $N_{\text{symb}}^{\text{DL}}$ consecutive OFDM symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{DL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 6.2.3-1. A physical resource block thus consists of $N_{\text{symb}}^{\text{DL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Physical resource blocks are numbered from 0 to $N_{\text{RB}}^{\text{DL}} - 1$ in the frequency domain. The relation between the physical resource block number $n_{\text{PRB}}$ in the frequency domain and resource elements $(k, l)$ in a slot is given by

$$n_{\text{PRB}} = \left\lfloor \frac{k}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$$

**Table 6.2.3-1: Physical resource blocks parameters**

| Configuration | | $N_{\text{sc}}^{\text{RB}}$ | $N_{\text{symb}}^{\text{DL}}$ |
|---|---|---|---|
| Normal cyclic prefix | $\Delta f = 15$ kHz | 12 | 7 |
| Extended cyclic prefix | $\Delta f = 15$ kHz | | 6 |
| | $\Delta f = 7.5$ kHz | 24 | 3 |

A physical resource-block pair is defined as the two physical resource blocks in one subframe having the same physical resource-block number $n_{\text{PRB}}$.

A virtual resource block is of the same size as a physical resource block. Two types of virtual resource blocks are defined:

- Virtual resource blocks of localized type
- Virtual resource blocks of distributed type

For each type of virtual resource blocks, a pair of virtual resource blocks over two slots in a subframe is assigned together by a single virtual resource block number, $n_{\text{VRB}}$.

### 6.2.3.1 Virtual resource blocks of localized type

Virtual resource blocks of localized type are mapped directly to physical resource blocks such that virtual resource block $n_{\text{VRB}}$ corresponds to physical resource block $n_{\text{PRB}} = n_{\text{VRB}}$. Virtual resource blocks are numbered from 0 to $N_{\text{VRB}}^{\text{DL}} - 1$, where $N_{\text{VRB}}^{\text{DL}} = N_{\text{RB}}^{\text{DL}}$.

### 6.2.3.2 Virtual resource blocks of distributed type

Virtual resource blocks of distributed type are mapped to physical resource blocks as described below.

**Table 6.2.3.2-1: RB gap values**

| System BW ( $N_{RB}^{DL}$ ) | Gap ( $N_{gap}$ ) | |
|---|---|---|
| | 1st Gap ( $N_{gap,1}$ ) | 2nd Gap ( $N_{gap,2}$ ) |
| 6-10 | $\lceil N_{RB}^{DL}/2 \rceil$ | N/A |
| 11 | 4 | N/A |
| 12-19 | 8 | N/A |
| 20-26 | 12 | N/A |
| 27-44 | 18 | N/A |
| 45-49 | 27 | N/A |
| 50-63 | 27 | 9 |
| 64-79 | 32 | 16 |
| 80-110 | 48 | 16 |

The parameter $N_{gap}$ is given by Table 6.2.3.2-1. For $6 \le N_{RB}^{DL} \le 49$, only one gap value $N_{gap,1}$ is defined and $N_{gap} = N_{gap,1}$. For $50 \le N_{RB}^{DL} \le 110$, two gap values $N_{gap,1}$ and $N_{gap,2}$ are defined. Whether $N_{gap} = N_{gap,1}$ or $N_{gap} = N_{gap,2}$ is signaled as part of the downlink scheduling assignment as described in 3GPP TS 36.212 [3].

Virtual resource blocks of distributed type are numbered from 0 to $N_{VRB}^{DL} - 1$, where $N_{VRB}^{DL} = N_{VRB,gap1}^{DL} = 2 \cdot \min(N_{gap}, N_{RB}^{DL} - N_{gap})$ for $N_{gap} = N_{gap,1}$ and $N_{VRB}^{DL} = N_{VRB,gap2}^{DL} = \lfloor N_{RB}^{DL}/2N_{gap} \rfloor \cdot 2N_{gap}$ for $N_{gap} = N_{gap,2}$.

Consecutive $\tilde{N}_{VRB}^{DL}$ VRB numbers compose a unit of VRB number interleaving, where $\tilde{N}_{VRB}^{DL} = N_{VRB}^{DL}$ for $N_{gap} = N_{gap,1}$ and $\tilde{N}_{VRB}^{DL} = 2N_{gap}$ for $N_{gap} = N_{gap,2}$. Interleaving of VRB numbers of each interleaving unit is performed with 4 columns and $N_{row}$ rows, where $N_{row} = \lceil \tilde{N}_{VRB}^{DL}/(4P) \rceil \cdot P$, and $P$ is RBG size as described in 3GPP TS 36.213 [4]. VRB numbers are written row by row in the rectangular matrix, and read out column by column. $N_{null}$ nulls are inserted in the last $N_{null}/2$ rows of the 2nd and 4th column, where $N_{null} = 4N_{row} - \tilde{N}_{VRB}^{DL}$. Nulls are ignored when reading out. The VRB numbers mapping to PRB numbers including interleaving is derived as follows:

For even slot number $n_s$;

$$\tilde{n}_{PRB}(n_s) = \begin{cases} \tilde{n}'_{PRB} - N_{row} & , N_{null} \neq 0 \quad \text{and} \quad \tilde{n}_{VRB} \ge \tilde{N}_{VRB}^{DL} - N_{null} \quad \text{and} \quad \tilde{n}_{VRB} \bmod 2 = 1 \\ \tilde{n}'_{PRB} - N_{row} + N_{null}/2 & , N_{null} \neq 0 \quad \text{and} \quad \tilde{n}_{VRB} \ge \tilde{N}_{VRB}^{DL} - N_{null} \quad \text{and} \quad \tilde{n}_{VRB} \bmod 2 = 0 \\ \tilde{n}''_{PRB} - N_{null}/2 & , N_{null} \neq 0 \quad \text{and} \quad \tilde{n}_{VRB} < \tilde{N}_{VRB}^{DL} - N_{null} \quad \text{and} \quad \tilde{n}_{VRB} \bmod 4 \ge 2 \\ \tilde{n}''_{PRB} & , \text{otherwise} \end{cases},$$

where $\tilde{n}'_{PRB} = 2N_{row} \cdot (\tilde{n}_{VRB} \bmod 2) + \lfloor \tilde{n}_{VRB}/2 \rfloor + \tilde{N}_{VRB}^{DL} \cdot \lfloor n_{VRB}/\tilde{N}_{VRB}^{DL} \rfloor$,

and $\tilde{n}''_{PRB} = N_{row} \cdot (\tilde{n}_{VRB} \bmod 4) + \lfloor \tilde{n}_{VRB}/4 \rfloor + \tilde{N}_{VRB}^{DL} \cdot \lfloor n_{VRB}/\tilde{N}_{VRB}^{DL} \rfloor$,

where $\tilde{n}_{VRB} = n_{VRB} \bmod \tilde{N}_{VRB}^{DL}$ and $n_{VRB}$ is obtained from the downlink scheduling assignment as described in 3GPP TS 36.213 [4].

For odd slot number $n_s$;

$$\tilde{n}_{PRB}(n_s) = \left(\tilde{n}_{PRB}(n_s - 1) + \tilde{N}_{VRB}^{DL}/2\right) \bmod \tilde{N}_{VRB}^{DL} + \tilde{N}_{VRB}^{DL} \cdot \lfloor n_{VRB}/\tilde{N}_{VRB}^{DL} \rfloor$$

Then, for all $n_s$;

$$n_{PRB}(n_s) = \begin{cases} \tilde{n}_{PRB}(n_s), & \tilde{n}_{PRB}(n_s) < \tilde{N}_{VRB}^{DL}/2 \\ \tilde{n}_{PRB}(n_s) + N_{gap} - \tilde{N}_{VRB}^{DL}/2, & \tilde{n}_{PRB}(n_s) \ge \tilde{N}_{VRB}^{DL}/2 \end{cases}.$$

## 6.2.4 Resource-element groups

Resource-element groups are used for defining the mapping of control channels to resource elements.

A resource-element group is represented by the index pair $(k',l')$ of the resource element with the lowest index $k$ in the group with all resource elements in the group having the same value of $l$. The set of resource elements $(k,l)$ in a resource-element group depends on the number of cell-specific reference signals configured as described below with $k_0 = n_{\text{PRB}} \cdot N_{\text{sc}}^{\text{RB}}$, $0 \le n_{\text{PRB}} < N_{\text{RB}}^{\text{DL}}$.

- In the first OFDM symbol of the first slot in a subframe the two resource-element groups in physical resource block $n_{\text{PRB}}$ consist of resource elements $(k,l=0)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 5$ and $k = k_0 + 6, k_0 + 7, ..., k_0 + 11$, respectively.

- In the second OFDM symbol of the first slot in a subframe in case of one or two cell-specific reference signals configured, the three resource-element groups in physical resource block $n_{\text{PRB}}$ consist of resource elements $(k,l=1)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 3$, $k = k_0 + 4, k_0 + 5, ..., k_0 + 7$ and $k = k_0 + 8, k_0 + 9, ..., k_0 + 11$, respectively.

- In the second OFDM symbol of the first slot in a subframe in case of four cell-specific reference signals configured, the two resource-element groups in physical resource block $n_{\text{PRB}}$ consist of resource elements $(k,l=1)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 5$ and $k = k_0 + 6, k_0 + 7, ..., k_0 + 11$, respectively.

- In the third OFDM symbol of the first slot in a subframe, the three resource-element groups in physical resource block $n_{\text{PRB}}$ consist of resource elements $(k,l=2)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 3$, $k = k_0 + 4, k_0 + 5, ..., k_0 + 7$ and $k = k_0 + 8, k_0 + 9, ..., k_0 + 11$, respectively.

- In the fourth OFDM symbol of the first slot in a subframe in case of normal cyclic prefix, the three resource-element groups in physical resource block $n_{\text{PRB}}$ consist of resource elements $(k,l=3)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 3$, $k = k_0 + 4, k_0 + 5, ..., k_0 + 7$ and $k = k_0 + 8, k_0 + 9, ..., k_0 + 11$, respectively.

- In the fourth OFDM symbol of the first slot in a subframe in case of extended cyclic prefix, the two resource-element groups in physical resource block $n_{\text{PRB}}$ consist of resource elements $(k,l=3)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 5$ and $k = k_0 + 6, k_0 + 7, ..., k_0 + 11$, respectively.

Mapping of a symbol-quadruplet $\langle z(i), z(i+1), z(i+2), z(i+3) \rangle$ onto a resource-element group represented by resource-element $(k',l')$ is defined such that elements $z(i)$ are mapped to resource elements $(k,l)$ of the resource-element group not used for cell-specific reference signals in increasing order of $i$ and $k$. In case a single cell-specific reference signal is configured, cell-specific reference signals shall be assumed to be present on antenna ports 0 and 1 for the purpose of mapping a symbol-quadruplet to a resource-element group, otherwise the number of cell-specific reference signals shall be assumed equal to the actual number of antenna ports used for cell-specific reference signals. The UE shall not make any assumptions about resource elements assumed to be reserved for reference signals but not used for transmission of a reference signal.

### 6.2.4A Enhanced Resource-Element Groups (EREGs)

EREGs are used for defining the mapping of enhanced control channels to resource elements.

There are 16 EREGs, numbered from 0 to 15, per physical resource block pair. Number all resource elements, except resource elements carrying DM-RS for antenna ports $p = \{107,108,109,110\}$ for normal cyclic prefix or $p = \{107,108\}$ for extended cyclic prefix, in a physical resource-block pair cyclically from 0 to 15 in an increasing order of first frequency, then time. All resource elements with number $i$ in that physical resource-block pair constitutes EREG number $i$.

### 6.2.5 Guard period for half-duplex FDD operation

For half-duplex FDD operation, a guard period is created by the UE by not receiving the last part of a downlink subframe immediately preceding an uplink subframe from the same UE.

### 6.2.6 Guard Period for TDD Operation

For frame structure type 2, the GP field in Figure 4.2-1 serves as a guard period.

# 6.3 General structure for downlink physical channels

This clause describes a general structure, applicable to more than one physical channel.

The baseband signal representing a downlink physical channel is defined in terms of the following steps:

- scrambling of coded bits in each of the codewords to be transmitted on a physical channel
- modulation of scrambled bits to generate complex-valued modulation symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports
- mapping of complex-valued modulation symbols for each antenna port to resource elements
- generation of complex-valued time-domain OFDM signal for each antenna port

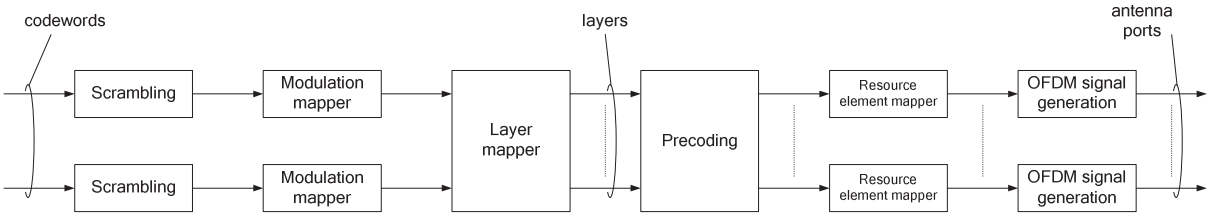



**Figure 6.3-1: Overview of physical channel processing**

## 6.3.1 Scrambling

For each codeword $q$, the block of bits $b^{(q)}(0),...,b^{(q)}(M_{\text{bit}}^{(q)}-1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits in codeword $q$ transmitted on the physical channel in one subframe, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$ according to

$$\tilde{b}^{(q)}(i) = \left(b^{(q)}(i) + c^{(q)}(i)\right) \bmod 2$$

where the scrambling sequence $c^{(q)}(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised at the start of each subframe, where the initialisation value of $c_{\text{init}}$ depends on the transport channel type according to

$$c_{\text{init}} = \begin{cases} n_{\text{RNTI}} \cdot 2^{14} + q \cdot 2^{13} + \lfloor n_s/2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{cell}} & \text{for PDSCH} \\ \lfloor n_s/2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{MBSFN}} & \text{for PMCH} \end{cases}$$

where $n_{\text{RNTI}}$ corresponds to the RNTI associated with the PDSCH transmission as described in clause 7.1 3GPP TS 36.213 [4].

Up to two codewords can be transmitted in one subframe, i.e., $q \in \{0,1\}$. In the case of single codeword transmission, $q$ is equal to zero.

## 6.3.2 Modulation

For each codeword $q$, the block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$ shall be modulated as described in clause 7.1 using one of the modulation schemes in Table 6.3.2-1, resulting in a block of complex-valued modulation symbols $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(q)}-1)$.

**Table 6.3.2-1: Modulation schemes**

| Physical channel | Modulation schemes |
|---|---|
| PDSCH | QPSK, 16QAM, 64QAM |
| PMCH | QPSK, 16QAM, 64QAM |

## 6.3.3 Layer mapping

The complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or several layers. Complex-valued modulation symbols $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(\text{q})}-1)$ for codeword $q$ shall be mapped onto the layers $x(i)=\left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$, $i=0,1,...,M_{\text{symb}}^{\text{layer}}-1$ where $\upsilon$ is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.

### 6.3.3.1 Layer mapping for transmission on a single antenna port

For transmission on a single antenna port, a single layer is used, $\upsilon=1$, and the mapping is defined by

$$x^{(0)}(i)=d^{(0)}(i)$$

with $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}$.

### 6.3.3.2 Layer mapping for spatial multiplexing

For spatial multiplexing, the layer mapping shall be done according to Table 6.3.3.2-1. The number of layers $\upsilon$ is less than or equal to the number of antenna ports $P$ used for transmission of the physical channel. The case of a single codeword mapped to multiple layers is only applicable when the number of cell-specific reference signals is four or when the number of UE-specific reference signals is two or larger.

**Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing**

| Number of layers | Number of codewords | Codeword-to-layer mapping $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}} - 1$ | |
|---|---|---|---|
| 1 | 1 | $x^{(0)}(i) = d^{(0)}(i)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$ |
| 2 | 1 | $x^{(0)}(i) = d^{(0)}(2i)$<br>$x^{(1)}(i) = d^{(0)}(2i+1)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2$ |
| 2 | 2 | $x^{(0)}(i) = d^{(0)}(i)$<br>$x^{(1)}(i) = d^{(1)}(i)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$ |
| 3 | 1 | $x^{(0)}(i) = d^{(0)}(3i)$<br>$x^{(1)}(i) = d^{(0)}(3i+1)$<br>$x^{(2)}(i) = d^{(0)}(3i+2)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3$ |
| 3 | 2 | $x^{(0)}(i) = d^{(0)}(i)$<br>$x^{(1)}(i) = d^{(1)}(2i)$<br>$x^{(2)}(i) = d^{(1)}(2i+1)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}/2$ |
| 4 | 1 | $x^{(0)}(i) = d^{(0)}(4i)$<br>$x^{(1)}(i) = d^{(0)}(4i+1)$<br>$x^{(2)}(i) = d^{(0)}(4i+2)$<br>$x^{(3)}(i) = d^{(0)}(4i+3)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/4$ |
| 4 | 2 | $x^{(0)}(i) = d^{(0)}(2i)$<br>$x^{(1)}(i) = d^{(0)}(2i+1)$<br>$x^{(2)}(i) = d^{(1)}(2i)$<br>$x^{(3)}(i) = d^{(1)}(2i+1)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2 = M_{\text{symb}}^{(1)}/2$ |
| 5 | 2 | $x^{(0)}(i) = d^{(0)}(2i)$<br>$x^{(1)}(i) = d^{(0)}(2i+1)$<br>$x^{(2)}(i) = d^{(1)}(3i)$<br>$x^{(3)}(i) = d^{(1)}(3i+1)$<br>$x^{(4)}(i) = d^{(1)}(3i+2)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2 = M_{\text{symb}}^{(1)}/3$ |
| 6 | 2 | $x^{(0)}(i) = d^{(0)}(3i)$<br>$x^{(1)}(i) = d^{(0)}(3i+1)$<br>$x^{(2)}(i) = d^{(0)}(3i+2)$<br>$x^{(3)}(i) = d^{(1)}(3i)$<br>$x^{(4)}(i) = d^{(1)}(3i+1)$<br>$x^{(5)}(i) = d^{(1)}(3i+2)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3 = M_{\text{symb}}^{(1)}/3$ |
| 7 | 2 | $x^{(0)}(i) = d^{(0)}(3i)$<br>$x^{(1)}(i) = d^{(0)}(3i+1)$<br>$x^{(2)}(i) = d^{(0)}(3i+2)$<br>$x^{(3)}(i) = d^{(1)}(4i)$<br>$x^{(4)}(i) = d^{(1)}(4i+1)$<br>$x^{(5)}(i) = d^{(1)}(4i+2)$<br>$x^{(6)}(i) = d^{(1)}(4i+3)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3 = M_{\text{symb}}^{(1)}/4$ |

| | | | |
|---|---|---|---|
| 8 | 2 | $x^{(0)}(i) = d^{(0)}(4i)$<br>$x^{(1)}(i) = d^{(0)}(4i+1)$<br>$x^{(2)}(i) = d^{(0)}(4i+2)$<br>$x^{(3)}(i) = d^{(0)}(4i+3)$<br>$x^{(4)}(i) = d^{(1)}(4i)$<br>$x^{(5)}(i) = d^{(1)}(4i+1)$<br>$x^{(6)}(i) = d^{(1)}(4i+2)$<br>$x^{(7)}(i) = d^{(1)}(4i+3)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 4 = M_{\text{symb}}^{(1)} / 4$ |

### 6.3.3.3 Layer mapping for transmit diversity

For transmit diversity, the layer mapping shall be done according to Table 6.3.3.3-1. There is only one codeword and the number of layers $\upsilon$ is equal to the number of antenna ports $P$ used for transmission of the physical channel.

**Table 6.3.3.3-1: Codeword-to-layer mapping for transmit diversity**

| Number of layers | Number of codewords | Codeword-to-layer mapping $i = 0,1,...,M_{\text{symb}}^{\text{layer}} - 1$ | |
|---|---|---|---|
| 2 | 1 | $x^{(0)}(i) = d^{(0)}(2i)$<br>$x^{(1)}(i) = d^{(0)}(2i+1)$ | $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$ |
| 4 | 1 | $x^{(0)}(i) = d^{(0)}(4i)$<br>$x^{(1)}(i) = d^{(0)}(4i+1)$<br>$x^{(2)}(i) = d^{(0)}(4i+2)$<br>$x^{(3)}(i) = d^{(0)}(4i+3)$ | $M_{\text{symb}}^{\text{layer}} = \begin{cases} M_{\text{symb}}^{(0)} / 4 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 = 0 \\ (M_{\text{symb}}^{(0)} + 2) / 4 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 \neq 0 \end{cases}$<br>If $M_{\text{symb}}^{(0)} \bmod 4 \neq 0$ two null symbols shall be appended to $d^{(0)}(M_{\text{symb}}^{(0)} - 1)$ |

## 6.3.4 Precoding

The precoder takes as input a block of vectors $x(i) = \left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{layer}} - 1$ from the layer mapping and generates a block of vectors $y(i) = \left[... \quad y^{(p)}(i) \quad ...\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$ to be mapped onto resources on each of the antenna ports, where $y^{(p)}(i)$ represents the signal for antenna port $p$.

### 6.3.4.1 Precoding for transmission on a single antenna port

For transmission on a single antenna port, precoding is defined by

$$y^{(p)}(i) = x^{(0)}(i)$$

where $p \in \{0,4,5,7,8\}$ is the number of the single antenna port used for transmission of the physical channel and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

### 6.3.4.2 Precoding for spatial multiplexing using antenna ports with cell-specific reference signals

Precoding for spatial multiplexing using antenna ports with cell-specific reference signals is only used in combination with layer mapping for spatial multiplexing as described in clause 6.3.3.2. Spatial multiplexing supports two or four antenna ports and the set of antenna ports used is $p \in \{0,1\}$ or $p \in \{0,1,2,3\}$, respectively.

#### 6.3.4.2.1 Precoding without CDD

Without Cyclic Delay Diversity (CDD), precoding for spatial multiplexing is defined by

$$\begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(P-1)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where the precoding matrix $W(i)$ is of size $P \times \upsilon$ and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

For spatial multiplexing, the values of $W(i)$ shall be selected among the precoder elements in the codebook configured in the eNodeB and the UE. The eNodeB can further confine the precoder selection in the UE to a subset of the elements in the codebook using codebook subset restrictions. The configured codebook shall be selected from Table 6.3.4.2.3-1 or 6.3.4.2.3-2.

#### 6.3.4.2.2 Precoding for large delay CDD

For large-delay CDD, precoding for spatial multiplexing is defined by

$$\begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(P-1)}(i) \end{bmatrix} = W(i)D(i)U \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where the precoding matrix $W(i)$ is of size $P \times \upsilon$ and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$. The diagonal size-$\upsilon \times \upsilon$ matrix $D(i)$ supporting cyclic delay diversity and the size-$\upsilon \times \upsilon$ matrix $U$ are both given by Table 6.3.4.2.2-1 for different numbers of layers $\upsilon$.

The values of the precoding matrix $W(i)$ shall be selected among the precoder elements in the codebook configured in the eNodeB and the UE. The eNodeB can further confine the precoder selection in the UE to a subset of the elements in the codebook using codebook subset restriction. The configured codebook shall be selected from Table 6.3.4.2.3-1 or 6.3.4.2.3-2.

For 2 antenna ports, the precoder is selected according to $W(i) = C_1$ where $C_1$ denotes the precoding matrix corresponding to precoder index 0 in Table 6.3.4.2.3-1.

For 4 antenna ports, the UE may assume that the eNodeB cyclically assigns different precoders to different vectors $\left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$ on the physical downlink shared channel as follows. A different precoder is used every $\upsilon$ vectors, where $\upsilon$ denotes the number of transmission layers in the case of spatial multiplexing. In particular, the precoder is selected according to $W(i) = C_k$, where $k$ is the precoder index given by $k = \left(\left\lfloor \frac{i}{\upsilon} \right\rfloor \bmod 4\right) + 1 \in \{1,2,3,4\}$ and $C_1, C_2, C_3, C_4$ denote precoder matrices corresponding to precoder indices 12,13,14 and 15, respectively, in Table 6.3.4.2.3-2.

**Table 6.3.4.2.2-1: Large-delay cyclic delay diversity**

| Number of layers $\upsilon$ | $U$ | $D(i)$ |
|---|---|---|
| 2 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & e^{-j2\pi/2}\end{bmatrix}$ | $\begin{bmatrix}1 & 0\\ 0 & e^{-j2\pi i/2}\end{bmatrix}$ |
| 3 | $\frac{1}{\sqrt{3}}\begin{bmatrix}1 & 1 & 1\\ 1 & e^{-j2\pi/3} & e^{-j4\pi/3}\\ 1 & e^{-j4\pi/3} & e^{-j8\pi/3}\end{bmatrix}$ | $\begin{bmatrix}1 & 0 & 0\\ 0 & e^{-j2\pi i/3} & 0\\ 0 & 0 & e^{-j4\pi i/3}\end{bmatrix}$ |
| 4 | $\frac{1}{2}\begin{bmatrix}1 & 1 & 1 & 1\\ 1 & e^{-j2\pi/4} & e^{-j4\pi/4} & e^{-j6\pi/4}\\ 1 & e^{-j4\pi/4} & e^{-j8\pi/4} & e^{-j12\pi/4}\\ 1 & e^{-j6\pi/4} & e^{-j12\pi/4} & e^{-j18\pi/4}\end{bmatrix}$ | $\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & e^{-j2\pi i/4} & 0 & 0\\ 0 & 0 & e^{-j4\pi i/4} & 0\\ 0 & 0 & 0 & e^{-j6\pi i/4}\end{bmatrix}$ |

### 6.3.4.2.3 Codebook for precoding and CSI reporting

For transmission on two antenna ports, $p \in \{0,1\}$, and for the purpose of CSI reporting based on two antenna ports $p \in \{0,1\}$ or $p \in \{15,16\}$, the precoding matrix $W(i)$ shall be selected from Table 6.3.4.2.3-1 or a subset thereof. For the closed-loop spatial multiplexing transmission mode defined in 3GPP TS 36.213 [4], the codebook index 0 is not used when the number of layers is $\upsilon = 2$.

**Table 6.3.4.2.3-1: Codebook for transmission on antenna ports $\{0,1\}$ and for CSI reporting based on antenna ports $\{0,1\}$ or $\{15,16\}$**

| Codebook index | Number of layers $\upsilon$ | |
|---|---|---|
| | 1 | 2 |
| 0 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ 1\end{bmatrix}$ | $\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$ |
| 1 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ -1\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$ |
| 2 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ j\end{bmatrix}$ | $\frac{1}{2}\begin{bmatrix}1 & 1\\ j & -j\end{bmatrix}$ |
| 3 | $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ -j\end{bmatrix}$ | - |

For transmission on four antenna ports, $p \in \{0,1,2,3\}$, and for the purpose of CSI reporting based on four antenna ports $p \in \{0,1,2,3\}$ or $p \in \{15,16,17,18\}$, the precoding matrix $W$ shall be selected from Table 6.3.4.2.3-2 or a subset thereof. The quantity $W_n^{\{s\}}$ denotes the matrix defined by the columns given by the set $\{s\}$ from the expression $W_n = I - 2u_n u_n^H / u_n^H u_n$ where $I$ is the $4 \times 4$ identity matrix and the vector $u_n$ is given by Table 6.3.4.2.3-2.

**Table 6.3.4.2.3-2: Codebook for transmission on antenna ports $\{0,1,2,3\}$ and for CSI reporting based on antenna ports $\{0,1,2,3\}$ or $\{15,16,17,18\}$**

| Codebook index | $u_n$ | Number of layers $\upsilon$ | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 0 | $u_0 = \begin{bmatrix} 1 & -1 & -1 & -1 \end{bmatrix}^T$ | $W_0^{\{1\}}$ | $W_0^{\{14\}}/\sqrt{2}$ | $W_0^{\{124\}}/\sqrt{3}$ | $W_0^{\{1234\}}/2$ |
| 1 | $u_1 = \begin{bmatrix} 1 & -j & 1 & j \end{bmatrix}^T$ | $W_1^{\{1\}}$ | $W_1^{\{12\}}/\sqrt{2}$ | $W_1^{\{123\}}/\sqrt{3}$ | $W_1^{\{1234\}}/2$ |
| 2 | $u_2 = \begin{bmatrix} 1 & 1 & -1 & 1 \end{bmatrix}^T$ | $W_2^{\{1\}}$ | $W_2^{\{12\}}/\sqrt{2}$ | $W_2^{\{123\}}/\sqrt{3}$ | $W_2^{\{3214\}}/2$ |
| 3 | $u_3 = \begin{bmatrix} 1 & j & 1 & -j \end{bmatrix}^T$ | $W_3^{\{1\}}$ | $W_3^{\{12\}}/\sqrt{2}$ | $W_3^{\{123\}}/\sqrt{3}$ | $W_3^{\{3214\}}/2$ |
| 4 | $u_4 = \begin{bmatrix} 1 & (-1-j)/\sqrt{2} & -j & (1-j)/\sqrt{2} \end{bmatrix}^T$ | $W_4^{\{1\}}$ | $W_4^{\{14\}}/\sqrt{2}$ | $W_4^{\{124\}}/\sqrt{3}$ | $W_4^{\{1234\}}/2$ |
| 5 | $u_5 = \begin{bmatrix} 1 & (1-j)/\sqrt{2} & j & (-1-j)/\sqrt{2} \end{bmatrix}^T$ | $W_5^{\{1\}}$ | $W_5^{\{14\}}/\sqrt{2}$ | $W_5^{\{124\}}/\sqrt{3}$ | $W_5^{\{1234\}}/2$ |
| 6 | $u_6 = \begin{bmatrix} 1 & (1+j)/\sqrt{2} & -j & (-1+j)/\sqrt{2} \end{bmatrix}^T$ | $W_6^{\{1\}}$ | $W_6^{\{13\}}/\sqrt{2}$ | $W_6^{\{134\}}/\sqrt{3}$ | $W_6^{\{1324\}}/2$ |
| 7 | $u_7 = \begin{bmatrix} 1 & (-1+j)/\sqrt{2} & j & (1+j)/\sqrt{2} \end{bmatrix}^T$ | $W_7^{\{1\}}$ | $W_7^{\{13\}}/\sqrt{2}$ | $W_7^{\{134\}}/\sqrt{3}$ | $W_7^{\{1324\}}/2$ |
| 8 | $u_8 = \begin{bmatrix} 1 & -1 & 1 & 1 \end{bmatrix}^T$ | $W_8^{\{1\}}$ | $W_8^{\{12\}}/\sqrt{2}$ | $W_8^{\{124\}}/\sqrt{3}$ | $W_8^{\{1234\}}/2$ |
| 9 | $u_9 = \begin{bmatrix} 1 & -j & -1 & -j \end{bmatrix}^T$ | $W_9^{\{1\}}$ | $W_9^{\{14\}}/\sqrt{2}$ | $W_9^{\{134\}}/\sqrt{3}$ | $W_9^{\{1234\}}/2$ |
| 10 | $u_{10} = \begin{bmatrix} 1 & 1 & 1 & -1 \end{bmatrix}^T$ | $W_{10}^{\{1\}}$ | $W_{10}^{\{13\}}/\sqrt{2}$ | $W_{10}^{\{123\}}/\sqrt{3}$ | $W_{10}^{\{1324\}}/2$ |
| 11 | $u_{11} = \begin{bmatrix} 1 & j & -1 & j \end{bmatrix}^T$ | $W_{11}^{\{1\}}$ | $W_{11}^{\{13\}}/\sqrt{2}$ | $W_{11}^{\{134\}}/\sqrt{3}$ | $W_{11}^{\{1324\}}/2$ |
| 12 | $u_{12} = \begin{bmatrix} 1 & -1 & -1 & 1 \end{bmatrix}^T$ | $W_{12}^{\{1\}}$ | $W_{12}^{\{12\}}/\sqrt{2}$ | $W_{12}^{\{123\}}/\sqrt{3}$ | $W_{12}^{\{1234\}}/2$ |
| 13 | $u_{13} = \begin{bmatrix} 1 & -1 & 1 & -1 \end{bmatrix}^T$ | $W_{13}^{\{1\}}$ | $W_{13}^{\{13\}}/\sqrt{2}$ | $W_{13}^{\{123\}}/\sqrt{3}$ | $W_{13}^{\{1324\}}/2$ |
| 14 | $u_{14} = \begin{bmatrix} 1 & 1 & -1 & -1 \end{bmatrix}^T$ | $W_{14}^{\{1\}}$ | $W_{14}^{\{13\}}/\sqrt{2}$ | $W_{14}^{\{123\}}/\sqrt{3}$ | $W_{14}^{\{3214\}}/2$ |
| 15 | $u_{15} = \begin{bmatrix} 1 & 1 & 1 & 1 \end{bmatrix}^T$ | $W_{15}^{\{1\}}$ | $W_{15}^{\{12\}}/\sqrt{2}$ | $W_{15}^{\{123\}}/\sqrt{3}$ | $W_{15}^{\{1234\}}/2$ |

For the purpose of CSI reporting for eight CSI reference signals the codebooks are given in clause 7.2.4 of 3GPP TS 36.213 [4].

### 6.3.4.3 Precoding for transmit diversity

Precoding for transmit diversity is only used in combination with layer mapping for transmit diversity as described in clause 6.3.3.3. The precoding operation for transmit diversity is defined for two and four antenna ports.

For transmission on two antenna ports, $p \in \{0,1\}$, the output $y(i) = \begin{bmatrix} y^{(0)}(i) & y^{(1)}(i) \end{bmatrix}^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$ of the precoding operation is defined by

$$\begin{bmatrix} y^{(0)}(2i) \\ y^{(1)}(2i) \\ y^{(0)}(2i+1) \\ y^{(1)}(2i+1) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & j & 0 \\ 0 & -1 & 0 & j \\ 0 & 1 & 0 & j \\ 1 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \text{Re}\left(x^{(0)}(i)\right) \\ \text{Re}\left(x^{(1)}(i)\right) \\ \text{Im}\left(x^{(0)}(i)\right) \\ \text{Im}\left(x^{(1)}(i)\right) \end{bmatrix}$$

for $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}} - 1$ with $M_{\text{symb}}^{\text{ap}} = 2M_{\text{symb}}^{\text{layer}}$.

For transmission on four antenna ports, $p \in \{0,1,2,3\}$, the output $y(i) = \begin{bmatrix} y^{(0)}(i) & y^{(1)}(i) & y^{(2)}(i) & y^{(3)}(i) \end{bmatrix}^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$ of the precoding operation is defined by

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \mathrm{Re}\left(x^{(0)}(i)\right) \\ \mathrm{Re}\left(x^{(1)}(i)\right) \\ \mathrm{Re}\left(x^{(2)}(i)\right) \\ \mathrm{Re}\left(x^{(3)}(i)\right) \\ \mathrm{Im}\left(x^{(0)}(i)\right) \\ \mathrm{Im}\left(x^{(1)}(i)\right) \\ \mathrm{Im}\left(x^{(2)}(i)\right) \\ \mathrm{Im}\left(x^{(3)}(i)\right) \end{bmatrix}$$

for $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}} - 1$ with $M_{\text{symb}}^{\text{ap}} = \begin{cases} 4M_{\text{symb}}^{\text{layer}} & \text{if } M_{\text{symb}}^{(0)} \bmod 4 = 0 \\ \left(4M_{\text{symb}}^{\text{layer}}\right) - 2 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 \neq 0 \end{cases}$.

### 6.3.4.4 Precoding for spatial multiplexing using antenna ports with UE-specific reference signals

Precoding for spatial multiplexing using antenna ports with UE-specific reference signals is only used in combination with layer mapping for spatial multiplexing as described in clause 6.3.3.2. Spatial multiplexing using antenna ports with UE-specific reference signals supports up to eight antenna ports and the set of antenna ports used is $p = 7,8,\ldots,\upsilon + 6$.

For transmission on $\upsilon$ antenna ports, the precoding operation is defined by

$$\begin{bmatrix} y^{(7)}(i) \\ y^{(8)}(i) \\ \vdots \\ y^{(6+\upsilon)}(i) \end{bmatrix} = \begin{bmatrix} x^{(0)}(i) \\ x^{(1)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

### 6.3.5 Mapping to resource elements

For each of the antenna ports used for transmission of the physical channel, the block of complex-valued symbols $y^{(p)}(0),...,y^{(p)}(M^{\text{ap}}_{\text{symb}}-1)$ shall conform to the downlink power allocation specified in clause 5.2 in

3GPP TS 36.213 [4] and be mapped in sequence starting with $y^{(p)}(0)$ to resource elements $(k,l)$ which meet all of the following criteria in the current subframe:

- they are in the physical resource blocks corresponding to the virtual resource blocks assigned for transmission, and
- they are not used for transmission of PBCH, synchronization signals, and
- they are assumed by the UE not to be used for cell-specific reference signals, where the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports for and the frequency shift of cell-specific reference signals derived as described in clause 6.10.1.2 4, and

The mapping to resource elements $(k,l)$ on antenna port $p$ not reserved for other purposes shall be in increasing order of first the index $k$ over the assigned physical resource blocks and then the index $l$, starting with the first slot in a subframe.

## 6.4 Physical downlink shared channel

The physical downlink shared channel shall be processed and mapped to resource elements as described in clause 6.3 with the following additions and exceptions:

- In resource blocks in which UE-specific reference signals are not transmitted, the PDSCH shall be transmitted on the same set of antenna ports as the PBCH, which is one of $\{0\}$, $\{0,1\}$, or $\{0,1,2,3\}$.
- In resource blocks in which UE-specific reference signals are transmitted, the PDSCH shall be transmitted on antenna port(s) $\{5\}$, $\{7\}$, $\{8\}$, or $p \in \{7,8,...,\upsilon+6\}$, where $\upsilon$ is the number of layers used for transmission of the PDSCH.
- If PDSCH is transmitted in MBSFN subframes as defined in 3GPP TS 36.213 [4], the PDSCH shall be transmitted on one or several of antenna port(s) $p \in \{7,8,...,\upsilon+6\}$, where $\upsilon$ is the number of layers used for transmission of the PDSCH.
- PDSCH is not mapped to resource elements used for UE-specific reference signals associated with PDSCH
- In mapping to resource elements, the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports and the frequency shift of the cell-specific reference signals derived as described in clause 6.10.1.2, unless other values for these parameters are provided by clause 7.1.9 in 3GPP TS 36.213 [4], in which case these values are used in the resource blocks indicated by the relevant DCI.
- If the DCI associated with the PDSCH uses the C-RNTI or semi-persistent C-RNTI, the PDSCH is not mapped to resource elements assumed by the UE to be used for transmission of CSI reference signals, where the positions of the CSI reference signals are given by clause 6.10.5.2.The configuration for zero power CSI reference signals is obtained as described in clause 6.10.5.2, unless other values for these parameters are provided by clause 7.1.9 in 3GPP TS 36.213 [4], in which case these values are used in the resource blocks indicated by the relevant DCI. The configuration for non-zero power CSI reference signals is obtained as described in clause 6.10.5.2,
- PDSCH is not mapped to any physical resource-block pair(s) carrying an EPDCCH associated with the PDSCH.
- The index $l$ in the first slot in a subframe fulfils $l \geq l_{\text{DataStart}}$ where $l_{\text{DataStart}}$ is given by clause 7.1.6.4 of 3GPP TS 36.213 [4].
- In mapping to resource elements, if the DCI associated with the PDSCH uses the C-RNTI or semi-persistent C-RNTI and transmit diversity according to clause 6.3.4.3 is used, resource elements in an OFDM symbol assumed by the UE to contain CSI-RS shall be used in the mapping if and only if all of the following criteria are fulfilled:
  - there is an even number of resource elements for the OFDM symbol in each resource block assigned for transmission, and
- the complex-valued symbols $y^{(p)}(i)$ and $y^{(p)}(i+1)$, where $i$ is an even number, can be mapped to resource elements $(k,l)$ and $(k+n,l)$ in the same OFDM symbol with $n<3$.

## 6.5 Physical multicast channel

The physical multicast channel shall be processed and mapped to resource elements as described in clause 6.3 with the following exceptions:

- No transmit diversity scheme is specified.
- Layer mapping and precoding shall be done assuming a single antenna port and the transmission shall use antenna port 4.
- The PMCH can only be transmitted in the MBSFN region of an MBSFN subframe.
- The PMCH shall use extended cyclic prefix.
- The PMCH is not mapped to resource elements used for transmission of MBSFN reference signals.

# 6.6 Physical broadcast channel

## 6.6.1 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}}-1)$, where $M_{\text{bit}}$, the number of bits transmitted on the physical broadcast channel, equals 1920 for normal cyclic prefix and 1728 for extended cyclic prefix, shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence shall be initialised with $c_{\text{init}} = N_{\text{ID}}^{\text{cell}}$ in each radio frame fulfilling $n_{\text{f}} \bmod 4 = 0$.

## 6.6.2 Modulation

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$. Table 6.6.2-1 specifies the modulation mappings applicable for the physical broadcast channel.

**Table 6.6.2-1: PBCH modulation schemes.**

| Physical channel | Modulation schemes |
|---|---|
| PBCH | QPSK |

## 6.6.3 Layer mapping and precoding

The block of modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ shall be mapped to layers according to one of clauses 6.3.3.1 or 6.3.3.3 with $M_{\text{symb}}^{(0)} = M_{\text{symb}}$ and precoded according to one of clauses 6.3.4.1 or 6.3.4.3, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i)\right]^T$, $i = 0,...,M_{\text{symb}}-1$, where $y^{(p)}(i)$ represents the signal for antenna port $p$ and where $p = 0,...,P-1$ and the number of antenna ports for cell-specific reference signals $P \in \{1,2,4\}$.

## 6.6.4 Mapping to resource elements

The block of complex-valued symbols $y^{(p)}(0),...,y^{(p)}(M_{\text{symb}}-1)$ for each antenna port is transmitted during 4 consecutive radio frames starting in each radio frame fulfilling $n_{\text{f}} \bmod 4 = 0$ and shall be mapped in sequence starting with $y(0)$ to resource elements $(k,l)$. The mapping to resource elements $(k,l)$ not reserved for transmission of reference signals shall be in increasing order of first the index $k$, then the index $l$ in slot 1 in subframe 0 and finally the radio frame number. The resource-element indices are given by

$$k = \frac{N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}}{2} - 36 + k', \qquad k' = 0,1,...,71$$
$$l = 0,1,...,3$$

where resource elements reserved for reference signals shall be excluded. The mapping operation shall assume cell-specific reference signals for antenna ports 0-3 being present irrespective of the actual configuration. The UE shall assume that the resource elements assumed to be reserved for reference signals in the mapping operation above but not used for transmission of reference signal are not available for PDSCH transmission. The UE shall not make any other assumptions about these resource elements.

# 6.7 Physical control format indicator channel

The physical control format indicator channel carries information about the number of OFDM symbols used for transmission of PDCCHs in a subframe. The set of OFDM symbols possible to use for PDCCH in a subframe is given by Table 6.7-1.

**Table 6.7-1: Number of OFDM symbols used for PDCCH**

| Subframe | Number of OFDM symbols for PDCCH when $N_{RB}^{DL} > 10$ | Number of OFDM symbols for PDCCH when $N_{RB}^{DL} \leq 10$ |
|---|---|---|
| Subframe 1 and 6 for frame structure type 2 | 1, 2 | 2 |
| MBSFN subframes on a carrier supporting PDSCH, configured with 1 or 2 cell-specific antenna ports | 1, 2 | 2 |
| MBSFN subframes on a carrier supporting PDSCH, configured with 4 cell-specific antenna ports | 2 | 2 |
| Subframes on a carrier not supporting PDSCH | 0 | 0 |
| Non-MBSFN subframes (except subframe 6 for frame structure type 2) configured with positioning reference signals | 1, 2, 3 | 2, 3 |
| All other cases | 1, 2, 3 | 2, 3, 4 |

The PCFICH shall be transmitted when the number of OFDM symbols for PDCCH is greater than zero.

## 6.7.1 Scrambling

The block of bits $b(0),...,b(31)$ transmitted in one subframe shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(31)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{init} = \left(\lfloor n_s/2 \rfloor + 1\right) \cdot \left(2N_{ID}^{cell} + 1\right) \cdot 2^9 + N_{ID}^{cell}$ at the start of each subframe.

## 6.7.2 Modulation

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(31)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(15)$. Table 6.7.2-1 specifies the modulation mappings applicable for the physical control format indicator channel.

**Table 6.7.2-1: PCFICH modulation schemes**

| Physical channel | Modulation schemes |
|---|---|
| PCFICH | QPSK |

## 6.7.3 Layer mapping and precoding

The block of modulation symbols $d(0),...,d(15)$ shall be mapped to layers according to one of clauses 6.3.3.1 or 6.3.3.3 with $M_{symb}^{(0)} = 16$ and precoded according to one of clauses 6.3.4.1 or 6.3.4.3, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i)\right]^T$, $i = 0,...,15$, where $y^{(p)}(i)$ represents the signal for antenna port $p$ and where $p = 0,...,P-1$ and the number of antenna ports for cell-specific reference signals $P \in \{1,2,4\}$. The PCFICH shall be transmitted on the same set of antenna ports as the PBCH.

## 6.7.4 Mapping to resource elements

The mapping to resource elements is defined in terms of quadruplets of complex-valued symbols. Let $z^{(p)}(i) = \left\langle y^{(p)}(4i), y^{(p)}(4i+1), y^{(p)}(4i+2), y^{(p)}(4i+3) \right\rangle$ denote symbol quadruplet $i$ for antenna port $p$. For each of the antenna ports, symbol quadruplets shall be mapped in increasing order of $i$ to the four resource-element groups in the first OFDM symbol in a downlink subframe with the representative resource-element as defined in clause 6.2.4 given by

$z^{(p)}(0)$ is mapped to the resource-element group represented by $k = \bar{k}$

$z^{(p)}(1)$ is mapped to the resource-element group represented by $k = \bar{k} + \left\lfloor N_{\text{RB}}^{\text{DL}}/2 \right\rfloor \cdot N_{\text{sc}}^{\text{RB}}/2$

$z^{(p)}(2)$ is mapped to the resource-element group represented by $k = \bar{k} + \left\lfloor 2N_{\text{RB}}^{\text{DL}}/2 \right\rfloor \cdot N_{\text{sc}}^{\text{RB}}/2$

$z^{(p)}(3)$ is mapped to the resource-element group represented by $k = \bar{k} + \left\lfloor 3N_{\text{RB}}^{\text{DL}}/2 \right\rfloor \cdot N_{\text{sc}}^{\text{RB}}/2$

where the additions are modulo $N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}$,

$$\bar{k} = \left(N_{\text{sc}}^{\text{RB}}/2\right) \cdot \left(N_{\text{ID}}^{\text{cell}} \bmod 2N_{\text{RB}}^{\text{DL}}\right)$$

and $N_{\text{ID}}^{\text{cell}}$ is the physical-layer cell identity as given by clause 6.11.

# 6.8 Physical downlink control channel

## 6.8.1 PDCCH formats

The physical downlink control channel carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), where a control channel element corresponds to 9 resource element groups. The number of resource-element groups not assigned to PCFICH or PHICH is $N_{\text{REG}}$. The CCEs available in the system are numbered from 0 to $N_{\text{CCE}}-1$, where $N_{\text{CCE}}=\lfloor N_{\text{REG}}/9\rfloor$. The PDCCH supports multiple formats as listed in Table 6.8.1-1. A PDCCH consisting of $n$ consecutive CCEs may only start on a CCE fulfilling $i \bmod n = 0$, where $i$ is the CCE number.

Multiple PDCCHs can be transmitted in a subframe.

**Table 6.8.1-1: Supported PDCCH formats**

| PDCCH format | Number of CCEs | Number of resource-element groups | Number of PDCCH bits |
|---|---|---|---|
| 0 | 1 | 9 | 72 |
| 1 | 2 | 18 | 144 |
| 2 | 4 | 36 | 288 |
| 3 | 8 | 72 | 576 |

## 6.8.2 PDCCH multiplexing and scrambling

The block of bits $b^{(i)}(0),...,b^{(i)}(M_{\text{bit}}^{(\text{i})}-1)$ on each of the control channels to be transmitted in a subframe, where $M_{\text{bit}}^{(\text{i})}$ is the number of bits in one subframe to be transmitted on physical downlink control channel number $i$, shall be multiplexed, resulting in a block of bits $b^{(0)}(0),...,b^{(0)}(M_{\text{bit}}^{(0)}-1),b^{(1)}(0),...,b^{(1)}(M_{\text{bit}}^{(1)}-1),...,b^{(n_{\text{PDCCH}}-1)}(0),...,b^{(n_{\text{PDCCH}}-1)}(M_{\text{bit}}^{(n_{\text{PDCCH}}-1)}-1)$, where $n_{\text{PDCCH}}$ is the number of PDCCHs transmitted in the subframe.

The block of bits $b^{(0)}(0),...,b^{(0)}(M_{\text{bit}}^{(0)}-1),b^{(1)}(0),...,b^{(1)}(M_{\text{bit}}^{(1)}-1),...,b^{(n_{\text{PDCCH}}-1)}(0),...,b^{(n_{\text{PDCCH}}-1)}(M_{\text{bit}}^{(n_{\text{PDCCH}}-1)}-1)$ shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{tot}}-1)$ according to

$$\tilde{b}(i)=\left(b(i)+c(i)\right)\bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}}=\lfloor n_{\text{s}}/2\rfloor 2^{9}+N_{\text{ID}}^{\text{cell}}$ at the start of each subframe.

CCE number $n$ corresponds to bits $b(72n),b(72n+1),...,b(72n+71)$. If necessary, <NIL> elements shall be inserted in the block of bits prior to scrambling to ensure that the PDCCHs starts at the CCE positions as described in 3GPP TS 36.213 [4] and to ensure that the length $M_{\text{tot}}=8N_{\text{REG}}\geq\sum_{i=0}^{n_{\text{PDCCH}}-1}M_{\text{bit}}^{(i)}$ of the scrambled block of bits matches the amount of resource-element groups not assigned to PCFICH or PHICH.

## 6.8.3 Modulation

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{tot}}-1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$. Table 6.8.3-1 specifies the modulation mappings applicable for the physical downlink control channel.

**Table 6.8.3-1: PDCCH modulation schemes**

| Physical channel | Modulation schemes |
|---|---|
| PDCCH | QPSK |

## 6.8.4 Layer mapping and precoding

The block of modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ shall be mapped to layers according to one of clauses 6.3.3.1 or 6.3.3.3 with $M_{\text{symb}}^{(0)} = M_{\text{symb}}$ and precoded according to one of clauses 6.3.4.1 or 6.3.4.3, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i)\right]^T$, $i = 0,...,M_{\text{symb}}-1$ to be mapped onto resources on the antenna ports used for transmission, where $y^{(p)}(i)$ represents the signal for antenna port $p$. The PDCCH shall be transmitted on the same set of antenna ports as the PBCH.

## 6.8.5 Mapping to resource elements

The mapping to resource elements is defined by operations on quadruplets of complex-valued symbols. Let $z^{(p)}(i) = \left\langle y^{(p)}(4i), y^{(p)}(4i+1), y^{(p)}(4i+2), y^{(p)}(4i+3)\right\rangle$ denote symbol quadruplet $i$ for antenna port $p$.

The block of quadruplets $z^{(p)}(0),...,z^{(p)}(M_{\text{quad}}-1)$, where $M_{\text{quad}} = M_{\text{symb}}/4$, shall be permuted resulting in $w^{(p)}(0),...,w^{(p)}(M_{\text{quad}}-1)$. The permutation shall be according to the sub-block interleaver in clause 5.1.4.2.1 of 3GPP TS 36.212 [3] with the following exceptions:

- the input and output to the interleaver is defined by symbol quadruplets instead of bits
- interleaving is performed on symbol quadruplets instead of bits by substituting the terms "bit", "bits" and "bit sequence" in clause 5.1.4.2.1 of 3GPP TS 36.212 [3] by "symbol quadruplet", "symbol quadruplets" and "symbol-quadruplet sequence", respectively

<NULL> elements at the output of the interleaver in 3GPP TS 36.212 [3] shall be removed when forming $w^{(p)}(0),...,w^{(p)}(M_{\text{quad}}-1)$. Note that the removal of <NULL> elements does not affect any <NIL> elements inserted in clause 6.8.2.

The block of quadruplets $w^{(p)}(0),...,w^{(p)}(M_{\text{quad}}-1)$ shall be cyclically shifted, resulting in $\overline{w}^{(p)}(0),...,\overline{w}^{(p)}(M_{\text{quad}}-1)$ where $\overline{w}^{(p)}(i) = w^{(p)}\left((i+N_{\text{ID}}^{\text{cell}}) \bmod M_{\text{quad}}\right)$.

Mapping of the block of quadruplets $\overline{w}^{(p)}(0),...,\overline{w}^{(p)}(M_{\text{quad}}-1)$ is defined in terms of resource-element groups, specified in clause 6.2.4, according to steps 1–10 below:

1) Initialize $m' = 0$ (resource-element group number)
2) Initialize $k' = 0$
    3) Initialize $l' = 0$
        4) If the resource element $(k',l')$ represents a resource-element group and the resource-element group is not assigned to PCFICH or PHICH then perform step 5 and 6, else go to step 7
            5) Map symbol-quadruplet $\overline{w}^{(p)}(m')$ to the resource-element group represented by $(k',l')$ for each antenna port $p$
            6) Increase $m'$ by 1
    7) Increase $l'$ by 1

8) Repeat from step 4 if $l' < L$, where $L$ corresponds to the number of OFDM symbols used for PDCCH transmission as indicated by the sequence transmitted on the PCFICH

9) Increase $k'$ by 1

10) Repeat from step 3 if $k' < N_{\mathrm{RB}}^{\mathrm{DL}} \cdot N_{\mathrm{sc}}^{\mathrm{RB}}$

# 6.8A Enhanced physical downlink control channel

## 6.8A.1 EPDCCH formats

The enhanced physical downlink control channel (EPDCCH) carries scheduling assignments. An enhanced physical downlink control channel is transmitted using an aggregation of one or several consecutive enhanced control channel elements (ECCEs) where each ECCE consists of multiple enhanced resource element groups (EREGs), defined in clause 6.2.4A. The number of ECCEs used for one EPDCCH depends on the EPDCCH format as given by Table 6.8A.1-2 and the number of EREGs per ECCE is given by Table 6.8A.1-1.Both localized and distributed transmission is supported.

An EPDCCH can use either localized or distributed transmission, differing in the mapping of ECCEs to EREGs and PRB pairs.

A UE shall monitor multiple EPDCCHs as defined in 3GPP TS 36.213 [4]. One or two sets of physical resource-block pairs which a UE shall monitor for EPDCCH transmissions can be configured. All EPDCCH candidates in EPDCCH set $X_m$ use either only localized or only distributed transmission as configured by higher layers. Within EPDCCH set $X_m$ in subframe $i$, the ECCEs available for transmission of EPDCCHs are numbered from 0 to $N_{\mathrm{ECCE},m,i} - 1$ and ECCE number $n$ corresponds to

- EREGs numbered $\left(n \bmod N_{\mathrm{ECCE}}^{\mathrm{RB}}\right) + jN_{\mathrm{ECCE}}^{\mathrm{RB}}$ in PRB index $\left\lfloor n / N_{\mathrm{ECCE}}^{\mathrm{RB}} \right\rfloor$ for localized mapping, and
- EREGs numbered $\left\lfloor n / N_{\mathrm{RB}}^{X_m} \right\rfloor + jN_{\mathrm{ECCE}}^{\mathrm{RB}}$ in PRB indices $\left(n + j \max\left(1, N_{\mathrm{RB}}^{X_m} / N_{\mathrm{EREG}}^{\mathrm{ECCE}}\right)\right) \bmod N_{\mathrm{RB}}^{X_m}$ for distributed mapping,

where $j = 0,1,\ldots, N_{\mathrm{EREG}}^{\mathrm{ECCE}} - 1$, $N_{\mathrm{EREG}}^{\mathrm{ECCE}}$ is the number of EREGs per ECCE, and $N_{\mathrm{ECCE}}^{\mathrm{RB}} = 16 / N_{\mathrm{EREG}}^{\mathrm{ECCE}}$ is the number of ECCEs per resource-block pair. The physical resource-block pairs constituting EPDCCH set $X_m$ are in this paragraph assumed to be numbered in ascending order from 0 to $N_{\mathrm{RB}}^{X_m} - 1$.

**Table 6.8A.1-1: Number of EREGs per ECCE, $N_{\mathrm{EREG}}^{\mathrm{ECCE}}$**

| Normal cyclic prefix | | | Extended cyclic prefix | |
|---|---|---|---|---|
| Normal subframe | Special subframe, configuration 3, 4, 8 | Special subframe, configuration 1, 2, 6, 7, 9 | Normal subframe | Special subframe, configuration 1, 2, 3, 5, 6 |
| 4 | | 8 | | |

**Table 6.8A.1-2: Supported EPDCCH formats**

| EPDCCH format | Number of ECCEs for one EPDCCH, $N_{\mathrm{ECCE}}^{\mathrm{EPDCCH}}$ | | | |
|---|---|---|---|---|
| | Case A | | Case B | |
| | Localized transmission | Distributed transmission | Localized transmission | Distributed transmission |
| 0 | 2 | 2 | 1 | 1 |
| 1 | 4 | 4 | 2 | 2 |
| 2 | 8 | 8 | 4 | 4 |
| 3 | 16 | 16 | 8 | 8 |
| 4 | - | 32 | - | 16 |

Case A in Table 6.8A.1-2 is used when the conditions corresponding to case 1 in clause 9.1.4 of 3GPP TS 36.213 [4] are satisfied, otherwise case B is used. The quantity $n_{\text{EPDCCH}}$ for a particular UE and referenced in 3GPP TS 36.213 [4] is defined as the number of downlink resource elements $(k,l)$ in a physical resource-block pair configured for possible EPDCCH transmission of EPDCCH set $X_0$ and fulfilling all of the following criteria:

- they are part of any one of the 16 EREGs in the physical resource-block pair, and
- they are assumed by the UE not to be used for cell-specific reference signals, where the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports for and the frequency shift of cell-specific reference signals derived as described in clause 6.10.1.2 unless other values for these parameters are provided by clause 9.1.4.3 in 3GPP TS 36.213 [4], and-
- they are assumed by the UE not to be used for transmission of CSI reference signals, where the positions of the CSI reference signals are given by clause 6.10.5.2 with the configuration for zero power CSI reference signals obtained as described in clause 6.10.5.2 unless other values are provided by clause 9.1.4.3 in 3GPP TS 36.213 [4], and with the configuration for non-zero power CSI reference signals obtained as described in clause 6.10.5.2, and
- the index $l$ in the first slot in a subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l_{\text{EPDCCHStart}}$ is given by clause 9.1.4.1 of 3GPP TS 36.213 [4].

## 6.8A.2 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}}-1)$ to be transmitted on an EPDCCH in a subframe shall be scrambled, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the UE-specific scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialized with $c_{\text{init}} = \lfloor n_s/2 \rfloor \cdot 2^9 + n_{\text{ID},m}^{\text{EPDCCH}}$ where $m$ is the EPDCCH set number.

## 6.8A.3 Modulation

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$. Table 6.8A.3-1 specifies the modulation mappings applicable for the enhanced physical downlink control channel.

**Table 6.8A.3-1: EPDCCH modulation schemes**

| Physical channel | Modulation schemes |
|---|---|
| EPDCCH | QPSK |

## 6.8A.4 Layer mapping and precoding

The block of complex-valued modulation symbols shall be mapped to a single layer and precoded according to $y(i) = d(i)$, $i = 0,...,M_{\text{symb}}-1$.

## 6.8A.5 Mapping to resource elements

The block of complex-valued symbols $y(0),...,y(M_{\text{symb}}-1)$ shall be mapped in sequence starting with $y(0)$ to resource elements $(k,l)$ on the associated antenna port which meet all of the following criteria:

- they are part of the EREGs assigned for the EPDCCH transmission, and

- they are assumed by the UE not to be used for cell-specific reference signals, where the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports for and the frequency shift of cell-specific reference signals derived as described in clause 6.10.1.2 unless other values for these parameters are provided by clause 9.1.4.3 in 3GPP TS 36.213 [4], and
- they are assumed by the UE not to be used for transmission of CSI reference signals, where the positions of the CSI reference signals are given by clause 6.10.5.2 with the configuration for zero power CSI reference signals obtained as described in clause 6.10.5.2 unless other values are provided by clause 9.1.4.3 in 3GPP TS 36.213 [4], and with the configuration for non-zero power CSI reference signals obtained as described in clause 6.10.5.2, and
- the index $l$ in the first slot in a subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l_{\text{EPDCCHStart}}$ is given by clause 9.1.4.1 of 3GPP TS 36.213 [4].

The mapping to resource elements $(k,l)$ on antenna port $p$ meeting the criteria above shall be in increasing order of first the index $k$ and then the index $l$, starting with the first slot and ending with the second slot in a subframe.

For localized transmission, the single antenna port $p$ to use is given by Table 6.8A.5-1 with

$$n' = n_{\text{ECCE,low}} \bmod N_{\text{ECCE}}^{\text{RB}} + n_{\text{RNTI}} \bmod \min(N_{\text{ECCE}}^{\text{EPDCCH}}, N_{\text{ECCE}}^{\text{RB}})$$

where $n_{\text{ECCE,low}}$ is the lowest ECCE index used by this EPDCCH transmission in the EPDCCH set, $n_{\text{RNTI}}$ equals the C-RNTI, and $N_{\text{ECCE}}^{\text{EPDCCH}}$ is the number of ECCEs used for this EPDCCH.

**Table 6.8A.5-1: Antenna port to use for localized EPDCCH transmission**

| $n'$ | Normal cyclic prefix | | Extended cyclic prefix |
|---|---|---|---|
| | Normal subframes, Special subframes, configurations 3, 4, 8 | Special subframes, configurations 1, 2, 6, 7, 9 | Any subframe |
| 0 | 107 | 107 | 107 |
| 1 | 108 | 109 | 108 |
| 2 | 109 | - | - |
| 3 | 110 | - | - |

For distributed transmission, each resource element in an EREG is associated with one out of two antenna ports in an alternating manner, starting with antenna port 107, where $p \in \{107,109\}$ for normal cyclic prefix and $p \in \{107,108\}$ for extended cyclic prefix.

# 6.9 Physical hybrid ARQ indicator channel

The PHICH carries the hybrid-ARQ ACK/NACK. Multiple PHICHs mapped to the same set of resource elements constitute a PHICH group, where PHICHs within the same PHICH group are separated through different orthogonal sequences. A PHICH resource is identified by the index pair $\left(n_{\text{PHICH}}^{\text{group}}, n_{\text{PHICH}}^{\text{seq}}\right)$, where $n_{\text{PHICH}}^{\text{group}}$ is the PHICH group number and $n_{\text{PHICH}}^{\text{seq}}$ is the orthogonal sequence index within the group.

For frame structure type 1, the number of PHICH groups $N_{\text{PHICH}}^{\text{group}}$ is constant in all subframes and given by

$$N_{\text{PHICH}}^{\text{group}} = \begin{cases} \left\lceil N_{\text{g}}\left(N_{\text{RB}}^{\text{DL}}/8\right)\right\rceil & \text{for normal cyclic prefix} \\ 2\cdot\left\lceil N_{\text{g}}\left(N_{\text{RB}}^{\text{DL}}/8\right)\right\rceil & \text{for extended cyclic prefix} \end{cases}$$

where $N_{\text{g}} \in \{1/6, 1/2, 1, 2\}$ is provided by higher layers. The index $n_{\text{PHICH}}^{\text{group}}$ ranges from $0$ to $N_{\text{PHICH}}^{\text{group}} - 1$.

For frame structure type 2, the number of PHICH groups may vary between downlink subframes and is given by $m_i \cdot N_{\text{PHICH}}^{\text{group}}$ where $m_i$ is given by Table 6.9-1 and $N_{\text{PHICH}}^{\text{group}}$ by the expression above. The index $n_{\text{PHICH}}^{\text{group}}$ in a downlink subframe with non-zero PHICH resources ranges from $0$ to $m_i \cdot N_{\text{PHICH}}^{\text{group}} - 1$.

**Table 6.9-1: The factor $m_i$ for frame structure type 2**

| Uplink-downlink configuration | Subframe number $i$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 2 | 1 | - | - | - | 2 | 1 | - | - | - |
| 1 | 0 | 1 | - | - | 1 | 0 | 1 | - | - | 1 |
| 2 | 0 | 0 | - | 1 | 0 | 0 | 0 | - | 1 | 0 |
| 3 | 1 | 0 | - | - | - | 0 | 0 | 0 | 1 | 1 |
| 4 | 0 | 0 | - | - | 0 | 0 | 0 | 0 | 1 | 1 |
| 5 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 6 | 1 | 1 | - | - | - | 1 | 1 | - | - | 1 |

## 6.9.1 Modulation

The block of bits $b(0),...,b(M_{\text{bit}}-1)$ transmitted on one PHICH in one subframe shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $z(0),...,z(M_{\text{s}}-1)$, where $M_{\text{s}} = M_{\text{bit}}$. Table 6.9.1-1 specifies the modulation mappings applicable for the physical hybrid ARQ indicator channel.

**Table 6.9.1-1: PHICH modulation schemes.**

| Physical channel | Modulation schemes |
|---|---|
| PHICH | BPSK |

The block of modulation symbols $z(0),...,z(M_{\text{s}}-1)$ shall be symbol-wise multiplied with an orthogonal sequence and scrambled, resulting in a sequence of modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ according to

$$d(i) = w\left(i \bmod N_{\text{SF}}^{\text{PHICH}}\right)\cdot\left(1-2c(i)\right)\cdot z\left(\left\lfloor i/N_{\text{SF}}^{\text{PHICH}}\right\rfloor\right)$$

where

$$i = 0,...,M_{\text{symb}}-1$$

$$M_{\text{symb}} = N_{\text{SF}}^{\text{PHICH}}\cdot M_{\text{s}}$$

$$N_{\text{SF}}^{\text{PHICH}} = \begin{cases} 4 & \text{normal cyclic prefix} \\ 2 & \text{extended cyclic prefix} \end{cases}$$

and $c(i)$ is a cell-specific scrambling sequence generated according to clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = (\lfloor n_s/2 \rfloor + 1)\cdot(2N_{\text{ID}}^{\text{cell}} + 1)\cdot 2^9 + N_{\text{ID}}^{\text{cell}}$ at the start of each subframe.

The sequence $\left[w(0) \quad \cdots \quad w(N_{\text{SF}}^{\text{PHICH}} - 1)\right]$ is given by Table 6.9.1-2 where the sequence index $n_{\text{PHICH}}^{\text{seq}}$ corresponds to the PHICH number within the PHICH group.

**Table 6.9.1-2: Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{\text{SF}}^{\text{PHICH}} - 1)\right]$ for PHICH**

| Sequence index | Orthogonal sequence | |
|---|---|---|
| $n_{\text{PHICH}}^{\text{seq}}$ | Normal cyclic prefix $N_{\text{SF}}^{\text{PHICH}} = 4$ | Extended cyclic prefix $N_{\text{SF}}^{\text{PHICH}} = 2$ |
| 0 | $[+1 \quad +1 \quad +1 \quad +1]$ | $[+1 \quad +1]$ |
| 1 | $[+1 \quad -1 \quad +1 \quad -1]$ | $[+1 \quad -1]$ |
| 2 | $[+1 \quad +1 \quad -1 \quad -1]$ | $[+j \quad +j]$ |
| 3 | $[+1 \quad -1 \quad -1 \quad +1]$ | $[+j \quad -j]$ |
| 4 | $[+j \quad +j \quad +j \quad +j]$ | - |
| 5 | $[+j \quad -j \quad +j \quad -j]$ | - |
| 6 | $[+j \quad +j \quad -j \quad -j]$ | - |
| 7 | $[+j \quad -j \quad -j \quad +j]$ | - |

## 6.9.2 Resource group alignment, layer mapping and precoding

The block of symbols $d(0),...,d(M_{\text{symb}} - 1)$ should be first aligned with resource element group size, resulting in a block of symbols $d^{(0)}(0),...,d^{(0)}(c\cdot M_{\text{symb}} - 1)$, where $c = 1$ for normal cyclic prefix; and $c = 2$ for extended cyclic prefix.

For normal cyclic prefix, $d^{(0)}(i) = d(i)$, for $i = 0,...,M_{\text{symb}} - 1$.

For extended cyclic prefix,

$$\left[d^{(0)}(4i) \quad d^{(0)}(4i+1) \quad d^{(0)}(4i+2) \quad d^{(0)}(4i+3)\right]^T = \begin{cases} [d(2i) \quad d(2i+1) \quad 0 \quad 0]^T & n_{\text{PHICH}}^{\text{group}} \bmod 2 = 0 \\ [0 \quad 0 \quad d(2i) \quad d(2i+1)]^T & n_{\text{PHICH}}^{\text{group}} \bmod 2 = 1 \end{cases}$$

for $i = 0,...,(M_{\text{symb}}/2) - 1$.

The block of symbols $d^{(0)}(0),...,d^{(0)}(c\cdot M_{\text{symb}} - 1)$ shall be mapped to layers and precoded, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i)\right]^T$, $i = 0,...,c\cdot M_{\text{symb}} - 1$, where $y^{(p)}(i)$ represents the signal for antenna port $p$, $p = 0,...,P-1$ and the number of cell-specific reference signals $P \in \{1,2,4\}$. The layer mapping and precoding operation depends on the cyclic prefix length and the number of antenna ports used for transmission of the PHICH. The PHICH shall be transmitted on the same set of antenna ports as the PBCH.

For transmission on a single antenna port, $P = 1$, layer mapping and precoding are defined by clauses 6.3.3.1 and 6.3.4.1, respectively, with $M_{\text{symb}}^{(0)} = c\cdot M_{\text{symb}}$.

For transmission on two antenna ports, $P = 2$, layer mapping and precoding are defined by clauses 6.3.3.3 and 6.3.4.3, respectively, with $M_{\text{symb}}^{(0)} = c\cdot M_{\text{symb}}$.

For transmission on four antenna ports, $P = 4$, layer mapping is defined by clause 6.3.3.3 with $M_{\text{symb}}^{(0)} = c \cdot M_{\text{symb}}$ and precoding by

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \text{Re}\left(x^{(0)}(i)\right) \\ \text{Re}\left(x^{(1)}(i)\right) \\ \text{Re}\left(x^{(2)}(i)\right) \\ \text{Re}\left(x^{(3)}(i)\right) \\ \text{Im}\left(x^{(0)}(i)\right) \\ \text{Im}\left(x^{(1)}(i)\right) \\ \text{Im}\left(x^{(2)}(i)\right) \\ \text{Im}\left(x^{(3)}(i)\right) \end{bmatrix}$$

if $(i + n_{\text{PHICH}}^{\text{group}}) \bmod 2 = 0$ for normal cyclic prefix, or $(i + \lfloor n_{\text{PHICH}}^{\text{group}} / 2 \rfloor) \bmod 2 = 0$ for extended cyclic prefix, where $n_{\text{PHICH}}^{\text{group}}$ is the PHICH group number and $i = 0,1,2$, and by

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \text{Re}\left(x^{(0)}(i)\right) \\ \text{Re}\left(x^{(1)}(i)\right) \\ \text{Re}\left(x^{(2)}(i)\right) \\ \text{Re}\left(x^{(3)}(i)\right) \\ \text{Im}\left(x^{(0)}(i)\right) \\ \text{Im}\left(x^{(1)}(i)\right) \\ \text{Im}\left(x^{(2)}(i)\right) \\ \text{Im}\left(x^{(3)}(i)\right) \end{bmatrix}$$

otherwise for $i = 0,1,2$.

### 6.9.3 Mapping to resource elements

The sequence $\bar{y}^{(p)}(0),...,\bar{y}^{(p)}(M_{\text{symb}}^{(0)}-1)$ for each of the PHICH groups is defined by

$$\bar{y}^{(p)}(n)=\sum y_i^{(p)}(n)$$

where the sum is over all PHICHs in the PHICH group and $y_i^{(p)}(n)$ represents the symbol sequence from the $i$ :th PHICH in the PHICH group.

PHICH groups are mapped to PHICH mapping units.

For normal cyclic prefix, the mapping of PHICH group $m$ to PHICH mapping unit $m'$ is defined by

$$\tilde{y}_{m'}^{(p)}(n)=\bar{y}_m^{(p)}(n)$$

where

$$m'=m=\begin{cases}0,1,...,N_{\text{PHICH}}^{\text{group}}-1 & \text{for frame structure type 1}\\ 0,1,...,m_i\cdot N_{\text{PHICH}}^{\text{group}}-1 & \text{for frame structure type 2}\end{cases},$$

and where $m_i$ is given by Table 6.9-1.

For extended cyclic prefix, the mapping of PHICH group $m$ and $m+1$ to PHICH mapping unit $m'$ is defined by

$$\tilde{y}_{m'}^{(p)}(n)=\bar{y}_m^{(p)}(n)+\bar{y}_{m+1}^{(p)}(n)$$

where

$$m'=m/2$$

$$m=\begin{cases}0,2,...,N_{\text{PHICH}}^{\text{group}}-2 & \text{for frame structure type 1}\\ 0,2,...,m_i\cdot N_{\text{PHICH}}^{\text{group}}-2 & \text{for frame structure type 2}\end{cases}$$

and where $m_i$ is given by Table 6.9-1.

Let $z^{(p)}(i)=\left\langle \tilde{y}^{(p)}(4i),\tilde{y}^{(p)}(4i+1),\tilde{y}^{(p)}(4i+2),\tilde{y}^{(p)}(4i+3)\right\rangle$, $i=0,1,2$ denote symbol quadruplet $i$ for antenna port $p$. Mapping to resource elements is defined in terms of symbol quadruplets according to steps 1–10 below:

1) For each value of $l'$

   2) Let $n_{l'}$ denote the number of resource element groups not assigned to PCFICH in OFDM symbol $l'$

   3) Number the resource-element groups not assigned to PCFICH in OFDM symbol $l'$ from 0 to $n_{l'}-1$, starting from the resource-element group with the lowest frequency-domain index.

4) Initialize $m'=0$ (PHICH mapping unit number)

5) For each value of $i=0,1,2$

   6) Symbol-quadruplet $z^{(p)}(i)$ from PHICH mapping unit $m'$ is mapped to the resource-element group represented by $(k',l')_i$ as defined in clause 6.2.4 where the indices $k_i'$ and $l_i'$ are given by steps 7 and 8 below:

      7) The time-domain index $l_i'$ is given by

$$l'_i = \begin{cases} 0 & \text{normal PHICH duration, all subframes} \\ (\lfloor m'/2 \rfloor + i + 1) \bmod 2 & \text{extended PHICH duration, MBSFN subframes} \\ (\lfloor m'/2 \rfloor + i + 1) \bmod 2 & \text{extended PHICH duration, subframe 1 and 6 in frame structure type 2} \\ i & \text{otherwise} \end{cases}$$

8) Set the frequency-domain index $k'_i$ to the resource-element group assigned the number $\bar{n}_i$ in step 3 above, where $\bar{n}_i$ is given by

$$\bar{n}_i = \begin{cases} \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_1 \rfloor + m'\right) \bmod n_{l'_i} & i = 0 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_1 \rfloor + m' + \lfloor n_{l'_i} / 3 \rfloor\right) \bmod n_{l'_i} & i = 1 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_1 \rfloor + m' + \lfloor 2\, n_{l'_i} / 3 \rfloor\right) \bmod n_{l'_i} & i = 2 \end{cases}$$

in case of extended PHICH duration in MBSFN subframes, or extended PHICH duration in subframes 1 and 6 for frame structure type 2 and by

$$\bar{n}_i = \begin{cases} \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_0 \rfloor + m'\right) \bmod n_{l'_i} & i = 0 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_0 \rfloor + m' + \lfloor n_{l'_i} / 3 \rfloor\right) \bmod n_{l'_i} & i = 1 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_0 \rfloor + m' + \lfloor 2\, n_{l'_i} / 3 \rfloor\right) \bmod n_{l'_i} & i = 2 \end{cases}$$

otherwise.

9) Increase $m'$ by 1.

10) Repeat from step 5 until all PHICH mapping units have been assigned.

The PHICH duration is configurable by higher layers according to Table 6.9.3-1.

**Table 6.9.3-1: PHICH duration in MBSFN and non-MBSFN subframes**

| PHICH duration | Non-MBSFN subframes | | MBSFN subframes on a carrier supporting PDSCH |
|---|---|---|---|
| | Subframes 1 and 6 in case of frame structure type 2 | All other cases | |
| Normal | 1 | 1 | 1 |
| Extended | 2 | 3 | 2 |

# 6.10 Reference signals

Six types of downlink reference signals are defined:

- Cell-specific Reference Signal (CRS)
- MBSFN reference signal
- UE-specific Reference Signal (DM-RS) associated with PDSCH
- DeModulation Reference Signal (DM-RS) associated with EPDCCH
- Positioning Reference Signal (PRS)
- CSI Reference Signal (CSI-RS)

There is one reference signal transmitted per downlink antenna port.

## 6.10.1 Cell-specific Reference Signal (CRS)

Cell-specific reference signals shall be transmitted in all downlink subframes in a cell supporting PDSCH transmission.

Cell-specific reference signals are transmitted on one or several of antenna ports 0 to 3.

Cell-specific reference signals are defined for $\Delta f = 15\,\text{kHz}$ only.

### 6.10.1.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right), \quad m = 0,1,\ldots,2N_{\text{RB}}^{\max,\text{DL}}-1$$

where $n_s$ is the slot number within a radio frame and $l$ is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = 2^{10}\cdot\left(7\cdot\left(n_s+1\right)+l+1\right)\cdot\left(2\cdot N_{\text{ID}}^{\text{cell}}+1\right)+2\cdot N_{\text{ID}}^{\text{cell}}+N_{\text{CP}}$ at the start of each OFDM symbol where

$$N_{\text{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

### 6.10.1.2 Mapping to resource elements

The reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols for antenna port $p$ in slot $n_s$ according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

$$k = 6m + \left(v + v_{\text{shift}}\right) \bmod 6$$

$$l = \begin{cases} 0, N_{\text{symb}}^{\text{DL}}-3 & \text{if } p \in \{0,1\} \\ 1 & \text{if } p \in \{2,3\} \end{cases}$$

$$m = 0,1,\ldots,2\cdot N_{\text{RB}}^{\text{DL}}-1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}$$

The variables $v$ and $v_{\text{shift}}$ define the position in the frequency domain for the different reference signals where $v$ is given by

$$v = \begin{cases} 0 & \text{if } p = 0 \text{ and } l = 0 \\ 3 & \text{if } p = 0 \text{ and } l \neq 0 \\ 3 & \text{if } p = 1 \text{ and } l = 0 \\ 0 & \text{if } p = 1 \text{ and } l \neq 0 \\ 3(n_{\text{s}} \bmod 2) & \text{if } p = 2 \\ 3 + 3(n_{\text{s}} \bmod 2) & \text{if } p = 3 \end{cases}$$

The cell-specific frequency shift is given by $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 6$.

Resource elements $(k,l)$ used for transmission of cell-specific reference signals on any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero.

In an MBSFN subframe, cell-specific reference signals shall only be transmitted in the non-MBSFN region of the MBSFN subframe.

Figures 6.10.1.2-1 and 6.10.1.2-2 illustrate the resource elements used for reference signal transmission according to the above definition. The notation $R_p$ is used to denote a resource element used for reference signal transmission on antenna port $p$.

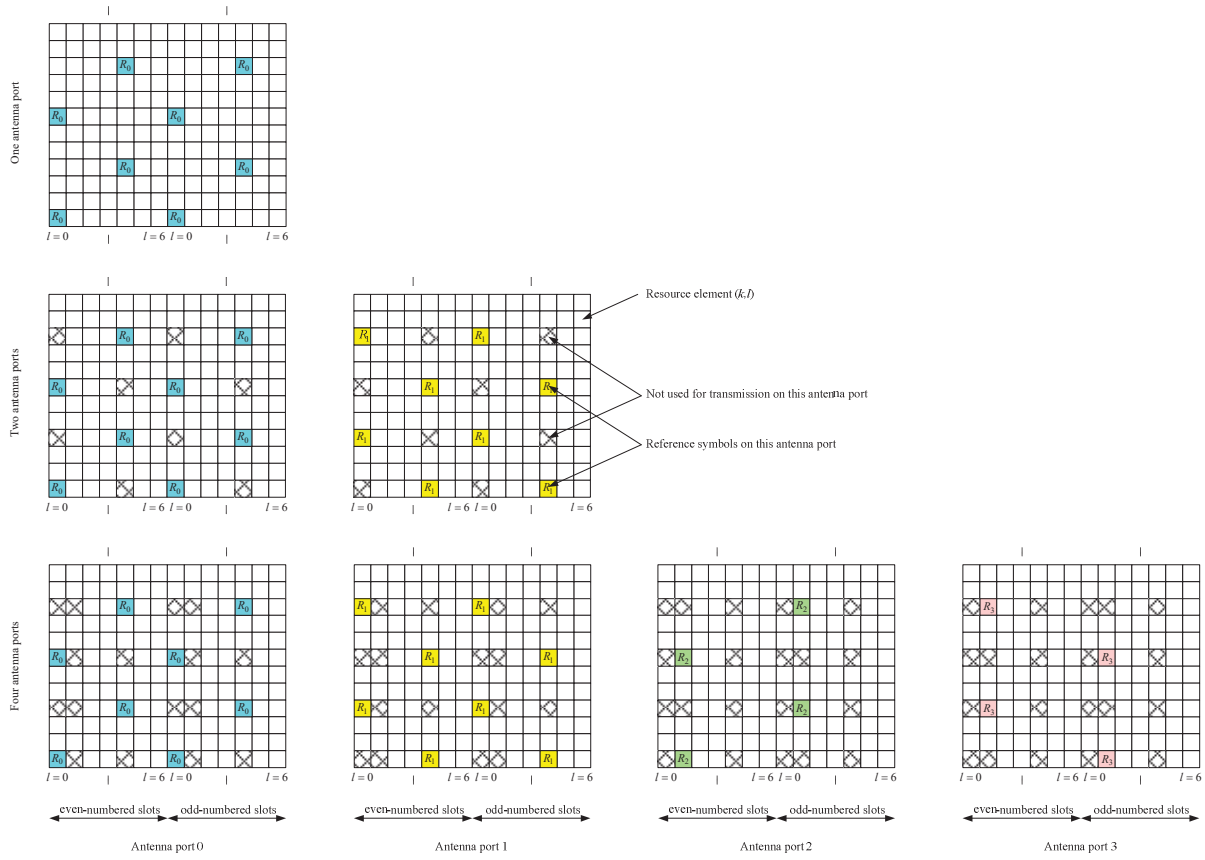



**Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix)**

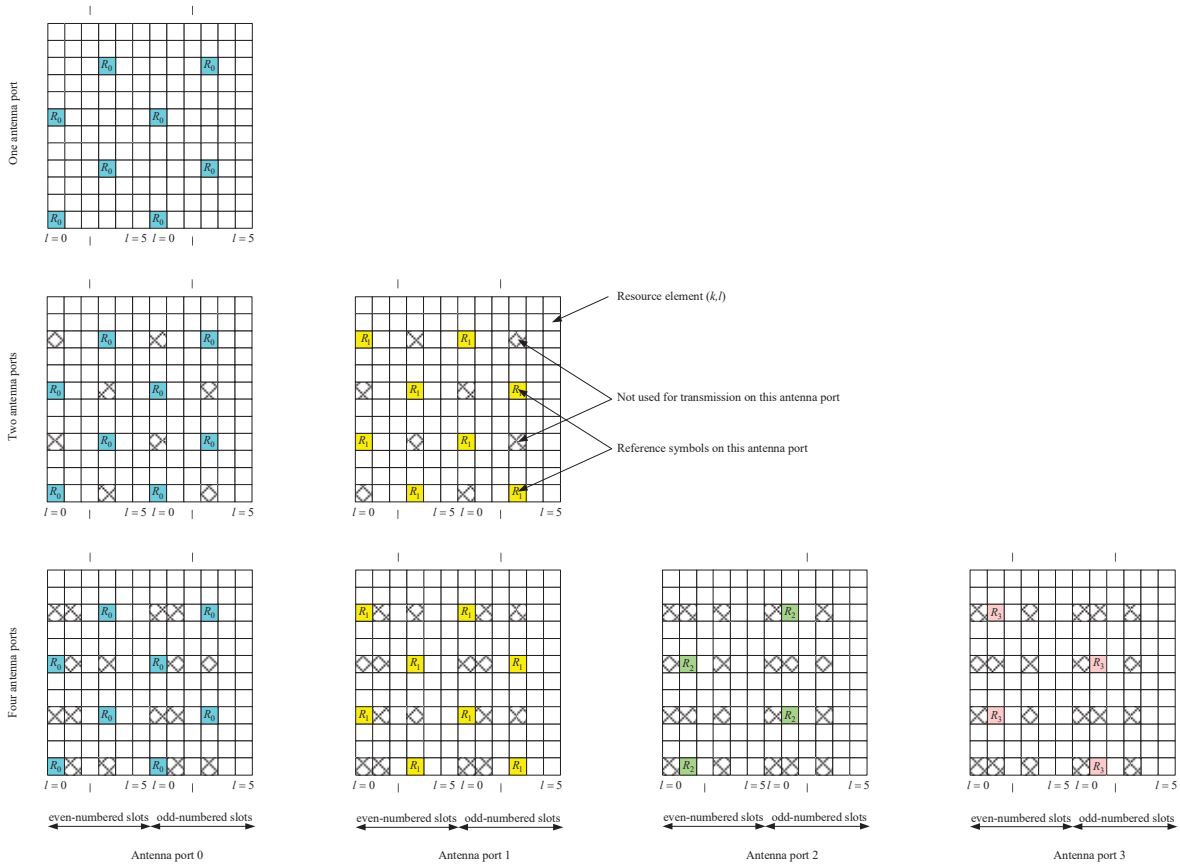



**Figure 6.10.1.2-2. Mapping of downlink reference signals (extended cyclic prefix)**

## 6.10.2 MBSFN reference signals

MBSFN reference signals shall be transmitted in the MBSFN region of MBSFN subframes only when the PMCH is transmitted. MBSFN reference signals are transmitted on antenna port 4.

MBSFN reference signals are defined for extended cyclic prefix only.

### 6.10.2.1 Sequence generation

The MBSFN reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right), \quad m = 0,1,\ldots,6N_{\text{RB}}^{\max,\text{DL}}-1$$

where $n_s$ is the slot number within a radio frame and $l$ is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = 2^9\cdot\left(7\cdot\left(n_s+1\right)+l+1\right)\cdot\left(2\cdot N_{\text{ID}}^{\text{MBSFN}}+1\right)+N_{\text{ID}}^{\text{MBSFN}}$ at the start of each OFDM symbol.

### 6.10.2.2 Mapping to resource elements

The reference-signal sequence $r_{l,n_s}(m')$ in OFDM symbol $l$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ with $p=4$ according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

$$k = \begin{cases} 2m & \text{if } l \neq 0 \text{ and } \Delta f = 15\text{ kHz} \\ 2m+1 & \text{if } l = 0 \text{ and } \Delta f = 15\text{ kHz} \\ 4m & \text{if } l \neq 0 \text{ and } \Delta f = 7.5\text{ kHz} \\ 4m+2 & \text{if } l = 0 \text{ and } \Delta f = 7.5\text{ kHz} \end{cases}$$

$$l = \begin{cases} 2 & \text{if } n_s \bmod 2 = 0 \text{ and } \Delta f = 15\text{ kHz} \\ 0,4 & \text{if } n_s \bmod 2 = 1 \text{ and } \Delta f = 15\text{ kHz} \\ 1 & \text{if } n_s \bmod 2 = 0 \text{ and } \Delta f = 7.5\text{ kHz} \\ 0,2 & \text{if } n_s \bmod 2 = 1 \text{ and } \Delta f = 7.5\text{ kHz} \end{cases}$$

$$m = 0,1,\ldots,6N_{\text{RB}}^{\text{DL}}-1$$

$$m' = m + 3\left(N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}\right)$$

Figure 6.10.2.2-1 illustrates the resource elements used for MBSFN reference signal transmission in case of $\Delta f = 15$ kHz. In case of $\Delta f = 7.5$ kHz for a MBSFN-dedicated cell, the MBSFN reference signal shall be mapped to resource elements according to Figure 6.10.2.2-3. The notation $R_p$ is used to denote a resource element used for reference signal transmission on antenna port $p$.

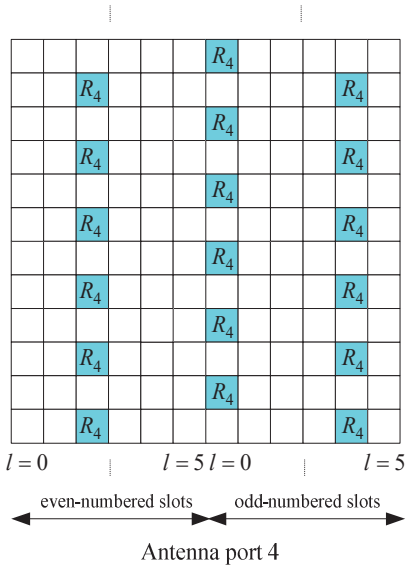



**Figure 6.10.2.2-1: Mapping of MBSFN reference signals (extended cyclic prefix, $\Delta f = 15\,\text{kHz}$)**

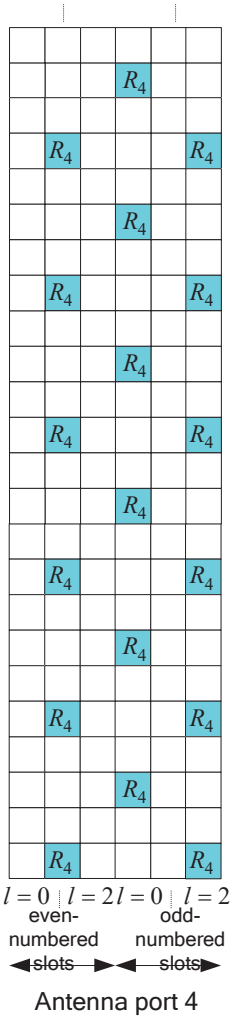



**Figure 6.10.2.2-3: Mapping of MBSFN reference signals (extended cyclic prefix, $\Delta f = 7.5\,\text{kHz}$)**

## 6.10.3 UE-specific reference signals associated with PDSCH

UE-specific reference signals associated with PDSCH

- are transmitted on antenna port(s) $p=5$, $p=7$, $p=8$ or $p=7,8,...,\upsilon+6$, where $\upsilon$ is the number of layers used for transmission of the PDSCH;
- are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to clause 7.1 of 3GPP TS 36.213 [4];
- are transmitted only on the physical resource blocks upon which the corresponding PDSCH is mapped.

A UE-specific reference signal associated with PDSCH is not transmitted in resource elements $(k,l)$ in which one of the physical channels or physical signals other than the UE-specific reference signals defined in 6.1 are transmitted using resource elements with the same index pair $(k,l)$ regardless of their antenna port $p$.

### 6.10.3.1 Sequence generation

For antenna port 5, the UE-specific reference-signal sequence $r_{n_s}(m)$ is defined by

$$r_{n_s}(m)=\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right)+j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right),\qquad m=0,1,...,12N_{\mathrm{RB}}^{\mathrm{PDSCH}}-1$$

where $N_{\mathrm{RB}}^{\mathrm{PDSCH}}$ denotes the assigned bandwidth in resource blocks of the corresponding PDSCH transmission. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\mathrm{init}}=\left(\lfloor n_s/2\rfloor+1\right)\cdot\left(2N_{\mathrm{ID}}^{\mathrm{cell}}+1\right)\cdot 2^{16}+n_{\mathrm{RNTI}}$ at the start of each subframe where $n_{\mathrm{RNTI}}$ is as described in clause 7.1 3GPP TS 36.213 [4].

For any of the antenna ports $p\in\{7,8,...,\upsilon+6\}$, the reference-signal sequence $r(m)$ is defined by

$$r(m)=\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right)+j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right),\qquad m=\begin{cases}0,1,...,12N_{\mathrm{RB}}^{\max,\mathrm{DL}}-1 & \text{normal cyclic prefix}\\ 0,1,...,16N_{\mathrm{RB}}^{\max,\mathrm{DL}}-1 & \text{extended cyclic prefix}\end{cases}.$$

The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with

$$c_{\mathrm{init}}=\left(\lfloor n_s/2\rfloor+1\right)\cdot\left(2n_{\mathrm{ID}}^{(n_{\mathrm{SCID}})}+1\right)\cdot 2^{16}+n_{\mathrm{SCID}}$$

at the start of each subframe.

The quantities $n_{\mathrm{ID}}^{(i)}$, $i=0,1$, are given by

- $n_{\mathrm{ID}}^{(i)}=N_{\mathrm{ID}}^{\mathrm{cell}}$ if no value for $n_{\mathrm{ID}}^{\mathrm{DMRS},i}$ is provided by higher layers or if DCI format 1A, 2B or 2C is used for the DCI associated with the PDSCH transmission
- $n_{\mathrm{ID}}^{(i)}=n_{\mathrm{ID}}^{\mathrm{DMRS},i}$ otherwise

The value of $n_{\mathrm{SCID}}$ is zero unless specified otherwise. For a PDSCH transmission on ports 7 or 8, $n_{\mathrm{SCID}}$ is given by the DCI format 2B, 2C or 2D in 3GPP TS 36.212 [3] associated with the PDSCH transmission.
In the case of DCI format 2B, $n_{\mathrm{SCID}}$ is indicated by the scrambling identity field according to Table 6.10.3.1-1. In the case of DCI format 2C or 2D, $n_{\mathrm{SCID}}$ is given by Table 5.3.3.1.5C-1 in 3GPP TS 36.212 [3].

**Table 6.10.3.1-1: Mapping of scrambling identity field in DCI format 2B to $n_{\mathrm{SCID}}$ values for antenna ports 7 and 8**

| Scrambling identity field in DCI format 2B (3GPP TS 36.212 [3]) | $n_{\mathrm{SCID}}$ |
|---|---|
| 0 | 0 |
| 1 | 1 |

### 6.10.3.2 Mapping to resource elements

For antenna port 5, in a physical resource block with frequency-domain index $n_{\mathrm{PRB}}$ assigned for the corresponding PDSCH transmission, the reference signal sequence $r_{n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ with $p=5$ in a subframe according to:

Normal cyclic prefix:

$$a_{k,l}^{(p)} = r_{n_s}(3\cdot l'\cdot N_{\mathrm{RB}}^{\mathrm{PDSCH}} + m')$$

$$k = (k') \bmod N_{\mathrm{sc}}^{\mathrm{RB}} + N_{\mathrm{sc}}^{\mathrm{RB}}\cdot n_{\mathrm{PRB}}$$

$$k' = \begin{cases} 4m'+v_{\mathrm{shift}} & \text{if } l\in\{2,3\} \\ 4\mathrm{m}'+(2+v_{\mathrm{shift}}) \bmod 4 & \text{if } l\in\{5,6\} \end{cases}$$

$$l = \begin{cases} 3 & l'=0 \\ 6 & l'=1 \\ 2 & l'=2 \\ 5 & l'=3 \end{cases}$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \\ 2,3 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0,1,\ldots,3N_{\mathrm{RB}}^{\mathrm{PDSCH}}-1$$

Extended cyclic prefix:

$$a_{k,l}^{(p)} = r_{n_s}(4\cdot l'\cdot N_{\mathrm{RB}}^{\mathrm{PDSCH}} + m')$$

$$k = (k') \bmod N_{\mathrm{sc}}^{\mathrm{RB}} + N_{\mathrm{sc}}^{\mathrm{RB}}\cdot n_{\mathrm{PRB}}$$

$$k' = \begin{cases} 3m'+v_{\mathrm{shift}} & \text{if } l=4 \\ 3\mathrm{m}'+(2+v_{\mathrm{shift}}) \bmod 3 & \text{if } l=1 \end{cases}$$

$$l = \begin{cases} 4 & l'\in\{0,2\} \\ 1 & l'=1 \end{cases}$$

$$l' = \begin{cases} 0 & \text{if } n_s \bmod 2 = 0 \\ 1,2 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0,1,\ldots,4N_{\mathrm{RB}}^{\mathrm{PDSCH}}-1$$

where $m'$ is the counter of UE-specific reference signal resource elements within a respective OFDM symbol of the PDSCH transmission.

The cell-specific frequency shift is given by $v_{\mathrm{shift}} = N_{\mathrm{ID}}^{\mathrm{cell}} \bmod 3$.

The mapping shall be in increasing order of the frequency-domain index $n_{\mathrm{PRB}}$ of the physical resource blocks assigned for the corresponding PDSCH transmission. The quantity $N_{\mathrm{RB}}^{\mathrm{PDSCH}}$ denotes the assigned bandwidth in resource blocks of the corresponding PDSCH transmission.

Figure 6.10.3.2-1 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix for antenna port 5.

Figure 6.10.3.2-2 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix for antenna port 5.

The notation $R_p$ is used to denote a resource element used for reference signal transmission on antenna port $p$.

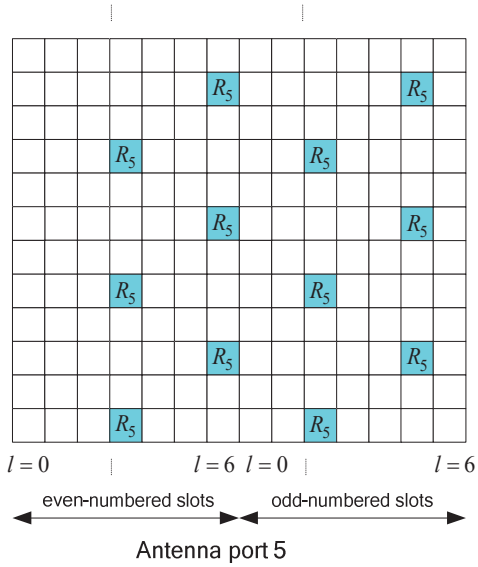



**Figure 6.10.3.2-1: Mapping of UE-specific reference signals, antenna port 5 (normal cyclic prefix)**

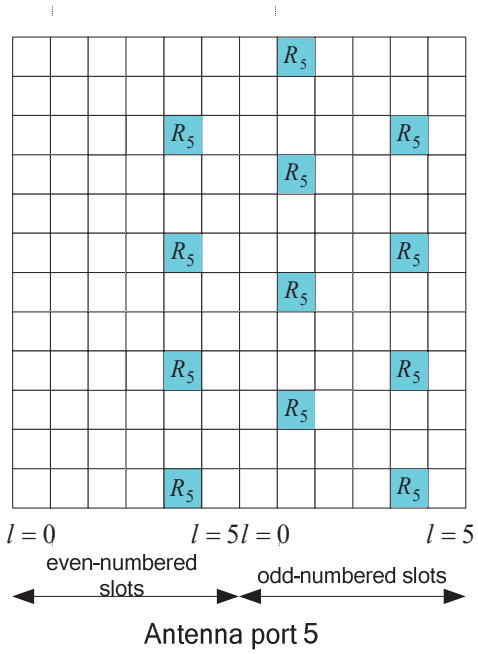



**Figure 6.10.3.2-2: Mapping of UE-specific reference signals, antenna port 5 (extended cyclic prefix)**

For antenna ports $p = 7$, $p = 8$ or $p = 7,8,\ldots,\upsilon + 6$, in a physical resource block with frequency-domain index $n_{\text{PRB}}$ assigned for the corresponding PDSCH transmission, a part of the reference signal sequence $r(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ in a subframe according to

Normal cyclic prefix:

$$a_{k,l}^{(p)} = w_p(l') \cdot r(3 \cdot l' \cdot N_{\mathrm{RB}}^{\max,\mathrm{DL}} + 3 \cdot n_{\mathrm{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & (m'+n_{\mathrm{PRB}}) \bmod 2 = 0 \\ \overline{w}_p(3-i) & (m'+n_{\mathrm{PRB}}) \bmod 2 = 1 \end{cases}$$

$$k = 5m' + N_{\mathrm{sc}}^{\mathrm{RB}} n_{\mathrm{PRB}} + k'$$

$$k' = \begin{cases} 1 & p \in \{7,8,11,13\} \\ 0 & p \in \{9,10,12,14\} \end{cases}$$

$$l = \begin{cases} l' \bmod 2 + 2 & \text{if in a special subframe with configuration 3, 4, 8 or 9 (see Table 4.2 -1)} \\ l' \bmod 2 + 2 + 3\lfloor l'/2 \rfloor & \text{if in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2 -1)} \\ l' \bmod 2 + 5 & \text{if not in a special subframe} \end{cases}$$

$$l' = \begin{cases} 0,1,2,3 & \text{if } n_{\mathrm{s}} \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2 -1)} \\ 0,1 & \text{if } n_{\mathrm{s}} \bmod 2 = 0 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2 -1)} \\ 2,3 & \text{if } n_{\mathrm{s}} \bmod 2 = 1 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2 -1)} \end{cases}$$

$$m' = 0,1,2$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3.2-1.

**Table 6.10.3.2-1: The sequence $\overline{w}_p(i)$ for normal cyclic prefix**

| Antenna port $p$ | $\left[\overline{w}_p(0) \quad \overline{w}_p(1) \quad \overline{w}_p(2) \quad \overline{w}_p(3)\right]$ |
|---|---|
| 7 | $[+1 \quad +1 \quad +1 \quad +1]$ |
| 8 | $[+1 \quad -1 \quad +1 \quad -1]$ |
| 9 | $[+1 \quad +1 \quad +1 \quad +1]$ |
| 10 | $[+1 \quad -1 \quad +1 \quad -1]$ |
| 11 | $[+1 \quad +1 \quad -1 \quad -1]$ |
| 12 | $[-1 \quad -1 \quad +1 \quad +1]$ |
| 13 | $[+1 \quad -1 \quad -1 \quad +1]$ |
| 14 | $[-1 \quad +1 \quad +1 \quad -1]$ |

Extended cyclic prefix:

$$a_{k,l}^{(p)} = w_p(l' \bmod 2) \cdot r(4 \cdot l' \cdot N_{\mathrm{RB}}^{\max,\mathrm{DL}} + 4 \cdot n_{\mathrm{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & m' \bmod 2 = 0 \\ \overline{w}_p(1-i) & m' \bmod 2 = 1 \end{cases}$$

$$k = 3m' + N_{\mathrm{sc}}^{\mathrm{RB}} n_{\mathrm{PRB}} + k'$$

$$k' = \begin{cases} 1 & \text{if } n_{\mathrm{s}} \bmod 2 = 0 \text{ and } p \in \{7,8\} \\ 2 & \text{if } n_{\mathrm{s}} \bmod 2 = 1 \text{ and } p \in \{7,8\} \end{cases}$$

$$l = l' \bmod 2 + 4$$

$$l' = \begin{cases} 0,1 & \text{if } n_{\mathrm{s}} \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 3, 5 or 6 (see Table 4.2 -1)} \\ 0,1 & \text{if } n_{\mathrm{s}} \bmod 2 = 0 \text{ and not in a special subframe} \\ 2,3 & \text{if } n_{\mathrm{s}} \bmod 2 = 1 \text{ and not in a special subframe} \end{cases}$$

$$m' = 0,1,2,3$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3.2-2.

**Table 6.10.3.2-2: The sequence $\overline{w}_p(i)$ for extended cyclic prefix**

| Antenna port $p$ | $\left[\overline{w}_p(0) \quad \overline{w}_p(1)\right]$ |
|---|---|
| 7 | $\left[+1 \quad +1\right]$ |
| 8 | $\left[-1 \quad +1\right]$ |

For extended cyclic prefix, UE-specific reference signals are not supported on antenna ports 9 to 14.

Resource elements $(k,l)$ used for transmission of UE-specific reference signals to one UE on any of the antenna ports in the set $S$, where $S = \{7,8,11,13\}$ or $S = \{9,10,12,14\}$ shall

- not be used for transmission of PDSCH on any antenna port in the same slot, and
- not be used for UE-specific reference signals to the same UE on any antenna port other than those in $S$ in the same slot.

Figure 6.10.3.2-3 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix for antenna ports 7, 8, 9 and 10. Figure 6.10.3.2-4 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix for antenna ports 7, 8.

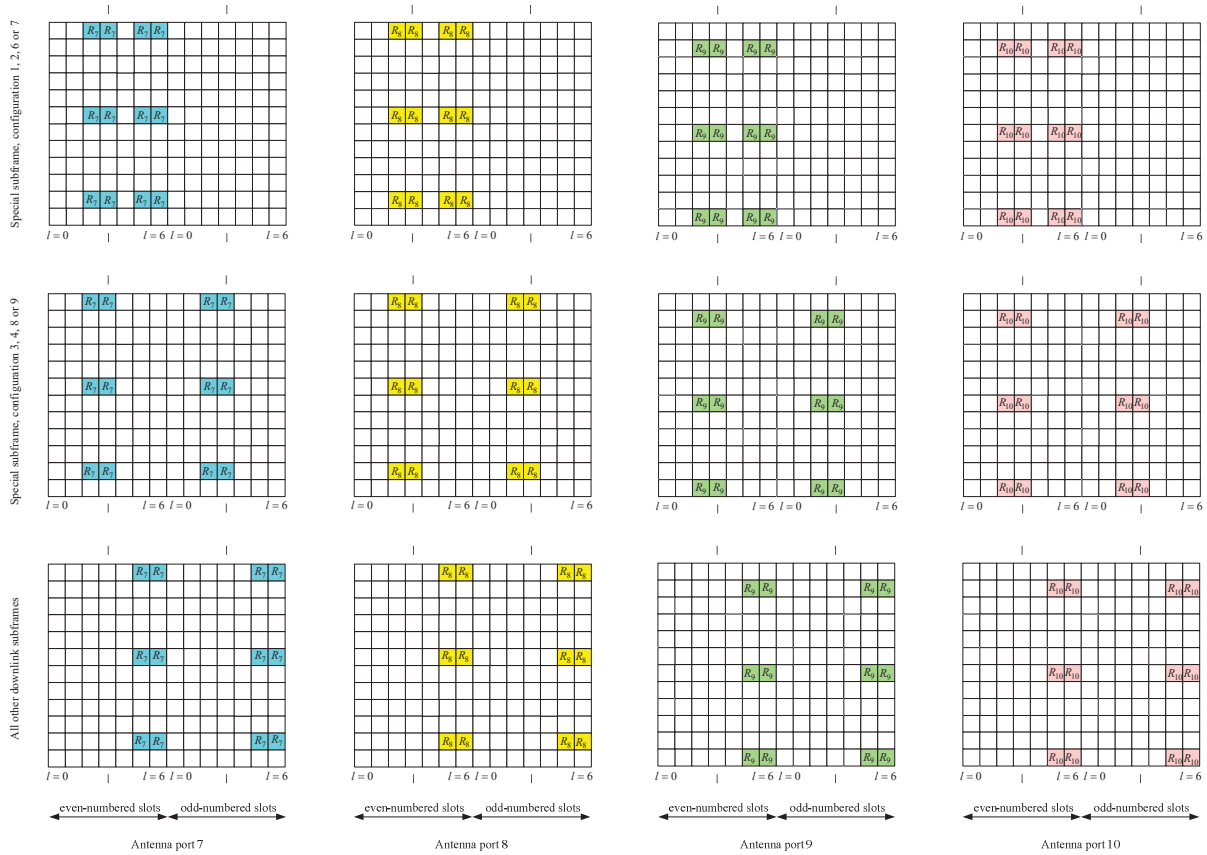



**Figure 6.10.3.2-3: Mapping of UE-specific reference signals, antenna ports 7, 8, 9 and 10 (normal cyclic prefix)**

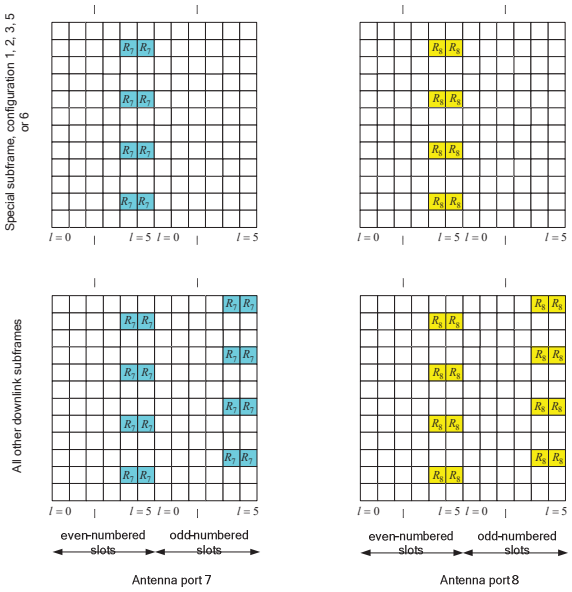



**Figure 6.10.3.2-4: Mapping of UE-specific reference signals, antenna ports 7 and 8 (extended cyclic prefix)**

## 6.10.3A Demodulation reference signals associated with EPDCCH

The demodulation reference signal associated with EPDCCH

- is transmitted on the same antenna port $p \in \{107,108,109,110\}$ as the associated EPDCCH physical resource;
- is present and is a valid reference for EPDCCH demodulation only if the EPDCCH transmission is associated with the corresponding antenna port;
- is transmitted only on the physical resource blocks upon which the corresponding EPDCCH is mapped.

A demodulation reference signal associated with EPDCCH is not transmitted in resource elements $(k,l)$ in which one of the physical channels or physical signals other than the demodulation reference signals defined in 6.1 are transmitted using resource elements with the same index pair $(k,l)$ regardless of their antenna port $p$.

### 6.10.3A.1 Sequence generation

For any of the antenna ports $p \in \{107,108,109,110\}$, the reference-signal sequence $r(m)$ is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1-2\cdot c(2m)) + j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \qquad m = \begin{cases} 0,1,\ldots,12N_{\text{RB}}^{\max,\text{DL}}-1 & \text{normal cyclic prefix} \\ 0,1,\ldots,16N_{\text{RB}}^{\max,\text{DL}}-1 & \text{extended cyclic prefix} \end{cases}.$$

The pseudo-random sequence $c(n)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with

$$c_{\text{init}} = (\lfloor n_{\text{s}}/2 \rfloor + 1)\cdot(2n_{\text{ID},i}^{\text{EPDCCH}} + 1)\cdot 2^{16} + n_{\text{SCID}}^{\text{EPDCCH}}$$

at the start of each subframe where $n_{\text{SCID}}^{\text{EPDCCH}} = 2$ and $n_{\text{ID},i}^{\text{EPDCCH}}$ is configured by higher layers. The EPDCCH set to which the EPDCCH associated with the demodulation reference signal belong is denoted $i \in \{0,1\}$.

### 6.10.3A.2 Mapping to resource elements

For the antenna port $p \in \{107,108,109,110\}$ in a physical resource block $n_{\text{PRB}}$ assigned for the associated EPDCCH, a part of the reference signal sequence $r(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ in a subframe according to

Normal cyclic prefix:

$$a_{k,l}^{(p)} = w_p(l')\cdot r(3\cdot l'\cdot N_{\text{RB}}^{\max,\text{DL}} + 3\cdot n_{\text{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & (m'+n_{\text{PRB}}) \bmod 2 = 0 \\ \overline{w}_p(3-i) & (m'+n_{\text{PRB}}) \bmod 2 = 1 \end{cases}$$

$$k = 5m' + N_{\text{sc}}^{\text{RB}} n_{\text{PRB}} + k'$$

$$k' = \begin{cases} 1 & p \in \{107,108\} \\ 0 & p \in \{109,110\} \end{cases}$$

$$l = \begin{cases} l' \bmod 2 + 2 & \text{if in a special subframe with configuration 3, 4, 8 or 9 (see Table 4.2-1)} \\ l' \bmod 2 + 2 + 3\lfloor l'/2 \rfloor & \text{if in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ l' \bmod 2 + 5 & \text{if not in a special subframe} \end{cases}$$

$$l' = \begin{cases} 0,1,2,3 & \text{if } n_{\text{s}} \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 0,1 & \text{if } n_{\text{s}} \bmod 2 = 0 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 2,3 & \text{if } n_{\text{s}} \bmod 2 = 1 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \end{cases}$$

$$m' = 0,1,2$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3A.2-1.

**Table 6.10.3A.2-1: The sequence $\overline{w}_p(i)$ for normal cyclic prefix**

| Antenna port $p$ | $\left[\overline{w}_p(0) \quad \overline{w}_p(1) \quad \overline{w}_p(2) \quad \overline{w}_p(3)\right]$ |
|---|---|
| 107 | $\left[+1 \quad +1 \quad +1 \quad +1\right]$ |
| 108 | $\left[+1 \quad -1 \quad +1 \quad -1\right]$ |
| 109 | $\left[+1 \quad +1 \quad +1 \quad +1\right]$ |
| 110 | $\left[+1 \quad -1 \quad +1 \quad -1\right]$ |

Extended cyclic prefix:

$$a_{k,l}^{(p)} = w_p(l' \bmod 2) \cdot r(4 \cdot l' \cdot N_{\mathrm{RB}}^{\max,\mathrm{DL}} + 4 \cdot n_{\mathrm{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & m' \bmod 2 = 0 \\ \overline{w}_p(1-i) & m' \bmod 2 = 1 \end{cases}$$

$$k = 3m' + N_{\mathrm{sc}}^{\mathrm{RB}} n_{\mathrm{PRB}} + k'$$

$$k' = \begin{cases} 1 & \text{if } n_s \bmod 2 = 0 \text{ and } p \in \{107,108\} \\ 2 & \text{if } n_s \bmod 2 = 1 \text{ and } p \in \{107,108\} \end{cases}$$

$$l = l' \bmod 2 + 4$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 3, 5 or 6 (see Table 4.2 -1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in a special subframe} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in a special subframe} \end{cases}$$

$$m' = 0,1,2,3$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3A.2-2.

**Table 6.10.3A.2-2: The sequence $\overline{w}_p(i)$ for extended cyclic prefix**

| Antenna port $p$ | $\left[\overline{w}_p(0) \quad \overline{w}_p(1)\right]$ |
|---|---|
| 107 | $\left[+1 \quad +1\right]$ |
| 108 | $\left[-1 \quad +1\right]$ |

For extended cyclic prefix, demodulation reference signals are not supported on antenna ports 109 to 110.

Resource elements $(k,l)$ used for transmission of demodulation reference signals to one UE on any of the antenna ports in the set $S$, where $S = \{107,108\}$ or $S = \{109,110\}$ shall

- not be used for transmission of EPDCCH on any antenna port in the same slot, and
- not be used for demodulation reference signals to the same UE on any antenna port other than those in $S$ in the same slot.

Replacing antenna port numbers 7 – 10 by 107 – 110 in Figure 6.10.3.2-3 provides an illustration of the resource elements used for demodulation reference signals associated with EPDCCH for normal cyclic prefix. Replacing antenna port numbers 7 – 8 by 107 – 108 in Figure 6.10.3.2-4 provides an illustration of the resource elements used for demodulation reference signals associated with EPDCCH for extended cyclic prefix.

## 6.10.4 Positioning reference signals

Positioning reference signals shall only be transmitted in resource blocks in downlink subframes configured for positioning reference signal transmission. If both normal and MBSFN subframes are configured as positioning subframes within a cell, the OFDM symbols in a MBSFN subframe configured for positioning reference signal transmission shall use the same cyclic prefix as used for subframe #0. If only MBSFN subframes are configured as positioning subframes within a cell, the OFDM symbols configured for positioning reference signals in the MBSFN region of these subframes shall use extended cyclic prefix length. In a subframe configured for positioning reference signal transmission, the starting positions of the OFDM symbols configured for positioning reference signal transmission shall be identical to those in a subframe in which all OFDM symbols have the same cyclic prefix length as the OFDM symbols configured for positioning reference signal transmission.

Positioning reference signals are transmitted on antenna port 6.

The positioning reference signals shall not be mapped to resource elements $(k,l)$ allocated to PBCH, PSS or SSS regardless of their antenna port $p$.

Positioning reference signals are defined for $\Delta f = 15\,\text{kHz}$ only.

### 6.10.4.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}(1-2\cdot c(2m)) + j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \quad m = 0,1,...,2N_{\text{RB}}^{\max,\text{DL}} - 1$$

where $n_s$ is the slot number within a radio frame, $l$ is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = 2^{10}\cdot(7\cdot(n_s+1)+l+1)\cdot(2\cdot N_{\text{ID}}^{\text{cell}}+1)+2\cdot N_{\text{ID}}^{\text{cell}}+N_{\text{CP}}$ at the start of each OFDM symbol where

$$N_{\text{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

### 6.10.4.2 Mapping to resource elements

The reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference signal for antenna port $p = 6$ in slot $n_s$ according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

Normal cyclic prefix:

$$k = 6\left(m + N_{\text{RB}}^{\text{DL}} - N_{\text{RB}}^{\text{PRS}}\right) + \left(6 - l + v_{\text{shift}}\right) \bmod 6$$

$$l = \begin{cases} 3,5,6 & \text{if } n_s \bmod 2 = 0 \\ 1,2,3,5,6 & \text{if } n_s \bmod 2 = 1 \text{ and } (1 \text{ or } 2 \text{ PBCH antenna ports}) \\ 2,3,5,6 & \text{if } n_s \bmod 2 = 1 \text{ and } (4 \text{ PBCH antenna ports}) \end{cases}$$

$$m = 0,1,\ldots,2\cdot N_{\text{RB}}^{\text{PRS}} - 1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{PRS}}$$

Extended cyclic prefix:

$$k = 6\left(m + N_{\text{RB}}^{\text{DL}} - N_{\text{RB}}^{\text{PRS}}\right) + \left(5 - l + v_{\text{shift}}\right) \bmod 6$$

$$l = \begin{cases} 4,5 & \text{if } n_{\text{s}} \bmod 2 = 0 \\ 1,2,4,5 & \text{if } n_{\text{s}} \bmod 2 = 1 \text{ and } \left(1 \text{ or } 2 \text{ PBCH antenna ports}\right) \\ 2,4,5 & \text{if } n_{\text{s}} \bmod 2 = 1 \text{ and } \left(4 \text{ PBCH antenna ports}\right) \end{cases}$$

$$m = 0,1,\ldots,2 \cdot N_{\text{RB}}^{\text{PRS}} - 1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{PRS}}$$

The bandwidth for positioning reference signals $N_{\text{RB}}^{\text{PRS}}$ is configured by higher layers and the cell-specific frequency shift is given by $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 6$.

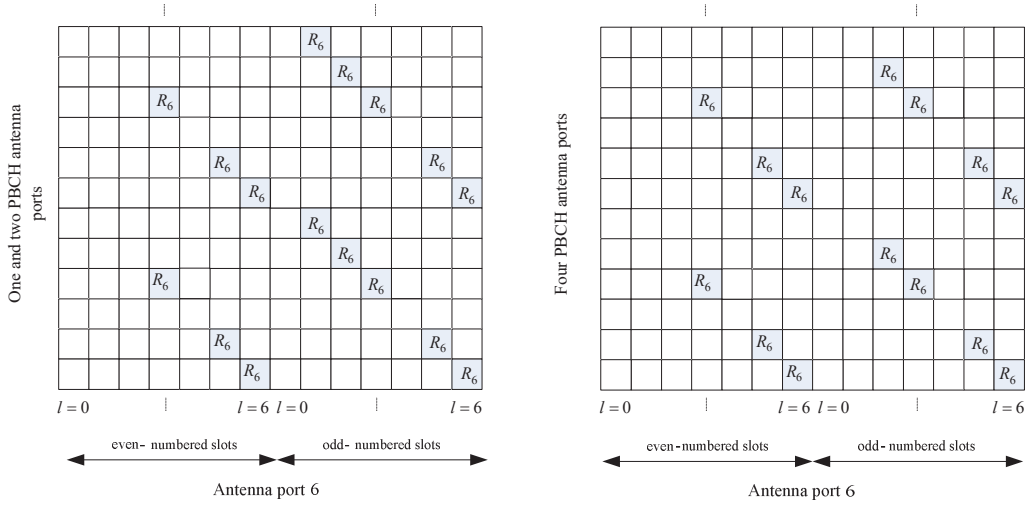



**Figure 6.10.4.2-1: Mapping of positioning reference signals (normal cyclic prefix)**

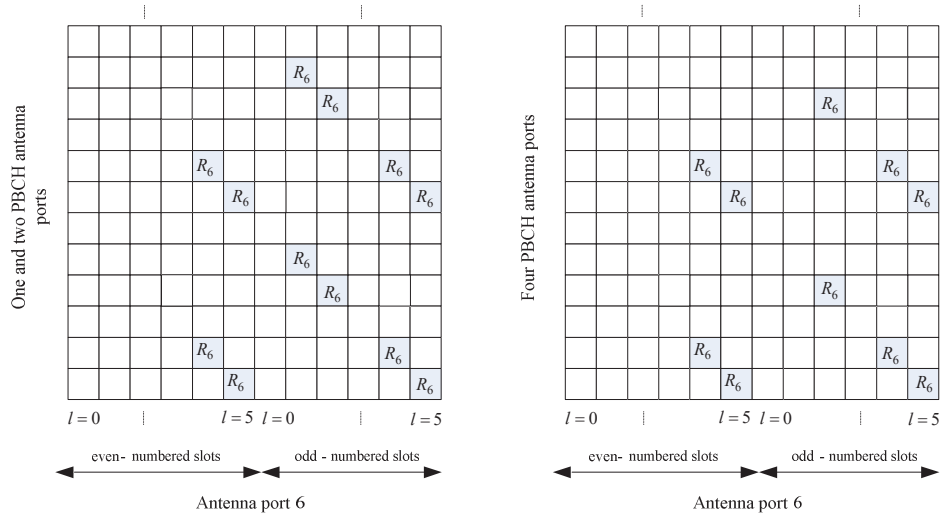



**Figure 6.10.4.2-2: Mapping of positioning reference signals (extended cyclic prefix)**

### 6.10.4.3 Positioning reference signal subframe configuration

The cell specific subframe configuration period $T_{\text{PRS}}$ and the cell specific subframe offset $\Delta_{\text{PRS}}$ for the transmission of positioning reference signals are listed in Table 6.10.4.3-1. The PRS configuration index $I_{\text{PRS}}$ is configured by higher layers. Positioning reference signals are transmitted only in configured DL subframes. Positioning reference signals

shall not be transmitted in special subframes. Positioning reference signals shall be transmitted in $N_{\mathrm{PRS}}$ consecutive downlink subframes, where $N_{\mathrm{PRS}}$ is configured by higher layers.

The positioning reference signal instances, for the first subframe of the $N_{\mathrm{PRS}}$ downlink subframes, shall satisfy $(10 \times n_{\mathrm{f}} + \lfloor n_{\mathrm{s}} / 2 \rfloor - \Delta_{\mathrm{PRS}}) \bmod T_{\mathrm{PRS}} = 0$ .

**Table 6.10.4.3-1: Positioning reference signal subframe configuration**

| PRS configuration Index $I_{\mathrm{PRS}}$ | PRS periodicity $T_{\mathrm{PRS}}$ (subframes) | PRS subframe offset $\Delta_{\mathrm{PRS}}$ (subframes) |
|---|---|---|
| 0 – 159 | 160 | $I_{\mathrm{PRS}}$ |
| 160 – 479 | 320 | $I_{\mathrm{PRS}} - 160$ |
| 480 – 1119 | 640 | $I_{\mathrm{PRS}} - 480$ |
| 1120 – 2399 | 1280 | $I_{\mathrm{PRS}} - 1120$ |
| 2400-4095 | Reserved | |

## 6.10.5 CSI reference signals

CSI reference signals are transmitted on one, two, four or eight antenna ports using $p=15$, $p=15,16$, $p=15,...,18$ and $p=15,...,22$, respectively.

CSI reference signals are defined for $\Delta f = 15$ kHz only.

### 6.10.5.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}(1-2\cdot c(2m)) + j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \quad m = 0,1,...,N_{\mathrm{RB}}^{\max,\mathrm{DL}}-1$$

where $n_s$ is the slot number within a radio frame and $l$ is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\mathrm{init}} = 2^{10}\cdot(7\cdot(n_s+1)+l+1)\cdot(2\cdot N_{\mathrm{ID}}^{\mathrm{CSI}}+1)+2\cdot N_{\mathrm{ID}}^{\mathrm{CSI}}+N_{\mathrm{CP}}$ at the start of each OFDM symbol where

$$N_{\mathrm{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

The quantity $N_{\mathrm{ID}}^{\mathrm{CSI}}$ equals $N_{\mathrm{ID}}^{\mathrm{cell}}$ unless configured by higher layers.

### 6.10.5.2 Mapping to resource elements

In subframes configured for CSI reference signal transmission, the reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols on antenna port $p$ according to

$$a_{k,l}^{(p)} = w_{l''}\cdot r_{l,n_s}(m')$$

where

$$k = k' + 12m + \begin{cases} -0 & \text{for } p\in\{15,16\}, \text{normal cyclic prefix} \\ -6 & \text{for } p\in\{17,18\}, \text{normal cyclic prefix} \\ -1 & \text{for } p\in\{19,20\}, \text{normal cyclic prefix} \\ -7 & \text{for } p\in\{21,22\}, \text{normal cyclic prefix} \\ -0 & \text{for } p\in\{15,16\}, \text{extended cyclic prefix} \\ -3 & \text{for } p\in\{17,18\}, \text{extended cyclic prefix} \\ -6 & \text{for } p\in\{19,20\}, \text{extended cyclic prefix} \\ -9 & \text{for } p\in\{21,22\}, \text{extended cyclic prefix} \end{cases}$$

$$l = l' + \begin{cases} l'' & \text{CSI reference signal configurations 0 - 19, normal cyclic prefix} \\ 2l'' & \text{CSI reference signal configurations 20 - 31, normal cyclic prefix} \\ l'' & \text{CSI reference signal configurations 0 - 27, extended cyclic prefix} \end{cases}$$

$$w_{l''} = \begin{cases} 1 & p\in\{15,17,19,21\} \\ (-1)^{l''} & p\in\{16,18,20,22\} \end{cases}$$

$$l'' = 0,1$$

$$m = 0,1,...,N_{\mathrm{RB}}^{\mathrm{DL}}-1$$

$$m' = m + \left\lfloor \frac{N_{\mathrm{RB}}^{\max,\mathrm{DL}} - N_{\mathrm{RB}}^{\mathrm{DL}}}{2} \right\rfloor$$

The quantity $(k',l')$ and the necessary conditions on $n_s$ are given by Tables 6.10.5.2-1 and 6.10.5.2-2 for normal and extended cyclic prefix, respectively.

Multiple CSI reference signal configurations can be used in a given cell. A UE can be configured with multiple sets of CSI reference signals,

- up to three configurations for which the UE shall assume non-zero transmission power for the CSI-RS, and
- zero or more configurations for which the UE shall assume zero transmission power.

The CSI-RS configurations for which the UE shall assume non-zero transmission power are provided by higher layers.

The CSI-RS configurations for which the UE shall assume zero transmission power in a subframe are given by a bitmap derived according to clause 7.2.7 in 3GPP TS 36.213 [4]. For each bit set to one in the 16-bit bitmap, the UE shall assume zero transmission power for the resource elements corresponding to the four CSI reference signal column in Tables 6.10.5.2-1 and 6.10.5.2-2 for normal and extended cyclic prefix, respectively, except for resource elements that overlap with those for which the UE shall assume non-zero transmission power CSI-RS as configured by higher layers. The most significant bit corresponds to the lowest CSI reference signal configuration index and subsequent bits in the bitmap correspond to configurations with indices in increasing order.

CSI reference signals can only occur in

- downlink slots where $n_s \bmod 2$ fulfils the condition in Tables 6.10.5.2-1 and 6.10.5.2-2 for normal and extended cyclic prefix, respectively, and
- where the subframe number fulfils the conditions in clause 6.10.5.3.

The UE shall assume that CSI reference signals are not transmitted

- in the special subframe(s) in case of frame structure type 2,
- in subframes where transmission of a CSI-RS would collide with *SystemInformationBlockType1* messages,
- in the primary cell in subframes configured for transmission of paging messages in the primary cell for any UE with the cell-specific paging configuration.

The UE shall assume that none of the CSI reference signals corresponding to a CSI reference signal configuration are transmitted in subframes where transmission of any of those CSI reference signals would collide with transmission of synchronization signals or PBCH.

Resource elements $(k,l)$ used for transmission of CSI reference signals on any of the antenna ports in the set $S$, where $S=\{15\}$, $S=\{15,16\}$, $S=\{17,18\}$, $S=\{19,20\}$ or $S=\{21,22\}$ shall not be used for transmission of PDSCH on any antenna port in the same slot.

The mapping for CSI reference signal configuration 0 is illustrated in Figures 6.10.5.2-1 and 6.10.5.2-2.

**Table 6.10.5.2-1: Mapping from CSI reference signal configuration to $(k',l')$ for normal cyclic prefix**

| | CSI reference signal configuration | Number of CSI reference signals configured | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 or 2 | | 4 | | 8 | |
| | | $(k',l')$ | $n_s \bmod 2$ | $(k',l')$ | $n_s \bmod 2$ | $(k',l')$ | $n_s \bmod 2$ |
| Frame structure type 1 and 2 | 0 | (9,5) | 0 | (9,5) | 0 | (9,5) | 0 |
| | 1 | (11,2) | 1 | (11,2) | 1 | (11,2) | 1 |
| | 2 | (9,2) | 1 | (9,2) | 1 | (9,2) | 1 |
| | 3 | (7,2) | 1 | (7,2) | 1 | (7,2) | 1 |
| | 4 | (9,5) | 1 | (9,5) | 1 | (9,5) | 1 |
| | 5 | (8,5) | 0 | (8,5) | 0 | | |
| | 6 | (10,2) | 1 | (10,2) | 1 | | |
| | 7 | (8,2) | 1 | (8,2) | 1 | | |
| | 8 | (6,2) | 1 | (6,2) | 1 | | |
| | 9 | (8,5) | 1 | (8,5) | 1 | | |
| | 10 | (3,5) | 0 | | | | |
| | 11 | (2,5) | 0 | | | | |
| | 12 | (5,2) | 1 | | | | |
| | 13 | (4,2) | 1 | | | | |
| | 14 | (3,2) | 1 | | | | |
| | 15 | (2,2) | 1 | | | | |
| | 16 | (1,2) | 1 | | | | |
| | 17 | (0,2) | 1 | | | | |
| | 18 | (3,5) | 1 | | | | |
| | 19 | (2,5) | 1 | | | | |
| Frame structure type 2 only | 20 | (11,1) | 1 | (11,1) | 1 | (11,1) | 1 |
| | 21 | (9,1) | 1 | (9,1) | 1 | (9,1) | 1 |
| | 22 | (7,1) | 1 | (7,1) | 1 | (7,1) | 1 |
| | 23 | (10,1) | 1 | (10,1) | 1 | | |
| | 24 | (8,1) | 1 | (8,1) | 1 | | |
| | 25 | (6,1) | 1 | (6,1) | 1 | | |
| | 26 | (5,1) | 1 | | | | |
| | 27 | (4,1) | 1 | | | | |
| | 28 | (3,1) | 1 | | | | |
| | 29 | (2,1) | 1 | | | | |
| | 30 | (1,1) | 1 | | | | |
| | 31 | (0,1) | 1 | | | | |

**Table 6.10.5.2-2: Mapping from CSI reference signal configuration to $(k',l')$ for extended cyclic prefix.**

| | CSI reference signal configuration | Number of CSI reference signals configured | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 or 2 | | 4 | | 8 | |
| | | $(k',l')$ | $n_s \bmod 2$ | $(k',l')$ | $n_s \bmod 2$ | $(k',l')$ | $n_s \bmod 2$ |
| Frame structure type 1 and 2 | 0 | (11,4) | 0 | (11,4) | 0 | (11,4) | 0 |
| | 1 | (9,4) | 0 | (9,4) | 0 | (9,4) | 0 |
| | 2 | (10,4) | 1 | (10,4) | 1 | (10,4) | 1 |
| | 3 | (9,4) | 1 | (9,4) | 1 | (9,4) | 1 |
| | 4 | (5,4) | 0 | (5,4) | 0 | | |
| | 5 | (3,4) | 0 | (3,4) | 0 | | |
| | 6 | (4,4) | 1 | (4,4) | 1 | | |
| | 7 | (3,4) | 1 | (3,4) | 1 | | |
| | 8 | (8,4) | 0 | | | | |
| | 9 | (6,4) | 0 | | | | |
| | 10 | (2,4) | 0 | | | | |
| | 11 | (0,4) | 0 | | | | |
| | 12 | (7,4) | 1 | | | | |
| | 13 | (6,4) | 1 | | | | |
| | 14 | (1,4) | 1 | | | | |
| | 15 | (0,4) | 1 | | | | |
| Frame structure type 2 only | 16 | (11,1) | 1 | (11,1) | 1 | (11,1) | 1 |
| | 17 | (10,1) | 1 | (10,1) | 1 | (10,1) | 1 |
| | 18 | (9,1) | 1 | (9,1) | 1 | (9,1) | 1 |
| | 19 | (5,1) | 1 | (5,1) | 1 | | |
| | 20 | (4,1) | 1 | (4,1) | 1 | | |
| | 21 | (3,1) | 1 | (3,1) | 1 | | |
| | 22 | (8,1) | 1 | | | | |
| | 23 | (7,1) | 1 | | | | |
| | 24 | (6,1) | 1 | | | | |
| | 25 | (2,1) | 1 | | | | |
| | 26 | (1,1) | 1 | | | | |
| | 27 | (0,1) | 1 | | | | |

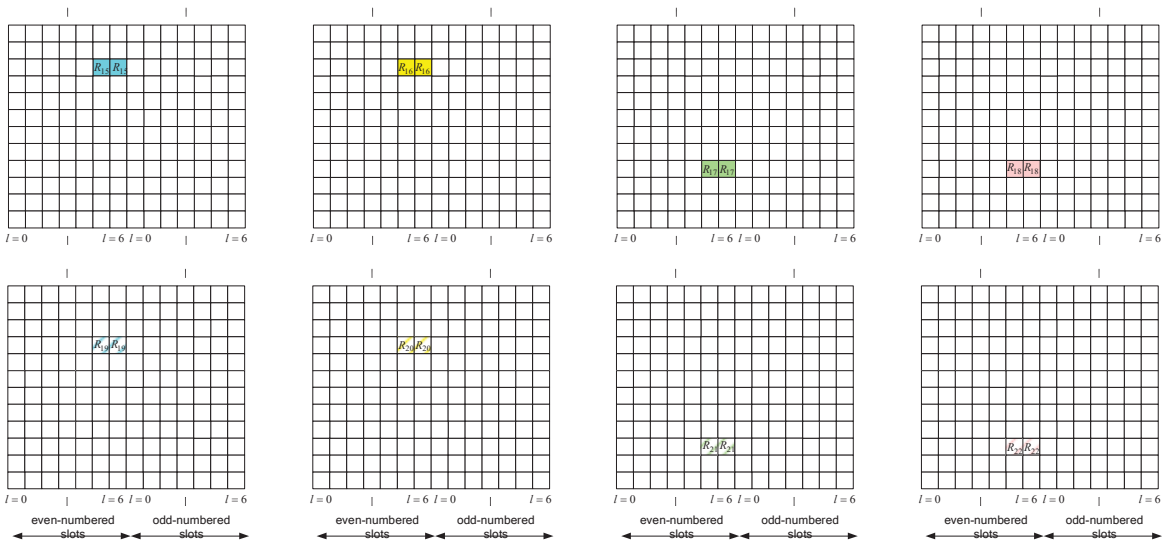



**Figure 6.10.5.2-1: Mapping of CSI reference signals (CSI configuration 0, normal cyclic prefix)**

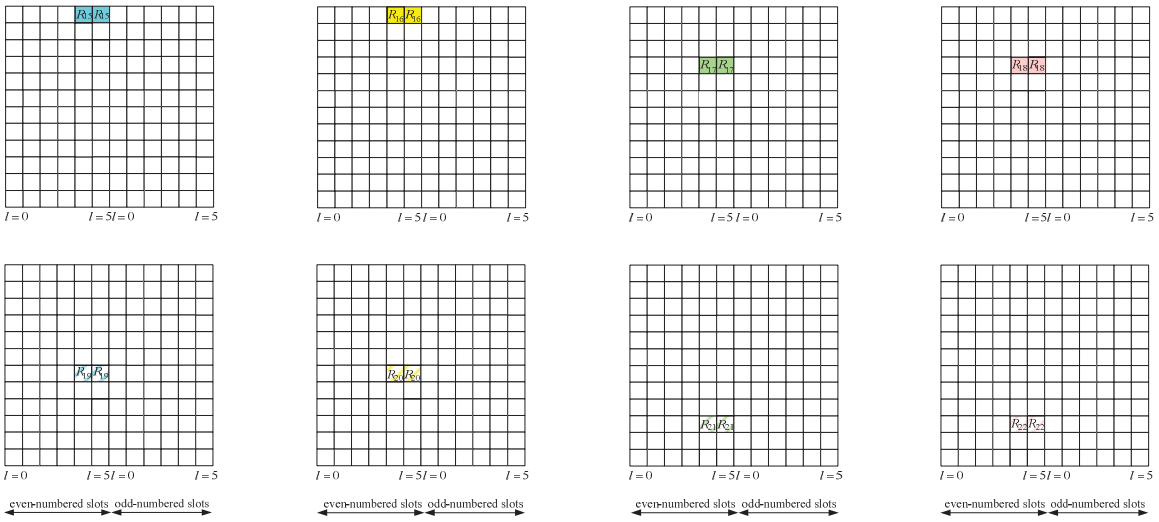



**Figure 6.10.5.2-2: Mapping of CSI reference signals (CSI configuration 0, extended cyclic prefix)**

### 6.10.5.3 CSI reference signal subframe configuration

The subframe configuration period $T_{\text{CSI-RS}}$ and the subframe offset $\Delta_{\text{CSI-RS}}$ for the occurence of CSI reference signals are listed in Table 6.10.5.3-1. The parameter $I_{\text{CSI-RS}}$ can be configured separately for CSI reference signals for which the UE shall assume non-zero and zero transmission power. Subframes containing CSI reference signals shall satisfy $(10n_{\text{f}} + \lfloor n_{\text{s}}/2 \rfloor - \Delta_{\text{CSI-RS}}) \bmod T_{\text{CSI-RS}} = 0$.

**Table 6.10.5.3-1: CSI reference signal subframe configuration**

| CSI-RS-SubframeConfig $I_{\text{CSI-RS}}$ | CSI-RS periodicity $T_{\text{CSI-RS}}$ (subframes) | CSI-RS subframe offset $\Delta_{\text{CSI-RS}}$ (subframes) |
|---|---|---|
| 0 – 4 | 5 | $I_{\text{CSI-RS}}$ |
| 5 – 14 | 10 | $I_{\text{CSI-RS}} - 5$ |
| 15 – 34 | 20 | $I_{\text{CSI-RS}} - 15$ |
| 35 – 74 | 40 | $I_{\text{CSI-RS}} - 35$ |
| 75 – 154 | 80 | $I_{\text{CSI-RS}} - 75$ |

# 6.11 Synchronization signals

There are 504 unique physical-layer cell identities. The physical-layer cell identities are grouped into 168 unique physical-layer cell-identity groups, each group containing three unique identities. The grouping is such that each physical-layer cell identity is part of one and only one physical-layer cell-identity group. A physical-layer cell identity $N_{\mathrm{ID}}^{\mathrm{cell}} = 3N_{\mathrm{ID}}^{(1)} + N_{\mathrm{ID}}^{(2)}$ is thus uniquely defined by a number $N_{\mathrm{ID}}^{(1)}$ in the range of 0 to 167, representing the physical-layer cell-identity group, and a number $N_{\mathrm{ID}}^{(2)}$ in the range of 0 to 2, representing the physical-layer identity within the physical-layer cell-identity group.

## 6.11.1 Primary synchronization signal

### 6.11.1.1 Sequence generation

The sequence $d(n)$ used for the primary synchronization signal is generated from a frequency-domain Zadoff-Chu sequence according to

$$d_u(n) = \begin{cases} e^{-j\frac{\pi un(n+1)}{63}} & n = 0,1,...,30 \\ e^{-j\frac{\pi u(n+1)(n+2)}{63}} & n = 31,32,...,61 \end{cases}$$

where the Zadoff-Chu root sequence index $u$ is given by Table 6.11.1.1-1.

**Table 6.11.1.1-1: Root indices for the primary synchronization signal**

| $N_{\mathrm{ID}}^{(2)}$ | Root index $u$ |
|---|---|
| 0 | 25 |
| 1 | 29 |
| 2 | 34 |

### 6.11.1.2 Mapping to resource elements

The mapping of the sequence to resource elements depends on the frame structure. The UE shall not assume that the primary synchronization signal is transmitted on the same antenna port as any of the downlink reference signals. The UE shall not assume that any transmission instance of the primary synchronization signal is transmitted on the same antenna port, or ports, used for any other transmission instance of the primary synchronization signal.

The sequence $d(n)$ shall be mapped to the resource elements according to

$$a_{k,l} = d(n), \qquad n = 0,...,61$$
$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$

For frame structure type 1, the primary synchronization signal shall be mapped to the last OFDM symbol in slots 0 and 10.

For frame structure type 2, the primary synchronization signal shall be mapped to the third OFDM symbol in subframes 1 and 6. Resource elements $(k,l)$ in the OFDM symbols used for transmission of the primary synchronization signal where

$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$
$$n = -5,-4,...,-1,62,63,...66$$

are reserved and not used for transmission of the primary synchronization signal.

## 6.11.2 Secondary synchronization signal

### 6.11.2.1 Sequence generation

The sequence $d(0),...,d(61)$ used for the second synchronization signal is an interleaved concatenation of two length-31 binary sequences. The concatenated sequence is scrambled with a scrambling sequence given by the primary synchronization signal.

The combination of two length-31 sequences defining the secondary synchronization signal differs between subframe 0 and subframe 5 according to

$$d(2n) = \begin{cases} s_0^{(m_0)}(n)c_0(n) & \text{in subframe 0} \\ s_1^{(m_1)}(n)c_0(n) & \text{in subframe 5} \end{cases}$$
$$d(2n+1) = \begin{cases} s_1^{(m_1)}(n)c_1(n)z_1^{(m_0)}(n) & \text{in subframe 0} \\ s_0^{(m_0)}(n)c_1(n)z_1^{(m_1)}(n) & \text{in subframe 5} \end{cases}$$

where $0 \le n \le 30$. The indices $m_0$ and $m_1$ are derived from the physical-layer cell-identity group $N_{\text{ID}}^{(1)}$ according to

$$m_0 = m' \bmod 31$$
$$m_1 = (m_0 + \lfloor m'/31 \rfloor + 1) \bmod 31$$
$$m' = N_{\text{ID}}^{(1)} + q(q+1)/2, \quad q = \left\lfloor \frac{N_{\text{ID}}^{(1)} + q'(q'+1)/2}{30} \right\rfloor, \quad q' = \lfloor N_{\text{ID}}^{(1)}/30 \rfloor$$

where the output of the above expression is listed in Table 6.11.2.1-1.

The two sequences $s_0^{(m_0)}(n)$ and $s_1^{(m_1)}(n)$ are defined as two different cyclic shifts of the m-sequence $\tilde{s}(n)$ according to

$$s_0^{(m_0)}(n) = \tilde{s}((n+m_0) \bmod 31)$$
$$s_1^{(m_1)}(n) = \tilde{s}((n+m_1) \bmod 31)$$

where $\tilde{s}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i}+5) = (x(\bar{i}+2) + x(\bar{i})) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1$.

The two scrambling sequences $c_0(n)$ and $c_1(n)$ depend on the primary synchronization signal and are defined by two different cyclic shifts of the m-sequence $\tilde{c}(n)$ according to

$$c_0(n) = \tilde{c}((n + N_{\text{ID}}^{(2)}) \bmod 31)$$
$$c_1(n) = \tilde{c}((n + N_{\text{ID}}^{(2)} + 3) \bmod 31)$$

where $N_{\text{ID}}^{(2)} \in \{0,1,2\}$ is the physical-layer identity within the physical-layer cell identity group $N_{\text{ID}}^{(1)}$ and $\tilde{c}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i}+5) = (x(\bar{i}+3) + x(\bar{i})) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1$.

The scrambling sequences $z_1^{(m_0)}(n)$ and $z_1^{(m_1)}(n)$ are defined by a cyclic shift of the m-sequence $\tilde{z}(n)$ according to

$$z_1^{(m_0)}(n) = \tilde{z}((n + (m_0 \bmod 8)) \bmod 31)$$

$$z_1^{(m_1)}(n) = \tilde{z}((n + (m_1 \bmod 8)) \bmod 31)$$

where $m_0$ and $m_1$ are obtained from Table 6.11.2.1-1 and $\tilde{z}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i} + 5) = \left(x(\bar{i} + 4) + x(\bar{i} + 2) + x(\bar{i} + 1) + x(\bar{i})\right) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1$.

**Table 6.11.2.1-1: Mapping between physical-layer cell-identity group $N_{\mathrm{ID}}^{(1)}$ and the indices $m_0$ and $m_1$**

| $N_{\mathrm{ID}}^{(1)}$ | $m_0$ | $m_1$ | $N_{\mathrm{ID}}^{(1)}$ | $m_0$ | $m_1$ | $N_{\mathrm{ID}}^{(1)}$ | $m_0$ | $m_1$ | $N_{\mathrm{ID}}^{(1)}$ | $m_0$ | $m_1$ | $N_{\mathrm{ID}}^{(1)}$ | $m_0$ | $m_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 34 | 4 | 6 | 68 | 9 | 12 | 102 | 15 | 19 | 136 | 22 | 27 |
| 1 | 1 | 2 | 35 | 5 | 7 | 69 | 10 | 13 | 103 | 16 | 20 | 137 | 23 | 28 |
| 2 | 2 | 3 | 36 | 6 | 8 | 70 | 11 | 14 | 104 | 17 | 21 | 138 | 24 | 29 |
| 3 | 3 | 4 | 37 | 7 | 9 | 71 | 12 | 15 | 105 | 18 | 22 | 139 | 25 | 30 |
| 4 | 4 | 5 | 38 | 8 | 10 | 72 | 13 | 16 | 106 | 19 | 23 | 140 | 0 | 6 |
| 5 | 5 | 6 | 39 | 9 | 11 | 73 | 14 | 17 | 107 | 20 | 24 | 141 | 1 | 7 |
| 6 | 6 | 7 | 40 | 10 | 12 | 74 | 15 | 18 | 108 | 21 | 25 | 142 | 2 | 8 |
| 7 | 7 | 8 | 41 | 11 | 13 | 75 | 16 | 19 | 109 | 22 | 26 | 143 | 3 | 9 |
| 8 | 8 | 9 | 42 | 12 | 14 | 76 | 17 | 20 | 110 | 23 | 27 | 144 | 4 | 10 |
| 9 | 9 | 10 | 43 | 13 | 15 | 77 | 18 | 21 | 111 | 24 | 28 | 145 | 5 | 11 |
| 10 | 10 | 11 | 44 | 14 | 16 | 78 | 19 | 22 | 112 | 25 | 29 | 146 | 6 | 12 |
| 11 | 11 | 12 | 45 | 15 | 17 | 79 | 20 | 23 | 113 | 26 | 30 | 147 | 7 | 13 |
| 12 | 12 | 13 | 46 | 16 | 18 | 80 | 21 | 24 | 114 | 0 | 5 | 148 | 8 | 14 |
| 13 | 13 | 14 | 47 | 17 | 19 | 81 | 22 | 25 | 115 | 1 | 6 | 149 | 9 | 15 |
| 14 | 14 | 15 | 48 | 18 | 20 | 82 | 23 | 26 | 116 | 2 | 7 | 150 | 10 | 16 |
| 15 | 15 | 16 | 49 | 19 | 21 | 83 | 24 | 27 | 117 | 3 | 8 | 151 | 11 | 17 |
| 16 | 16 | 17 | 50 | 20 | 22 | 84 | 25 | 28 | 118 | 4 | 9 | 152 | 12 | 18 |
| 17 | 17 | 18 | 51 | 21 | 23 | 85 | 26 | 29 | 119 | 5 | 10 | 153 | 13 | 19 |
| 18 | 18 | 19 | 52 | 22 | 24 | 86 | 27 | 30 | 120 | 6 | 11 | 154 | 14 | 20 |
| 19 | 19 | 20 | 53 | 23 | 25 | 87 | 0 | 4 | 121 | 7 | 12 | 155 | 15 | 21 |
| 20 | 20 | 21 | 54 | 24 | 26 | 88 | 1 | 5 | 122 | 8 | 13 | 156 | 16 | 22 |
| 21 | 21 | 22 | 55 | 25 | 27 | 89 | 2 | 6 | 123 | 9 | 14 | 157 | 17 | 23 |
| 22 | 22 | 23 | 56 | 26 | 28 | 90 | 3 | 7 | 124 | 10 | 15 | 158 | 18 | 24 |
| 23 | 23 | 24 | 57 | 27 | 29 | 91 | 4 | 8 | 125 | 11 | 16 | 159 | 19 | 25 |
| 24 | 24 | 25 | 58 | 28 | 30 | 92 | 5 | 9 | 126 | 12 | 17 | 160 | 20 | 26 |
| 25 | 25 | 26 | 59 | 0 | 3 | 93 | 6 | 10 | 127 | 13 | 18 | 161 | 21 | 27 |
| 26 | 26 | 27 | 60 | 1 | 4 | 94 | 7 | 11 | 128 | 14 | 19 | 162 | 22 | 28 |
| 27 | 27 | 28 | 61 | 2 | 5 | 95 | 8 | 12 | 129 | 15 | 20 | 163 | 23 | 29 |
| 28 | 28 | 29 | 62 | 3 | 6 | 96 | 9 | 13 | 130 | 16 | 21 | 164 | 24 | 30 |
| 29 | 29 | 30 | 63 | 4 | 7 | 97 | 10 | 14 | 131 | 17 | 22 | 165 | 0 | 7 |
| 30 | 0 | 2 | 64 | 5 | 8 | 98 | 11 | 15 | 132 | 18 | 23 | 166 | 1 | 8 |
| 31 | 1 | 3 | 65 | 6 | 9 | 99 | 12 | 16 | 133 | 19 | 24 | 167 | 2 | 9 |
| 32 | 2 | 4 | 66 | 7 | 10 | 100 | 13 | 17 | 134 | 20 | 25 | - | - | - |
| 33 | 3 | 5 | 67 | 8 | 11 | 101 | 14 | 18 | 135 | 21 | 26 | - | - | - |

### 6.11.2.2 Mapping to resource elements

The mapping of the sequence to resource elements depends on the frame structure. In a subframe for frame structure type 1 and in a half-frame for frame structure type 2, the same antenna port as for the primary synchronization signal shall be used for the secondary synchronization signal.

The sequence $d(n)$ shall be mapped to resource elements according to

$$a_{k,l} = d(n), \qquad n = 0,...,61$$

$$k = n - 31 + \frac{N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}}{2}$$

$$l = \begin{cases} N_{\text{symb}}^{\text{DL}} - 2 & \text{in slots 0 and 10} \quad \text{for frame structure type 1} \\ N_{\text{symb}}^{\text{DL}} - 1 & \text{in slots 1 and 11} \quad \text{for frame structure type 2} \end{cases}$$

Resource elements $(k,l)$ where

$$k = n - 31 + \frac{N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}}{2}$$

$$l = \begin{cases} N_{\text{symb}}^{\text{DL}} - 2 & \text{in slots 0 and 10} \quad \text{for frame structure type 1} \\ N_{\text{symb}}^{\text{DL}} - 1 & \text{in slots 1 and 11} \quad \text{for frame structure type 2} \end{cases}$$

$$n = -5,-4,...,-1,62,63,...66$$

are reserved and not used for transmission of the secondary synchronization signal.

# 6.12 OFDM baseband signal generation

The time-continuous signal $s_l^{(p)}(t)$ on antenna port $p$ in OFDM symbol $l$ in a downlink slot is defined by

$$s_l^{(p)}(t) = \sum_{k=-\left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rfloor}^{-1} a_{k^{(-)},l}^{(p)} \cdot e^{j2\pi k\Delta f\left(t-N_{\mathrm{CP},l}T_{\mathrm{s}}\right)} + \sum_{k=1}^{\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rceil} a_{k^{(+)},l}^{(p)} \cdot e^{j2\pi k\Delta f\left(t-N_{\mathrm{CP},l}T_{\mathrm{s}}\right)}$$

for $0 \le t < \left(N_{\mathrm{CP},l} + N\right) \times T_{\mathrm{s}}$ where $k^{(-)} = k + \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rfloor$ and $k^{(+)} = k + \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rfloor - 1$. The variable $N$ equals 2048 for $\Delta f = 15\,\mathrm{kHz}$ subcarrier spacing and 4096 for $\Delta f = 7.5\,\mathrm{kHz}$ subcarrier spacing.

The OFDM symbols in a slot shall be transmitted in increasing order of $l$, starting with $l = 0$, where OFDM symbol $l > 0$ starts at time $\sum_{l'=0}^{l-1}(N_{\mathrm{CP},l'} + N)T_{\mathrm{s}}$ within the slot. In case the first OFDM symbol(s) in a slot use normal cyclic prefix and the remaining OFDM symbols use extended cyclic prefix, the starting position the OFDM symbols with extended cyclic prefix shall be identical to those in a slot where all OFDM symbols use extended cyclic prefix. Thus there will be a part of the time slot between the two cyclic prefix regions where the transmitted signal is not specified.

Table 6.12-1 lists the value of $N_{\mathrm{CP},l}$ that shall be used. Note that different OFDM symbols within a slot in some cases have different cyclic prefix lengths.

**Table 6.12-1: OFDM parameters**

| Configuration | | Cyclic prefix length $N_{\mathrm{CP},l}$ |
|---|---|---|
| Normal cyclic prefix | $\Delta f = 15\,\mathrm{kHz}$ | 160 for $l = 0$<br>144 for $l = 1,2,\ldots,6$ |
| Extended cyclic prefix | $\Delta f = 15\,\mathrm{kHz}$ | 512 for $l = 0,1,\ldots,5$ |
| | $\Delta f = 7.5\,\mathrm{kHz}$ | 1024 for $l = 0,1,2$ |

# 6.13 Modulation and upconversion

Modulation and upconversion to the carrier frequency of the complex-valued OFDM baseband signal for each antenna port is shown in Figure 6.13-1. The filtering required prior to transmission is defined by the requirements in 3GPP TS 36.104 [6].

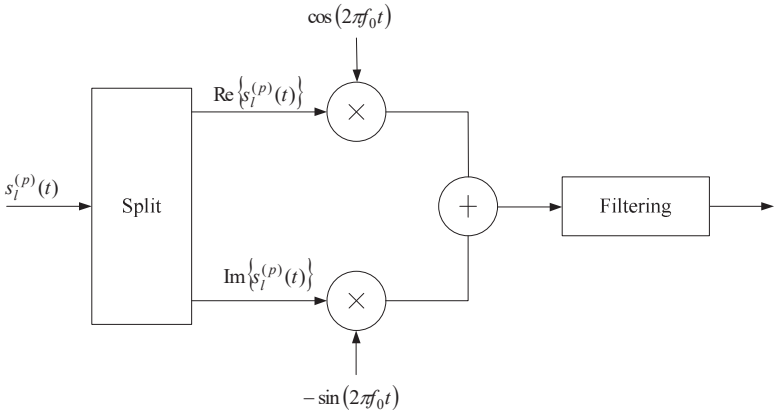



**Figure 6.13-1: Downlink modulation**

# 7 Generic functions

## 7.1 Modulation mapper

The modulation mapper takes binary digits, 0 or 1, as input and produces complex-valued modulation symbols, $x=I+jQ$, as output.

### 7.1.1 BPSK

In case of BPSK modulation, a single bit, $b(i)$, is mapped to a complex-valued modulation symbol $x=I+\mathrm{j}Q$ according to Table 7.1.1-1.

**Table 7.1.1-1: BPSK modulation mapping**

| $b(i)$ | *I* | *Q* |
|---|---|---|
| 0 | $1/\sqrt{2}$ | $1/\sqrt{2}$ |
| 1 | $-1/\sqrt{2}$ | $-1/\sqrt{2}$ |

### 7.1.2 QPSK

In case of QPSK modulation, pairs of bits, $b(i),b(i+1)$, are mapped to complex-valued modulation symbols $x=I+\mathrm{j}Q$ according to Table 7.1.2-1.

**Table 7.1.2-1: QPSK modulation mapping**

| $b(i),b(i+1)$ | *I* | *Q* |
|---|---|---|
| 00 | $1/\sqrt{2}$ | $1/\sqrt{2}$ |
| 01 | $1/\sqrt{2}$ | $-1/\sqrt{2}$ |
| 10 | $-1/\sqrt{2}$ | $1/\sqrt{2}$ |
| 11 | $-1/\sqrt{2}$ | $-1/\sqrt{2}$ |

## 7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i),b(i+1),b(i+2),b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

**Table 7.1.3-1: 16QAM modulation mapping**

| $b(i),b(i+1),b(i+2),b(i+3)$ | *I* | *Q* |
|---|---|---|
| 0000 | $1/\sqrt{10}$ | $1/\sqrt{10}$ |
| 0001 | $1/\sqrt{10}$ | $3/\sqrt{10}$ |
| 0010 | $3/\sqrt{10}$ | $1/\sqrt{10}$ |
| 0011 | $3/\sqrt{10}$ | $3/\sqrt{10}$ |
| 0100 | $1/\sqrt{10}$ | $-1/\sqrt{10}$ |
| 0101 | $1/\sqrt{10}$ | $-3/\sqrt{10}$ |
| 0110 | $3/\sqrt{10}$ | $-1/\sqrt{10}$ |
| 0111 | $3/\sqrt{10}$ | $-3/\sqrt{10}$ |
| 1000 | $-1/\sqrt{10}$ | $1/\sqrt{10}$ |
| 1001 | $-1/\sqrt{10}$ | $3/\sqrt{10}$ |
| 1010 | $-3/\sqrt{10}$ | $1/\sqrt{10}$ |
| 1011 | $-3/\sqrt{10}$ | $3/\sqrt{10}$ |
| 1100 | $-1/\sqrt{10}$ | $-1/\sqrt{10}$ |
| 1101 | $-1/\sqrt{10}$ | $-3/\sqrt{10}$ |
| 1110 | $-3/\sqrt{10}$ | $-1/\sqrt{10}$ |
| 1111 | $-3/\sqrt{10}$ | $-3/\sqrt{10}$ |

## 7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

**Table 7.1.4-1: 64QAM modulation mapping**

| $b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5)$ | $I$ | $Q$ | $b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5)$ | $I$ | $Q$ |
|---|---|---|---|---|---|
| 000000 | $3/\sqrt{42}$ | $3/\sqrt{42}$ | 100000 | $-3/\sqrt{42}$ | $3/\sqrt{42}$ |
| 000001 | $3/\sqrt{42}$ | $1/\sqrt{42}$ | 100001 | $-3/\sqrt{42}$ | $1/\sqrt{42}$ |
| 000010 | $1/\sqrt{42}$ | $3/\sqrt{42}$ | 100010 | $-1/\sqrt{42}$ | $3/\sqrt{42}$ |
| 000011 | $1/\sqrt{42}$ | $1/\sqrt{42}$ | 100011 | $-1/\sqrt{42}$ | $1/\sqrt{42}$ |
| 000100 | $3/\sqrt{42}$ | $5/\sqrt{42}$ | 100100 | $-3/\sqrt{42}$ | $5/\sqrt{42}$ |
| 000101 | $3/\sqrt{42}$ | $7/\sqrt{42}$ | 100101 | $-3/\sqrt{42}$ | $7/\sqrt{42}$ |
| 000110 | $1/\sqrt{42}$ | $5/\sqrt{42}$ | 100110 | $-1/\sqrt{42}$ | $5/\sqrt{42}$ |
| 000111 | $1/\sqrt{42}$ | $7/\sqrt{42}$ | 100111 | $-1/\sqrt{42}$ | $7/\sqrt{42}$ |
| 001000 | $5/\sqrt{42}$ | $3/\sqrt{42}$ | 101000 | $-5/\sqrt{42}$ | $3/\sqrt{42}$ |
| 001001 | $5/\sqrt{42}$ | $1/\sqrt{42}$ | 101001 | $-5/\sqrt{42}$ | $1/\sqrt{42}$ |
| 001010 | $7/\sqrt{42}$ | $3/\sqrt{42}$ | 101010 | $-7/\sqrt{42}$ | $3/\sqrt{42}$ |
| 001011 | $7/\sqrt{42}$ | $1/\sqrt{42}$ | 101011 | $-7/\sqrt{42}$ | $1/\sqrt{42}$ |
| 001100 | $5/\sqrt{42}$ | $5/\sqrt{42}$ | 101100 | $-5/\sqrt{42}$ | $5/\sqrt{42}$ |
| 001101 | $5/\sqrt{42}$ | $7/\sqrt{42}$ | 101101 | $-5/\sqrt{42}$ | $7/\sqrt{42}$ |
| 001110 | $7/\sqrt{42}$ | $5/\sqrt{42}$ | 101110 | $-7/\sqrt{42}$ | $5/\sqrt{42}$ |
| 001111 | $7/\sqrt{42}$ | $7/\sqrt{42}$ | 101111 | $-7/\sqrt{42}$ | $7/\sqrt{42}$ |
| 010000 | $3/\sqrt{42}$ | $-3/\sqrt{42}$ | 110000 | $-3/\sqrt{42}$ | $-3/\sqrt{42}$ |
| 010001 | $3/\sqrt{42}$ | $-1/\sqrt{42}$ | 110001 | $-3/\sqrt{42}$ | $-1/\sqrt{42}$ |
| 010010 | $1/\sqrt{42}$ | $-3/\sqrt{42}$ | 110010 | $-1/\sqrt{42}$ | $-3/\sqrt{42}$ |
| 010011 | $1/\sqrt{42}$ | $-1/\sqrt{42}$ | 110011 | $-1/\sqrt{42}$ | $-1/\sqrt{42}$ |
| 010100 | $3/\sqrt{42}$ | $-5/\sqrt{42}$ | 110100 | $-3/\sqrt{42}$ | $-5/\sqrt{42}$ |
| 010101 | $3/\sqrt{42}$ | $-7/\sqrt{42}$ | 110101 | $-3/\sqrt{42}$ | $-7/\sqrt{42}$ |
| 010110 | $1/\sqrt{42}$ | $-5/\sqrt{42}$ | 110110 | $-1/\sqrt{42}$ | $-5/\sqrt{42}$ |
| 010111 | $1/\sqrt{42}$ | $-7/\sqrt{42}$ | 110111 | $-1/\sqrt{42}$ | $-7/\sqrt{42}$ |
| 011000 | $5/\sqrt{42}$ | $-3/\sqrt{42}$ | 111000 | $-5/\sqrt{42}$ | $-3/\sqrt{42}$ |
| 011001 | $5/\sqrt{42}$ | $-1/\sqrt{42}$ | 111001 | $-5/\sqrt{42}$ | $-1/\sqrt{42}$ |
| 011010 | $7/\sqrt{42}$ | $-3/\sqrt{42}$ | 111010 | $-7/\sqrt{42}$ | $-3/\sqrt{42}$ |
| 011011 | $7/\sqrt{42}$ | $-1/\sqrt{42}$ | 111011 | $-7/\sqrt{42}$ | $-1/\sqrt{42}$ |
| 011100 | $5/\sqrt{42}$ | $-5/\sqrt{42}$ | 111100 | $-5/\sqrt{42}$ | $-5/\sqrt{42}$ |
| 011101 | $5/\sqrt{42}$ | $-7/\sqrt{42}$ | 111101 | $-5/\sqrt{42}$ | $-7/\sqrt{42}$ |
| 011110 | $7/\sqrt{42}$ | $-5/\sqrt{42}$ | 111110 | $-7/\sqrt{42}$ | $-5/\sqrt{42}$ |
| 011111 | $7/\sqrt{42}$ | $-7/\sqrt{42}$ | 111111 | $-7/\sqrt{42}$ | $-7/\sqrt{42}$ |

## 7.2 Pseudo-random sequence generation

Pseudo-random sequences are defined by a length-31 Gold sequence. The output sequence $c(n)$ of length $M_{\text{PN}}$, where $n = 0,1,...,M_{\text{PN}} - 1$, is defined by

$$c(n) = \left(x_1(n + N_C) + x_2(n + N_C)\right) \bmod 2$$
$$x_1(n + 31) = \left(x_1(n + 3) + x_1(n)\right) \bmod 2$$
$$x_2(n + 31) = \left(x_2(n + 3) + x_2(n + 2) + x_2(n + 1) + x_2(n)\right) \bmod 2$$

where $N_C = 1600$ and the first m-sequence shall be initialized with $x_1(0) = 1, x_1(n) = 0, n = 1,2,...,30$. The initialization of the second m-sequence is denoted by $c_{\text{init}} = \sum_{i=0}^{30} x_2(i) \cdot 2^i$ with the value depending on the application of the sequence.

# 8 Timing

## 8.1 Uplink-downlink frame timing

Transmission of the uplink radio frame number $i$ from the UE shall start $(N_{\text{TA}} + N_{\text{TA offset}}) \times T_{\text{s}}$ seconds before the start of the corresponding downlink radio frame at the UE, where $0 \le N_{\text{TA}} \le 20512$, $N_{\text{TA offset}} = 0$ for frame structure type 1 and $N_{\text{TA offset}} = 624$ for frame structure type 2. Note that not all slots in a radio frame may be transmitted. One example hereof is TDD, where only a subset of the slots in a radio frame is transmitted.

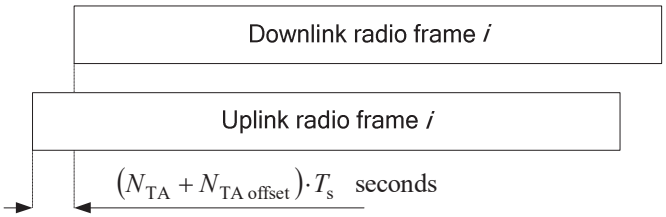



**Figure 8.1-1: Uplink-downlink timing relation**

# Annex A (informative): Change history

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 2006-09-24 | - | - | - | | Draft version created | - | 0.0.0 |
| 2006-10-09 | - | - | - | | Updated skeleton | 0.0.0 | 0.0.1 |
| 2006-10-13 | - | - | - | | Endorsed by RAN1 | 0.0.1 | 0.1.0 |
| 2006-10-23 | - | - | - | | Inclusion of decision from RAN1#46bis | 0.1.0 | 0.1.1 |
| 2006-11-06 | - | - | - | | Updated editor's version | 0.1.1 | 0.1.2 |
| 2006-11-09 | - | - | - | | Updated editor's version | 0.1.2 | 0.1.3 |
| 2006-11-10 | - | - | - | | Endorsed by RAN1#47 | 0.1.3 | 0.2.0 |
| 2006-11-27 | - | - | - | | Editor's version, including decisions from RAN1#47 | 0.2.0 | 0.2.1 |
| 2006-12-14 | - | - | - | | Updated editor's version | 0.2.1 | 0.2.2 |
| 2007-01-15 | - | - | - | | Updated editor's version | 0.2.2 | 0.2.3 |
| 2007-01-19 | - | - | - | | Endorsed by RAN1#47bis | 0.2.3 | 0.3.0 |
| 2007-02-01 | - | - | - | | Editor's version, including decisions from RAN1#47bis | 0.3.0 | 0.3.1 |
| 2007-02-12 | - | - | - | | Updated editor's version | 0.3.1 | 0.3.2 |
| 2007-02-16 | - | - | - | | Endorsed by RAN1#48 | 0.3.2 | 0.4.0 |
| 2007-02-16 | - | - | - | | Editor's version, including decisions from RAN1#48 | 0.4.0 | 0.4.1 |
| 2007-02-21 | - | - | - | | Updated editor's version | 0.4.1 | 0.4.2 |
| 2007-03-03 | RP_35 | RP-070169 | | | For information at RAN#35 | 0.4.2 | 1.0.0 |
| 2007-04-25 | - | - | - | | Editor's version, including decisions from RAN1#48bis and RAN1 TDD Ad Hoc | 1.0.0 | 1.0.1 |
| 2007-05-03 | - | - | - | - | Updated editor's version | 1.0.1 | 1.0.2 |
| 2007-05-08 | - | - | - | - | Updated editor's version | 1.0.2 | 1.0.3 |
| 2007-05-11 | - | - | - | - | Updated editor's version | 1.0.3 | 1.0.4 |
| 2007-05-11 | - | - | - | - | Endorsed by RAN1#49 | 1.0.4 | 1.1.0 |
| 2007-05-15 | - | - | - | - | Editor's version, including decisions from RAN1#49 | 1.1.0 | 1.1.1 |
| 2007-06-05 | - | - | - | - | Updated editor's version | 1.1.1 | 1.1.2 |
| 2007-06-25 | - | - | - | - | Endorsed by RAN1#49bis | 1.1.2 | 1.2.0 |
| 2007-07-10 | - | - | - | - | Editor's version, including decisions from RAN1#49bis | 1.2.0 | 1.2.1 |
| 2007-08-10 | - | - | - | - | Updated editor's version | 1.2.1 | 1.2.2 |
| 2007-08-20 | - | - | - | - | Updated editor's version | 1.2.2 | 1.2.3 |
| 2007-08-24 | - | - | - | - | Endorsed by RAN1#50 | 1.2.3 | 1.3.0 |
| 2007-08-27 | - | - | - | - | Editor's version, including decisions from RAN1#50 | 1.3.0 | 1.3.1 |
| 2007-09-05 | - | - | - | - | Updated editor's version | 1.3.1 | 1.3.2 |
| 2007-09-08 | RP_37 | RP-070729 | - | - | For approval at RAN#37 | 1.3.2 | 2.0.0 |
| 12/09/07 | RP_37 | RP-070729 | | | Approved version | 2.0.0 | 8.0.0 |
| 28/11/07 | RP_38 | RP-070949 | 0001 | - | Introduction of optimized FS2 for TDD | 8.0.0 | 8.1.0 |
| 28/11/07 | RP_38 | RP-070949 | 0002 | - | Introduction of scrambling sequences, uplink reference signal sequences, secondary synchronization sequences and control channel processing | 8.0.0 | 8.1.0 |
| 05/03/08 | RP_39 | RP-080219 | 0003 | 1 | Update of uplink reference-signal hopping, downlink reference signals, scrambling sequences, DwPTS/UpPTS lengths for TDD and control channel processing | 8.1.0 | 8.2.0 |
| 28/05/08 | RP_40 | RP-080432 | 0004 | - | Correction of the number of subcarriers in PUSCH transform precoding | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0005 | - | Correction of PHICH mapping | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0006 | - | Correction of PUCCH resource index for PUCCH format 2 | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0007 | 3 | Correction of the predefined hopping pattern for PUSCH | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0008 | - | Non-binary hashing functions | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0009 | 1 | PUCCH format 1 | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0010 | 1 | CR on Uplink DM RS hopping | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0012 | 1 | Correction to limitation of constellation size of ACK transmission in PUSCH | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0015 | 1 | PHICH mapping for one and two antenna ports in extended CP | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0016 | 1 | Correction of PUCCH in absent of mixed format | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0017 | - | Specification of CCE size and PHICH resource indication | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0018 | 3 | Correction of the description of frame structure type 2 | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0019 | - | On Delta^pucch_shift correction | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0021 | - | Corrections to Secondary Synchronization Signal Mapping | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0022 | - | Downlink VRB mapping to PRB for distributed transmission | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0023 | - | Clarification of modulation symbols to REs mapping for DVRB | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0024 | 1 | Consideration on the scrambling of PDSCH | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0025 | - | Corrections to Initialization of DL RS Scrambling | 8.2.0 | 8.3.0 |

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 28/05/08 | RP_40 | RP-080432 | 0026 | 1 | CR on Downlink RS | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0027 | - | CR on Uplink RS | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0028 | 1 | Fixed timing advance offset for LTE TDD and half-duplex FDD | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0029 | 1 | Timing of random access preamble format 4 | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0030 | 1 | Uplink sounding RS bandwidth configuration | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0031 | - | Use of common RS when UE-specific RS are configured | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0032 | 1 | Uplink RS Updates | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0033 | - | Orthogonal cover sequence for shortened PUCCH format 1a and 1b | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0034 | - | Clarification of PDCCH mapping | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0035 | - | TDD PRACH time/frequency mapping | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0036 | - | Cell Specific Uplink Sounding RS Subframe Configuration | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0038 | - | PDCCH length for carriers with mixed MBSFN and Unicast Traffic | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0040 | - | Correction to the scrambling sequence generation for PUCCH, PCFICH, PHICH, MBSFN RS and UE specific RS | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0041 | - | PDCCH coverage in narrow bandwidths | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0042 | - | Closed-Loop and Open-Loop Spatial Multiplexing | 8.2.0 | 8.3.0 |
| 28/05/08 | RP_40 | RP-080432 | 0043 | - | Removal of small-delay CDD | 8.2.0 | 8.3.0 |
| 09/09/08 | RP_41 | RP-080668 | 48 | 1 | Frequency Shifting of UE-specific RS | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 49 | 1 | Correction of PHICH to RE mapping in extended CP subframe | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 50 | - | Corrections to for handling remaining Res | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 51 | - | PRACH configuration for frame structure type 1 | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 52 | 2 | Correction of PUCCH index generation formula | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 53 | - | Orthogonal cover sequence for shortened PUCCH format 1a and 1b | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 54 | - | Correction of mapping of ACK/NAK to binary bit values | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 56 | 2 | Remaining issues on SRS hopping | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 57 | 1 | Correction of n_cs(n_s) and OC/CS remapping for PUCCH formats 1/1a/1b and 2/2a/2b | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 59 | - | Corrections to Rank information scrambling in Uplink Shared Channel | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 60 | - | Definition on the slot number for frame structure type 2 | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 61 | - | Correction of the Npucch sequence upper limit for the formats 1/1a/1b | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 62 | 1 | Clarifications for DMRS parameters | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 63 | - | Correction of n_prs | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 64 | 1 | Introducing missing L1 parameters to 36.211 | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 65 | 3 | Clarification on reception of synchronization signals | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 66 | - | Correction to the downlink/uplink timing | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 67 | - | ACK/NACK Scrambling scheme on PUCCH | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 68 | - | DCI format1C | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 69 | - | Refinement for REG Definition for n = 4 | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 71 | - | Correcting Ncs value for PRACH preamble format 0-3 | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 73 | - | Correction of the half duplex timing advance offset value | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 74 | - | Correction to Precoding for Transmit Diversity | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 75 | - | Clarification on number of OFDM symbols used for PDCCH | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 77 | - | Number of antenna ports for PDSCH | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 78 | - | Correction to Type 2 PUSCH predetermined hopping for Nsb=1 operation | 8.3.0 | 8.4.0 |
| 09/09/08 | RP_41 | RP-080668 | 79 | - | PRACH frequency location | 8.3.0 | 8.4.0 |
| 03/12/08 | RP_42 | RP-081074 | 70 | 1 | Correction for the definition of UE-specific reference signals | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 72 | 2 | Corrections to precoding for large delay CDD | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 80 | - | Correction to the definition of nbar_oc for extended CP | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 81 | 1 | Specification of reserved REs not used for RS | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 82 | 2 | Clarification of the random access preamble transmission timing | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 83 | 1 | Indexing of PRACH resources within the radio frame | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 84 | 6 | Alignment of RAN1/RAN2 specification | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 86 | - | Clarification on scrambling of ACK/NAK bits for PUCCH format 2a/2b | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 87 | - | Correction of introduction of shortened SR | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 88 | - | Corrections to 36.211 | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 89 | - | Clarification on PUSCH DM RS Cyclic Shift Hopping | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 92 | 1 | Correction to the uplink DM RS assignment | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 93 | - | Clarify the RNTI used in scrambling sequence initialization | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 94 | 1 | On linkage Among UL Power Control Parameters | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 95 | - | Clarification on PUSCH pre-determined hopping pattern | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 96 | - | Clarification of SRS sequence-group and base sequence number | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 97 | 1 | SRS subframe configuration | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 98 | - | Remaining SRS details for TDD | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 99 | - | Clarifying UL VRB Allocation | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 100 | - | Clarification on PUCCH resource hopping | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 101 | - | Correction for definition of Qm and a pseudo code syntax error in Scrambling. | 8.4.0 | 8.5.0 |

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| 03/12/08 | RP_42 | RP-081074 | 106 | - | Correction of reference to RAN4 specification of supported uplink bandwidth | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 107 | - | General corrections to SRS | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 109 | 2 | Correction to PCFICH specification | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 110 | 1 | Correction to Layer Mapping for Transmit Diversity with Four Antenna Ports | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 111 | - | Correction of the mapping of cyclic shift filed in DCI format 0 to the dynamic cyclic shift offset | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 112 | - | DRS collision handling | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 113 | - | Clarification to enable reuse of non-active PUCCH CQI RBs for PUSCH | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 114 | 1 | PUSCH Mirror Hopping operation | 8.4.0 | 8.5.0 |
| 03/12/08 | RP_42 | RP-081074 | 108 | 1 | Extended and normal cyclic prefix in DL and UL for LTE TDD | 8.4.0 | 8.5.0 |
| 04/03/09 | RP_43 | RP-090234 | 115 | 1 | Alignment of PRACH configuration index for FS type 1 and type 2 | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 118 | 1 | Clarification for DRS Collision handling | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 121 | 1 | Removing inverse modulo operation | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 123 | 1 | Clarification on the use of preamble format 4 | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 124 | - | Clarification of RNTI used in scrambling sequence | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 125 | 1 | Clarifying PDCCH RE mapping | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 126 | - | Correction of preamble format 4 timing | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 127 | 2 | Corrections to SRS | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 128 | 2 | Clarification of PDSCH Mapping to Resource Elements | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 129 | 1 | Alignment with correct ASN1 parameter names | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 130 | - | Correction to PUCCH format 1 mapping to physical resources | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 132 | - | Correction to type-2 PUSCH hopping | 8.5.0 | 8.6.0 |
| 04/03/09 | RP_43 | RP-090234 | 134 | - | Alignment of SRS configuration | 8.5.0 | 8.6.0 |
| 27/05/09 | RP_44 | RP-090527 | 135 | - | Correction on UE behavior for PRACH 20ms periodicity | 8.6.0 | 8.7.0 |
| 15/09/09 | RP_45 | RP-090888 | 137 | 1 | Clarification on DMRS sequence for PUSCH | 8.7.0 | 8.8.0 |
| 15/09/09 | RP_45 | RP-090888 | 138 | 1 | Correction to PHICH resource mapping for TDD and to PHICH scrambling | 8.7.0 | 8.8.0 |
| 01/12/09 | RP_46 | RP-091168 | 142 | - | Clarification of the transmit condition for UE specific reference signals | 8.8.0 | 8.9.0 |
| 01/12/09 | RP_46 | RP-091172 | 139 | 2 | Introduction of LTE positioning | 8.9.0 | 9.0.0 |
| 01/12/09 | RP_46 | RP-091177 | 140 | 3 | Editorial corrections to 36.211 | 8.9.0 | 9.0.0 |
| 01/12/09 | RP_46 | RP-091257 | 141 | 1 | Introduction of enhanced dual layer transmission | 8.9.0 | 9.0.0 |
| 16/03/10 | RP_47 | RP-100209 | 144 | 1 | Removal of square brackets on positioning subframe periodicities | 9.0.0 | 9.1.0 |
| 16/03/10 | RP_47 | RP-100209 | 145 | - | Clarification of the CP length of empty OFDM symbols in PRS subframes | 9.0.0 | 9.1.0 |
| 16/03/10 | RP_47 | RP-100210 | 146 | - | Clarification of MBSFN subframe definition | 9.0.0 | 9.1.0 |
| 07/12/10 | RP_50 | RP-101320 | 148 | - | Introduction of Rel-10 LTE-Advanced features in 36.211 | 9.1.0 | 10.0.0 |
| 15/03/11 | RP_51 | RP-110254 | 149 | 1 | Correction on UE behavior for PRACH preamble format 4 | 10.0.0 | 10.1.0 |
| 15/03/11 | RP_51 | RP-110256 | 150 | - | Corrections to Rel-10 LTE-Advanced features in 36.211 | 10.0.0 | 10.1.0 |
| 01/06/11 | RP_52 | RP-110818 | 153 | 2 | PUSCH interaction with periodic SRS | 10.1.0 | 10.2.0 |
| 01/06/11 | RP_52 | RP-110819 | 154 | 1 | Correction on describing PUCCH format 3 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP_52 | RP-110821 | 155 | 3 | Correction on codebooks for CSI-RS based feedback for up to 4 CSI-RS ports. | 10.1.0 | 10.2.0 |
| 01/06/11 | RP_52 | RP-110821 | 156 | - | Correction on overlapping non-zero-power and zero-power CSI-RS configurations | 10.1.0 | 10.2.0 |
| 01/06/11 | RP_52 | RP-110821 | 157 | - | Correction on CSI-RS configuration | 10.1.0 | 10.2.0 |
| 01/06/11 | RP_52 | RP-110821 | 158 | - | PDSCH transmission in MBSFN subframes | 10.1.0 | 10.2.0 |
| 01/06/11 | RP_52 | RP-110823 | 159 | - | Correction on implicit derivation of transmission comb per antenna port for SRS | 10.1.0 | 10.2.0 |
| 01/06/11 | RP_52 | RP-110823 | 160 | - | Uplink DMRS sequence in RACH procedure | 10.1.0 | 10.2.0 |
| 15/09/11 | RP_53 | RP-111229 | 162 | - | Corrections on DMRS for Extended CP | 10.2.0 | 10.3.0 |
| 15/09/11 | RP_53 | RP-111228 | 163 | - | Clarification of applicability of precoding power scaling factors for PDSCH | 10.2.0 | 10.3.0 |
| 15/09/11 | RP_53 | RP-111228 | 164 | - | Correction to modulation and upconversion on PRACH | 10.2.0 | 10.3.0 |
| 15/09/11 | RP_53 | RP-111229 | 165 | - | Clarification on cyclic prefix of PDSCH in MBSFN subframes | 10.2.0 | 10.3.0 |
| 15/09/11 | RP_53 | RP-111229 | 166 | 3 | Corrections on indication in scrambling identity field in DCI format 2B and 2C | 10.2.0 | 10.3.0 |
| 05/12/11 | RP_54 | RP-111668 | 167 | - | A correction to PDSCH precoding for CQI calculation | 10.3.0 | 10.4.0 |
| 05/12/11 | RP_54 | RP-111668 | 168 | - | Correction to figure of CSI-RS pattern in extended-CP subframe | 10.3.0 | 10.4.0 |
| 13/06/12 | RP_56 | RP-120736 | 169 | - | Correction to resource mapping for PDSCH | 10.4.0 | 10.5.0 |
| 13/06/12 | RP_56 | RP-120739 | 171 | - | Correction for DMRS group hopping and sequence hopping | 10.4.0 | 10.5.0 |
| 13/06/12 | RP_56 | RP-120738 | 172 | - | Correction to assumed CSI-RS transmissions in subframes used for paging | 10.4.0 | 10.5.0 |
| 04/09/12 | RP_57 | RP-121274 | 170 | 4 | Introduction of an additional special subframe configuration | 10.5.0 | 11.0.0 |
| 04/09/12 | RP_57 | RP-121272 | 173 | - | Inclusion of Rel-11 features | 10.5.0 | 11.0.0 |
| 04/12/12 | RP_58 | RP-121839 | 175 | - | Correction to assumed CSI-RS transmissions in secondary cells | 11.0.0 | 11.1.0 |
| 04/12/12 | RP_58 | RP-121846 | 176 | - | Correction to assumed CSI-RS transmissions in secondary cells | 11.0.0 | 11.1.0 |

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| 26/02/13 | RP_59 | RP-130254 | 178 | - | Clarification of CSI RS mapping to resource elements | 11.1.0 | 11.2.0 |
| 26/02/13 | RP_59 | RP-130254 | 180 | - | Correction to CSI Reference Signals | 11.1.0 | 11.2.0 |
| 26/02/13 | RP_59 | RP-130255 | 181 | - | Additional clarifications/corrections for introducing Rel-11 features | 11.1.0 | 11.2.0 |
| 11/06/13 | RP_60 | RP-130752 | 182 | - | Correction to EPDCCH PRB pair indication | 11.2.0 | 11.3.0 |
| 11/06/13 | RP_60 | RP-130752 | 183 | - | CR on collision between EPDCCH and PSS/SSS/PBCH | 11.2.0 | 11.3.0 |
| 03/09/13 | | | | | MCC clean-up | 11.3.0 | 11.4.0 |
| 03/09/13 | RP_60 | RP-131250 | 185 | - | Correction to QCL behaviour on CRS | 11.3.0 | 11.4.0 |
| 03/12/13 | RP_62 | RP-131894 | 186 | - | Correction on the derivation of the non-MBSFN region by PCFICH | 11.4.0 | 11.5.0 |
| 10/09/14 | RP_65 | RP-141477 | 193 | - | CR on port 5 UE-specific reference signal when PDSCH is overlapped with EPDCCH | 11.5.0 | 11.6.0 |

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*Technical Specification*

## 3rd Generation Partnership Project;
## Technical Specification Group Radio Access Network;
## Evolved Universal Terrestrial Radio Access (E-UTRA);
## Physical layer procedures
## (Release 11)







**Petitioners' Exhibit 1025**
**Google et al. v. KT Corporation et al.**
**IPR2025-00291**

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# Foreword

This Technical Specification (TS) has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of this present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

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  - 2 presented to TSG for approval;
  - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

# 1 Scope

The present document specifies and establishes the characteristics of the physicals layer procedures in the FDD and TDD modes of E-UTRA.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document.*

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer – General Description".

[3] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation".

[4] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".

[5] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer – Measurements".

[6] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".

[7] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

[8] 3GPP TS 36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".

[9] 3GPP TS 36.423, "Evolved Universal Terrestrial Radio Access (E-UTRA); X2 Application Protocol (X2AP)".

[10] 3GPP TS 36.133, "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management".

[11] 3GPP TS 36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification".

[12] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".

# 3 Symbols and abbreviations

## 3.1 Symbols

For the purposes of the present document, the following symbols apply:

| | |
|---|---|
| $n_f$ | System frame number as defined in [3] |
| $n_s$ | Slot number within a radio frame as defined in [3] |
| $N_{cells}^{DL}$ | Number of configured cells |
| $N_{\mathrm{RB}}^{\mathrm{DL}}$ | Downlink bandwidth configuration, expressed in units of $N_{\mathrm{sc}}^{\mathrm{RB}}$ as defined in [3] |
| $N_{\mathrm{RB}}^{\mathrm{UL}}$ | Uplink bandwidth configuration, expressed in units of $N_{\mathrm{sc}}^{\mathrm{RB}}$ as defined in [3] |
| $N_{\mathrm{symb}}^{\mathrm{UL}}$ | Number of SC-FDMA symbols in an uplink slot as defined in [3] |
| $N_{\mathrm{sc}}^{\mathrm{RB}}$ | Resource block size in the frequency domain, expressed as a number of subcarriers as defined in [3] |
| $T_s$ | Basic time unit as defined in [3] |

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

| | |
|---|---|
| ACK | Acknowledgement |
| BCH | Broadcast Channel |
| CCE | Control Channel Element |
| CDD | Cyclic Delay Diversity |
| CIF | Carrier Indicator Field |
| CQI | Channel Quality Indicator |
| CRC | Cyclic Redundancy Check |
| CSI | Channel State Information |
| CSI-IM | CSI-interference measurement |
| DAI | Downlink Assignment Index |
| DCI | Downlink Control Information |
| DL | Downlink |
| DL-SCH | Downlink Shared Channel |
| DTX | Discontinuous Transmission |
| EPDCCH | Enhanced Physical Downlink Control Channel |
| EPRE | Energy Per Resource Element |
| MCS | Modulation and Coding Scheme |
| NACK | Negative Acknowledgement |
| PBCH | Physical Broadcast Channel |
| PCFICH | Physical Control Format Indicator Channel |
| PDCCH | Physical Downlink Control Channel |
| PDSCH | Physical Downlink Shared Channel |
| PHICH | Physical Hybrid ARQ Indicator Channel |
| PMCH | Physical Multicast Channel |
| PMI | Precoding Matrix Indicator |
| PRACH | Physical Random Access Channel |
| PRS | Positioning Reference Signal |
| PRB | Physical Resource Block |
| PUCCH | Physical Uplink Control Channel |
| PUSCH | Physical Uplink Shared Channel |
| PTI | Precoding Type Indicator |
| RBG | Resource Block Group |

| | |
|---|---|
| RE | Resource Element |
| RI | Rank Indication |
| RS | Reference Signal |
| SINR | Signal to Interference plus Noise Ratio |
| SPS C-RNTI | Semi-Persistent Scheduling C-RNTI |
| SR | Scheduling Request |
| SRS | Sounding Reference Symbol |
| TAG | Timing Advance Group |
| TBS | Transport Block Size |
| UCI | Uplink Control Information |
| UE | User Equipment |
| UL | Uplink |
| UL-SCH | Uplink Shared Channel |
| VRB | Virtual Resource Block |

# 4 Synchronization procedures

## 4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards.

The following signals are transmitted in the downlink to facilitate cell search: the primary and secondary synchronization signals.

A UE may assume the antenna ports 0 – 3 and the antenna port for the primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

## 4.2 Timing synchronization

### 4.2.1 Radio link monitoring

The downlink radio link quality of the primary cell shall be monitored by the UE for the purpose of indicating out-of-sync/in-sync status to higher layers.

In non-DRX mode operation, the physical layer in the UE shall every radio frame assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds ($Q_{out}$ and $Q_{in}$) defined by relevant tests in [10].

In DRX mode operation, the physical layer in the UE shall at least once every DRX period assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds ($Q_{out}$ and $Q_{in}$) defined by relevant tests in [10].

If higher-layer signalling indicates certain subframes for restricted radio link monitoring, the radio link quality shall not be monitored in any subframe other than those indicated.

The physical layer in the UE shall in radio frames where the radio link quality is assessed indicate out-of-sync to higher layers when the radio link quality is worse than the threshold $Q_{out}$. When the radio link quality is better than the threshold $Q_{in}$, the physical layer in the UE shall in radio frames where the radio link quality is assessed indicate in-sync to higher layers.

### 4.2.2 Inter-cell synchronization

No functionality is specified in this subclause in this release.

### 4.2.3 Transmission timing adjustments

Upon reception of a timing advance command for a TAG containing the primary cell, the UE shall adjust uplink transmission timing for PUCCH/PUSCH/SRS of the primary cell based on the received timing advance command. The UL transmission timing for PUSCH/SRS of a secondary cell is the same as the primary cell if the secondary cell and the primary cell belong to the same TAG.

Upon reception of a timing advance command for a TAG not containing the primary cell, the UE shall adjust uplink transmission timing for PUSCH/SRS of all the secondary cells in the TAG based on the received timing advance command where the UL transmission timing for PUSCH /SRS is the same for all the secondary cells in the TAG.

The timing advance command for a TAG indicates the change of the uplink timing relative to the current uplink timing for the TAG as multiples of 16 $T_s$ . The start timing of the random access preamble is specified in [3].

In case of random access response, an 11-bit timing advance command [8], $T_A$, for a TAG indicates $N_{TA}$ values by index values of $T_A = 0, 1, 2, ..., 1282$, where an amount of the time alignment for the TAG is given by $N_{TA} = T_A \times 16$. $N_{TA}$ is defined in [3].

In other cases, a 6-bit timing advance command [8], $T_A$, for a TAG indicates adjustment of the current $N_{TA}$ value, $N_{TA,old}$, to the new $N_{TA}$ value, $N_{TA,new}$, by index values of $T_A = 0, 1, 2,..., 63$, where $N_{TA,new} = N_{TA,old} + (T_A - 31) \times 16$. Here, adjustment of $N_{TA}$ value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing for the TAG by a given amount respectively.

For a timing advance command received on subframe *n*, the corresponding adjustment of the uplink transmission timing shall apply from the beginning of subframe *n+6*. For serving cells in the same TAG, when the UE's uplink PUCCH/PUSCH/SRS transmissions in subframe *n* and subframe *n*+1 are overlapped due to the timing adjustment, the UE shall complete transmission of subframe *n* and not transmit the overlapped part of subframe *n*+1.

If the received downlink timing changes and is not compensated or is only partly compensated by the uplink timing adjustment without timing advance command as specified in [10], the UE changes $N_{TA}$ accordingly.

## 4.3 Timing for Secondary Cell Activation / Deactivation

When a UE receives an activation command [8] for a secondary cell in subframe *n*, the corresponding actions in [8] shall be applied no later than the minimum requirement defined in [10] and no earlier than subframe n+8, except for the following:

- the actions related to CSI reporting
- the actions related to the *sCellDeactivationTimer* associated with the secondary cell [8]

which shall be applied in subframe *n+8*.

When a UE receives a deactivation command [8] for a secondary cell or the *sCellDeactivationTimer* associated with the secondary cell expires in subframe *n*, the corresponding actions in [8] shall apply no later than the minimum requirement defined in [10], except for the actions related to CSI reporting which shall be applied in subframe *n+8*.

# 5 Power control

Downlink power control determines the Energy Per Resource Element (EPRE). The term Resource Element Energy denotes the energy prior to CP insertion. The term resource element energy also denotes the average energy taken over all constellation points for the modulation scheme applied. Uplink power control determines the average power over a SC-FDMA symbol in which the physical channel is transmitted.

## 5.1 Uplink power control

Uplink power control controls the transmit power of the different uplink physical channels.

For PUSCH, the transmit power $\hat{P}_{\text{PUSCH},c}(i)$ defined in subclause 5.1.1, is first scaled by the ratio of the number of antennas ports with a non-zero PUSCH transmission to the number of configured antenna ports for the transmission scheme. The resulting scaled power is then split equally across the antenna ports on which the non-zero PUSCH is transmitted.

For PUCCH or SRS, the transmit power $\hat{P}_{\text{PUCCH}}(i)$, defined in subclause 5.1.1.1, or $\hat{P}_{\text{SRS,c}}(i)$ is split equally across the configured antenna ports for PUCCH or SRS. $\hat{P}_{\text{SRS,c}}(i)$ is the linear value of $P_{\text{SRS,c}}(i)$ defined in subclause 5.1.3.

A cell wide overload indicator (OI) and a High Interference Indicator (HII) to control UL interference are defined in [9].

### 5.1.1 Physical uplink shared channel

#### 5.1.1.1 UE behaviour

The setting of the UE Transmit power for a Physical Uplink Shared Channel (PUSCH) transmission is defined as follows.

If the UE transmits PUSCH without a simultaneous PUCCH for the serving cell $c$, then the UE transmit power $P_{\text{PUSCH},c}(i)$ for PUSCH transmission in subframe $i$ for the serving cell $c$ is given by

$$P_{\text{PUSCH,c}}(i) = \min\begin{Bmatrix} P_{\text{CMAX},c}(i), \\ 10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i) \end{Bmatrix} \text{ [dBm]}$$

If the UE transmits PUSCH simultaneous with PUCCH for the serving cell $c$, then the UE transmit power $P_{\text{PUSCH},c}(i)$ for the PUSCH transmission in subframe $i$ for the serving cell $c$ is given by

$$P_{\text{PUSCH,c}}(i) = \min\begin{Bmatrix} 10\log_{10}\left(\hat{P}_{\text{CMAX},c}(i) - \hat{P}_{\text{PUCCH}}(i)\right), \\ 10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i) \end{Bmatrix} \text{ [dBm]}$$

If the UE is not transmitting PUSCH for the serving cell c, for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall assume that the UE transmit power $P_{\text{PUSCH},c}(i)$ for the PUSCH transmission in subframe $i$ for the serving cell $c$ is computed by

$$P_{\text{PUSCH,c}}(i) = \min\left\{P_{\text{CMAX,c}}(i),\ P_{\text{O_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right\} \quad \text{[dBm]}$$

where,

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe $i$ for serving cell $c$ and $\hat{P}_{\text{CMAX,c}}(i)$ is the linear value of $P_{\text{CMAX,c}}(i)$. If the UE transmits PUCCH without PUSCH in subframe $i$ for the serving cell c, for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall assume $P_{\text{CMAX,c}}(i)$ as given by subclause 5.1.2.1. If the UE does not transmit PUCCH and PUSCH in subframe $i$ for the serving cell c, for the accumulation of TPC command received with DCI format 3/3A

for PUSCH, the UE shall compute $P_{\mathrm{CMAX,c}}(i)$ assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and $\Delta T_C$ =0dB, where MPR, A-MPR, P-MPR and $\Delta T_C$ are defined in [6].

- $\hat{P}_{\mathrm{PUCCH}}(i)$ is the linear value of $P_{\mathrm{PUCCH}}(i)$ defined in subclause 5.1.2.1
- $M_{\mathrm{PUSCH,c}}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for subframe $i$ and serving cell $c$.
- $P_{\mathrm{O_PUSCH,c}}(j)$ is a parameter composed of the sum of a component $P_{\mathrm{O_NOMINAL_PUSCH,c}}(j)$ provided from higher layers for $j=0$ and $1$ and a component $P_{\mathrm{O_UE_PUSCH,c}}(j)$ provided by higher layers for $j=0$ and $1$ for serving cell $c$. For PUSCH (re)transmissions corresponding to a semi-persistent grant then $j=0$, for PUSCH (re)transmissions corresponding to a dynamic scheduled grant then $j=1$ and for PUSCH (re)transmissions corresponding to the random access response grant then $j=2$. $P_{\mathrm{O_UE_PUSCH,c}}(2) = 0$ and $P_{\mathrm{O_NOMINAL_PUSCH,c}}(2) = P_{\mathrm{O_PRE}} + \Delta_{PREAMBLE_Msg3}$, where the parameter *preambleInitialReceivedTargetPower* [8] ($P_{\mathrm{O_PRE}}$) and $\Delta_{PREAMBLE_Msg3}$ are signalled from higher layers for serving cell $c$.
- For $j$ =0 or $1$, $\alpha_c \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$ is a 3-bit parameter provided by higher layers for serving cell $c$. For j=2, $\alpha_c(j) = 1$.
- $PL_c$ is the downlink pathloss estimate calculated in the UE for serving cell $c$ in dB and $PL_c$ = *referenceSignalPower* – higher layer filtered RSRP, where *referenceSignalPower* is provided by higher layers and RSRP is defined in [5] for the reference serving cell and the higher layer filter configuration is defined in [11] for the reference serving cell. If serving cell $c$ belongs to a TAG containing the primary cell then, for the uplink of the primary cell, the primary cell is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP. For the uplink of the secondary cell, the serving cell configured by the higher layer parameter *pathlossReferenceLinking* defined in [11] is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP. If serving cell $c$ belongs to a TAG not containing the primary cell then serving cell $c$ is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP.
- $\Delta_{TF,c}(i) = 10\log_{10}\left(\left(2^{BPRE\cdot K_s} - 1\right)\cdot \beta_{offset}^{PUSCH}\right)$ for $K_S = 1.25$ and 0 for $K_S = 0$ where $K_S$ is given by the parameter *deltaMCS-Enabled* provided by higher layers for each serving cell $c$. $BPRE$ and $\beta_{offset}^{PUSCH}$, for each serving cell $c$, are computed as below. $K_S = 0$ for transmission mode 2.
  - $BPRE = O_{\mathrm{CQI}} / N_{\mathrm{RE}}$ for control data sent via PUSCH without UL-SCH data and $\sum_{r=0}^{C-1} K_r / N_{\mathrm{RE}}$ for other cases.
    - where $C$ is the number of code blocks, $K_r$ is the size for code block $r$, $O_{\mathrm{CQI}}$ is the number of CQI/PMI bits including CRC bits and $N_{\mathrm{RE}}$ is the number of resource elements determined as $N_{\mathrm{RE}} = M_{sc}^{PUSCH-initial} \cdot N_{\mathrm{symb}}^{\mathrm{PUSCH\text{-}initial}}$, where $C$, $K_r$, $M_{sc}^{PUSCH-initial}$ and $N_{\mathrm{symb}}^{\mathrm{PUSCH\text{-}initial}}$ are defined in [4].
  - $\beta_{offset}^{PUSCH} = \beta_{offset}^{CQI}$ for control data sent via PUSCH without UL-SCH data and $1$ for other cases.
- $\delta_{\mathrm{PUSCH,c}}$ is a correction value, also referred to as a TPC command and is included in PDCCH/EPDCCH with DCI format 0/4 for serving cell $c$ or jointly coded with other TPC commands in PDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUSCH-RNTI. The current PUSCH power control adjustment state for serving cell $c$ is given by $f_c(i)$ which is defined by:
  - $f_c(i) = f_c(i-1) + \delta_{\mathrm{PUSCH,c}}(i - K_{\mathrm{PUSCH}})$ if accumulation is enabled based on the parameter *Accumulation-enabled* provided by higher layers or if the TPC command $\delta_{\mathrm{PUSCH,c}}$ is included in a

PDCCH/EPDCCH with DCI format 0 for serving cell $c$ where the CRC is scrambled by the Temporary C-RNTI

- where $\delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ was signalled on PDCCH/EPDCCH with DCI format 0/4 or PDCCH with DCI format 3/3A on subframe $i - K_{PUSCH}$, and where $f_c(0)$ is the first value after reset of accumulation.
- The value of $K_{PUSCH}$ is
  - For FDD, $K_{PUSCH} = 4$
  - For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, the "TDD UL/DL configuration" refers to the UL-reference UL/DL configuration (defined in subclause 8.0) for serving cell $c$.
  - For TDD UL/DL configurations 1-6, $K_{PUSCH}$ is given in Table 5.1.1.1-1
  - For TDD UL/DL configuration 0
    - If the PUSCH transmission in subframe *2* or *7* is scheduled with a PDCCH/EPDCCH of DCI format 0/4 in which the LSB of the UL index is set to 1, $K_{PUSCH} = 7$
    - For all other PUSCH transmissions, $K_{PUSCH}$ is given in Table 5.1.1.1-1.
- For serving cell $c$ the UE attempts to decode a PDCCH/EPDCCH of DCI format 0/4 with the UE's C-RNTI or DCI format 0 for SPS C-RNTI and a PDCCH of DCI format 3/3A with this UE's TPC-PUSCH-RNTI in every subframe except when in DRX or where serving cell $c$ is deactivated.
- If DCI format 0/4 for serving cell $c$ and DCI format 3/3A are both detected in the same subframe, then the UE shall use the $\delta_{\text{PUSCH,c}}$ provided in DCI format 0/4.
- $\delta_{\text{PUSCH,c}} = 0$ dB for a subframe where no TPC command is decoded for serving cell $c$ or where DRX occurs or $i$ is not an uplink subframe in TDD.
- The $\delta_{\text{PUSCH,c}}$ dB accumulated values signalled on PDCCH/EPDCCH with DCI format 0/4 are given in Table 5.1.1.1-2. If the PDCCH/EPDCCH with DCI format 0 is validated as a SPS activation or release PDCCH/EPDCCH, then $\delta_{\text{PUSCH,c}}$ is 0dB.
- The $\delta_{\text{PUSCH}}$ dB accumulated values signalled on PDCCH with DCI format 3/3A are one of SET1 given in Table 5.1.1.1-2 or SET2 given in Table 5.1.1.1-3 as determined by the parameter *TPC-Index* provided by higher layers.
- If UE has reached $P_{\text{CMAX,c}}(i)$ for serving cell $c$, positive TPC commands for serving cell $c$ shall not be accumulated
- If UE has reached minimum power, negative TPC commands shall not be accumulated
- UE shall reset accumulation
  - For serving cell $c$, when $P_{\text{O_UE_PUSCH,c}}$ value is changed by higher layers
  - For serving cell $c$, when the UE receives random access response message for serving cell $c$

- $f_c(i) = \delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ if accumulation is not enabled for serving cell $c$ based on the parameter *Accumulation-enabled* provided by higher layers
  - where $\delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ was signalled on PDCCH/EPDCCH with DCI format 0/4 for serving cell $c$ on subframe $i - K_{PUSCH}$
  - The value of $K_{PUSCH}$ is

- For FDD, $K_{PUSCH} = 4$
- For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, the "TDD UL/DL configuration" refers to the UL-reference UL/DL configuration (defined in subclause 8.0) for serving cell $c$.
- For TDD UL/DL configurations 1-6, $K_{PUSCH}$ is given in Table 5.1.1.1-1.
- For TDD UL/DL configuration 0
  - If the PUSCH transmission in subframe *2* or *7* is scheduled with a PDCCH/EPDCCH of DCI format 0/4 in which the LSB of the UL index is set to 1, $K_{PUSCH} = 7$
  - For all other PUSCH transmissions, $K_{PUSCH}$ is given in Table 5.1.1.1-1.

▪ The $\delta_{\text{PUSCH,c}}$ dB absolute values signalled on PDCCH/EPDCCH with DCI format 0/4 are given in Table 5.1.1.1-2. If the PDCCH/EPDCCH with DCI format 0 is validated as a SPS activation or release PDCCH/EPDCCH, then $\delta_{\text{PUSCH,c}}$ is 0dB.

▪ $f_c(i) = f_c(i-1)$ for a subframe where no PDCCH/EPDCCH with DCI format 0/4 is decoded for serving cell $c$ or where DRX occurs or $i$ is not an uplink subframe in TDD.

o For both types of $f_c(*)$ (accumulation or current absolute) the first value is set as follows:

▪ If $P_{\text{O_UE_PUSCH,c}}$ value is changed by higher layers and serving cell $c$ is the primary cell or, if $P_{\text{O_UE_PUSCH,c}}$ value is received by higher layers and serving cell $c$ is a Secondary cell

- $f_c(0) = 0$

▪ Else

- If the UE receives the random access response message for a serving cell $c$
  - $f_c(0) = \Delta P_{rampupc} + \delta_{msg2,c}$, where
    - $\delta_{msg2,c}$ is the TPC command indicated in the random access response corresponding to the random access preamble transmitted in the serving cell $c$, see subclause 6.2, and
    - $$\Delta P_{rampup,c} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \begin{pmatrix} 10\log_{10}(M_{PUSCH,c}(0)) \\ + P_{O_PUSCH,c}(2) + \delta_{msg2} \\ + \alpha_c(2)\cdot PL + \Delta_{TF,c}(0) \end{pmatrix}\right)\right\}, \Delta P_{rampuprequested,c}\right]$$

      and $\Delta P_{rampuprequested,c}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last preamble in the serving cell $c$, $M_{\text{PUSCH,c}}(0)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for the subframe of first PUSCH transmission in the serving cell $c$, and $\Delta_{TF,c}(0)$ is the

power adjustment of first PUSCH transmission in the serving cell *c*.

**Table 5.1.1.1-1: $K_{PUSCH}$ for TDD configuration 0-6**

| TDD UL/DL Configuration | subframe number *i* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | - | - | 6 | 7 | 4 | - | - | 6 | 7 | 4 |
| 1 | - | - | 6 | 4 | - | - | - | 6 | 4 | - |
| 2 | - | - | 4 | - | - | - | - | 4 | - | - |
| 3 | - | - | 4 | 4 | 4 | - | - | - | - | - |
| 4 | - | - | 4 | 4 | - | - | - | - | - | - |
| 5 | - | - | 4 | - | - | - | - | - | - | - |
| 6 | - | - | 7 | 7 | 5 | - | - | 7 | 7 | - |

**Table 5.1.1.1-2: Mapping of TPC Command Field in DCI format 0/3/4 to absolute and accumulated $\delta_{\mathrm{PUSCH,c}}$ values**

| TPC Command Field in DCI format 0/3/4 | Accumulated $\delta_{\mathrm{PUSCH,c}}$ [dB] | Absolute $\delta_{\mathrm{PUSCH,c}}$ [dB] only DCI format 0/4 |
|---|---|---|
| 0 | -1 | -4 |
| 1 | 0 | -1 |
| 2 | 1 | 1 |
| 3 | 3 | 4 |

**Table 5.1.1.1-3: Mapping of TPC Command Field in DCI format 3A to accumulated $\delta_{\mathrm{PUSCH,c}}$ values**

| TPC Command Field in DCI format 3A | Accumulated $\delta_{\mathrm{PUSCH,c}}$ [dB] |
|---|---|
| 0 | -1 |
| 1 | 1 |

If the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\mathrm{PUSCH},c}(i)$ for the serving cell $c$ in subframe *i* such that the condition

$$\sum_{c} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \le \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUCCH}}(i)\right)$$

is satisfied where $\hat{P}_{\mathrm{PUCCH}}(i)$ is the linear value of $P_{\mathrm{PUCCH}}(i)$, $\hat{P}_{\mathrm{PUSCH},c}(i)$ is the linear value of $P_{\mathrm{PUSCH},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of the UE total configured maximum output power $P_{CMAX}$ defined in [6] in subframe *i* and $w(i)$ is a scaling factor of $\hat{P}_{\mathrm{PUSCH},c}(i)$ for serving cell $c$ where $0 \le w(i) \le 1$. In case there is no PUCCH transmission in subframe *i* $\hat{P}_{\mathrm{PUCCH}}(i) = 0$.

If the UE has PUSCH transmission with UCI on serving cell *j* and PUSCH without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\mathrm{PUSCH},c}(i)$ for the serving cells without UCI in subframe *i* such that the condition

$$\sum_{c \ne j} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \le \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUSCH},j}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUSCH},j}(i)$ is the PUSCH transmit power for the cell with UCI and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell $c$ without UCI. In this case, no power scaling is applied to $\hat{P}_{\text{PUSCH},j}(i)$ unless $\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) = 0$ and the total transmit power of the UE still would exceed $\hat{P}_{CMAX}(i)$.

Note that $w(i)$ values are the same across serving cells when $w(i) > 0$ but for certain serving cells $w(i)$ may be zero.

If the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell j and PUSCH transmission without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE obtains $\hat{P}_{\text{PUSCH},c}(i)$ according to

$$\hat{P}_{\text{PUSCH},j}(i) = \min\left(\hat{P}_{\text{PUSCH},j}(i), \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i)\right)\right)$$

and

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \leq \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$$

If the UE is configured with multiple TAGs, and if the PUCCH/PUSCH transmission of the UE on subframe $i$ for a given serving cell in a TAG overlaps some portion of the first symbol of the PUSCH transmission on subframe $i+1$ for a different serving cell in another TAG the UE shall adjust its total transmission power to not exceed $P_{CMAX}$ on any overlapped portion.

If the UE is configured with multiple TAGs, and if the PUSCH transmission of the UE on subframe $i$ for a given serving cell in a TAG overlaps some portion of the first symbol of the PUCCH transmission on subframe $i+1$ for a different serving cell in another TAG the UE shall adjust its total transmission power to not exceed $P_{CMAX}$ on any overlapped portion.

If the UE is configured with multiple TAGs, and if the SRS transmission of the UE in a symbol on subframe $i$ for a given serving cell in a TAG overlaps with the PUCCH/PUSCH transmission on subframe $i$ or subframe $i+1$ for a different serving cell in the same or another TAG the UE shall drop SRS if its total transmission power exceeds $P_{CMAX}$ on any overlapped portion of the symbol.

If the UE is configured with multiple TAGs and more than 2 serving cells, and if the SRS transmission of the UE in a symbol on subframe $i$ for a given serving cell overlaps with the SRS transmission on subframe $i$ for a different serving cell(s) and with PUSCH/PUCCH transmission on subframe $i$ or subframe $i+1$ for another serving cell(s) the UE shall drop the SRS transmissions if the total transmission power exceeds $P_{CMAX}$ on any overlapped portion of the symbol.

If the UE is configured with multiple TAGs, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in parallel with SRS transmission in a symbol on a subframe of a different serving cell belonging to a different TAG, drop SRS if the total transmission power exceeds $P_{CMAX}$ on any overlapped portion in the symbol.

If the UE is configured with multiple TAGs, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in parallel with PUSCH/PUCCH in a different serving cell belonging to a different TAG, adjust the transmission power of PUSCH/PUCCH so that its total transmission power does not exceed $P_{CMAX}$ on the overlapped portion.

#### 5.1.1.2 Power headroom

There are two types of UE power headroom reports defined. A UE power headroom $PH$ is valid for subframe *i* for serving cell $c$.

Type 1:

If the UE transmits PUSCH without PUCCH in subframe $i$ for serving cell $c$, power headroom for a Type 1 report is computed using

$$PH_{\text{type1,c}}(i) = P_{\text{CMAX},c}(i) - \left\{10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right\} \text{ [dB]}$$

where, $P_{\text{CMAX},c}(i)$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O_PUSCH,c}}(j)$, $\alpha_c(j)$, $PL_c$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are defined in subclause 5.1.1.1.

If the UE transmits PUSCH with PUCCH in subframe $i$ for serving cell $c$, power headroom for a Type 1 report is computed using

$$PH_{\text{type1,c}}(i) = \widetilde{P}_{\text{CMAX},c}(i) - \left\{10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right\} \text{ [dB]}$$

where, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O_PUSCH,c}}(j)$, $\alpha_c(j)$, $PL_c$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are defined in subclause 5.1.1.1. $\widetilde{P}_{\text{CMAX},c}(i)$ is computed based on the requirements in [6] assuming a PUSCH only transmission in subframe $i$. For this case, the physical layer delivers $\widetilde{P}_{\text{CMAX},c}(i)$ instead of $P_{\text{CMAX},c}(i)$ to higher layers.

If the UE does not transmit PUSCH in subframe $i$ for serving cell $c$, power headroom for a Type 1 report is computed using

$$PH_{\text{type1,c}}(i) = \widetilde{P}_{\text{CMAX},c}(i) - \left\{P_{\text{O_PUSCH, c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right\} \text{ [dB]}$$

where, $\widetilde{P}_{\text{CMAX,c}}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and $\Delta T_C$ =0dB, where MPR , A-MPR, P-MPR and $\Delta T_C$ are defined in [6]. $P_{\text{O_PUSCH,c}}(1)$, $\alpha_c(1)$, $PL_c$, and $f_c(i)$ are defined in subclause 5.1.1.1.

Type 2:

If the UE transmits PUSCH simultaneous with PUCCH in subframe $i$ for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0_PUCCH}} + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) + \Delta_{\text{F_PUCCH}}(F) + \Delta_{TxD}(F') + g(i)\right)/10} \end{array}\right) \text{ [dB]}$$

where, $P_{\text{CMAX,c}}$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\text{O_PUCCH}}$, $PL_c$, $h(n_{CQI}, n_{HARQ}, n_{SR})$, $\Delta_{\text{F_PUCCH}}(F)$, $\Delta_{TxD}(F')$ and $g(i)$ are defined in subclause 5.1.2.1

If the UE transmits PUSCH without PUCCH in subframe $i$ for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0_PUCCH}} + PL_c + g(i)\right)/10} \end{array}\right) \text{ [dB]}$$

where, $P_{\text{CMAX,c}}(i)$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\text{O_PUCCH}}$, $PL_c$ and $g(i)$ are defined in subclause 5.1.2.1.

If the UE transmits PUCCH without PUSCH in subframe $i$ for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(P_{\text{O_PUSCH,c}}(1)+\alpha_c(1)\cdot PL_c+f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0_PUCCH}}+PL_c+h\left(n_{CQI},n_{HARQ},n_{SR}\right)+\Delta_{\text{F_PUCCH}}(F)+\Delta_{TxD}(F')+g(i)\right)/10} \end{array}\right) \text{ [dB]}$$

where, $P_{\text{O_PUSCH,c}}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1, $P_{\text{CMAX,c}}(i)$, $P_{\text{O_PUCCH}}$, $PL_c$, $h(n_{CQI},n_{HARQ},n_{SR})$, $\Delta_{\text{F_PUCCH}}(F)$, $\Delta_{TxD}(F')$ and $g(i)$ are also defined in subclause 5.1.2.1.

If the UE does not transmit PUCCH or PUSCH in subframe $i$ for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = \widetilde{P}_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(P_{\text{O_PUSCH,c}}(1)+\alpha_c(1)\cdot PL_c+f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0_PUCCH}}+PL_c+g(i)\right)/10} \end{array}\right) \text{ [dB]}$$

where, $\widetilde{P}_{CMAX,c}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and $\Delta T_C$ =0dB, where MPR , A-MPR, P-MPR and $\Delta T_C$ are defined in [6], $P_{\text{O_PUSCH,c}}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\text{O_PUCCH}}$, $PL_c$ and $g(i)$ are defined in subclause 5.1.2.1.

The power headroom shall be rounded to the closest value in the range [40; -23] dB with steps of 1 dB and is delivered by the physical layer to higher layers.

## 5.1.2 Physical uplink control channel

### 5.1.2.1 UE behaviour

If serving cell $c$ is the primary cell, the setting of the UE Transmit power $P_{\text{PUCCH}}$ for the physical uplink control channel (PUCCH) transmission in subframe *i* is defined by

$$P_{\text{PUCCH}}(i) = \min\left\{\begin{array}{l} P_{\text{CMAX,c}}(i), \\ P_{\text{0_PUCCH}} + PL_c + h\left(n_{CQI},n_{HARQ},n_{SR}\right)+\Delta_{\text{F_PUCCH}}(F)+\Delta_{TxD}(F')+g(i) \end{array}\right\} \text{ [dBm]}$$

If the UE is not transmitting PUCCH for the primary cell, for the accumulation of TPC command for PUCCH, the UE shall assume that the UE transmit power $P_{\text{PUCCH}}$ for PUCCH in subframe *i* is computed by

$$P_{\text{PUCCH}}(i) = \min\left\{P_{\text{CMAX,c}}(i), P_{\text{0_PUCCH}} + PL_c + g(i)\right\} \text{ [dBm]}$$

where

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell $c$. If the UE transmits PUSCH without PUCCH in subframe $i$ for the serving cell c, for the accumulation of TPC command for PUCCH, the UE shall assume $P_{\text{CMAX,c}}(i)$ as given by subclause 5.1.1.1. If the UE does not transmit PUCCH and PUSCH in subframe $i$ for the serving cell c, for the accumulation of TPC command for PUCCH, the UE shall compute $P_{\text{CMAX,c}}(i)$ assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and $\Delta T_C$ =0dB, where MPR, A-MPR, P-MPR and $\Delta T_C$ are defined in [6].
- The parameter $\Delta_{\text{F_PUCCH}}(F)$ is provided by higher layers. Each $\Delta_{\text{F_PUCCH}}(F)$ value corresponds to a PUCCH format ($F$) relative to PUCCH format 1a, where each PUCCH format ($F$) is defined in Table 5.4-1 of [3].

- If the UE is configured by higher layers to transmit PUCCH on two antenna ports, the value of $\Delta_{TxD}(F')$ is provided by higher layers where each PUCCH format $F'$ is defined in Table 5.4-1 of [3] ; otherwise, $\Delta_{TxD}(F') = 0$.

- $h(n_{CQI}, n_{HARQ}, n_{SR})$ is a PUCCH format dependent value, where $n_{CQI}$ corresponds to the number of information bits for the channel quality information defined in subclause 5.2.3.3 in [4]. $n_{SR}$ = 1 if subframe $i$ is configured for SR for the UE not having any associated transport block for UL-SCH, otherwise $n_{SR}$ =0. If the UE is configured with more than one serving cell, or the UE is configured with one serving cell and transmitting using PUCCH format 3, the value of $n_{HARQ}$ is defined in subclause 10.1; otherwise, $n_{HARQ}$ is the number of HARQ-ACK bits sent in subframe $i$.
  - For PUCCH format 1,1a and 1b $h(n_{CQI}, n_{HARQ}, n_{SR}) = 0$
  - For PUCCH format 1b with channel selection, if the UE is configured with more than one serving cell, $h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{(n_{HARQ} - 1)}{2}$, otherwise, $h(n_{CQI}, n_{HARQ}, n_{SR}) = 0$
  - For PUCCH format 2, 2a, 2b and normal cyclic prefix
$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \begin{cases} 10\log_{10}\left(\frac{n_{CQI}}{4}\right) & \text{if } n_{CQI} \geq 4 \\ 0 & \text{otherwise} \end{cases}$$
  - For PUCCH format 2 and extended cyclic prefix
$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \begin{cases} 10\log_{10}\left(\frac{n_{CQI} + n_{HARQ}}{4}\right) & \text{if } n_{CQI} + n_{HARQ} \geq 4 \\ 0 & \text{otherwise} \end{cases}$$
  - For PUCCH format 3 and when UE transmits HARQ-ACK/SR without periodic CSI,
    - If the UE is configured by higher layers to transmit PUCCH format 3 on two antenna ports, or if the UE transmits more than 11 bits of HARQ-ACK/SR
$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} - 1}{3}$$
    - Otherwise
$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} - 1}{2}$$
  - For PUCCH format 3 and when UE transmits HARQ-ACK/SR and periodic CSI,
    - If the UE is configured by higher layers to transmit PUCCH format 3 on two antenna ports, or if the UE transmits more than 11 bits of HARQ-ACK/SR and CSI
$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} + n_{CQI} - 1}{3}$$
    - Otherwise
$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} + n_{CQI} - 1}{2}$$

- $P_{\text{O_PUCCH}}$ is a parameter composed of the sum of a parameter $P_{\text{O_NOMINAL_PUCCH}}$ provided by higher layers and a parameter $P_{\text{O_UE_PUCCH}}$ provided by higher layers.

- $\delta_{\text{PUCCH}}$ is a UE specific correction value, also referred to as a TPC command, included in a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D for the primary cell, or included in an EPDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D for the primary cell, or sent jointly coded with other UE specific PUCCH correction values on a PDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUCCH-RNTI.

- If a UE is not configured for EPDCCH monitoring, the UE attempts to decode a PDCCH of DCI format 3/3A with the UE's TPC-PUCCH-RNTI and one or several PDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C/2D with the UE's C-RNTI or SPS C-RNTI on every subframe except when in DRX.
- If a UE is configured for EPDCCH monitoring, the UE attempts to decode
  - a PDCCH of DCI format 3/3A with the UE's TPC-PUCCH-RNTI and one or several PDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C/2D with the UE's C-RNTI or SPS C-RNTI as described in subclause 9.1.1, and
  - one or several EPDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C/2D with the UE's C-RNTI or SPS C-RNTI, as described in subclause 9.1.4.
- If the UE decodes
  - a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D or
  - an EPDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D

  for the primary cell and the corresponding detected RNTI equals the C-RNTI or SPS C-RNTI of the UE and the TPC field in the DCI format is not used to determine the PUCCH resource as in subclause 10.1, the UE shall use the $\delta_{\text{PUCCH}}$ provided in that PDCCH/EPDCCH.

  else
  - if the UE decodes a PDCCH with DCI format 3/3A, the UE shall use the $\delta_{\text{PUCCH}}$ provided in that PDCCH

    else the UE shall set $\delta_{\text{PUCCH}}$ = 0 dB.

- $g(i) = g(i-1) + \sum_{m=0}^{M-1} \delta_{PUCCH}(i-k_m)$ where $g(i)$ is the current PUCCH power control adjustment state and where $g(0)$ is the first value after reset.
  - For FDD, $M = 1$ and $k_0 = 4$.
  - For TDD, values of $M$ and $k_m$ are given in Table 10.1.3.1-1.
  - The $\delta_{\text{PUCCH}}$ dB values signalled on PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D or EPDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D are given in Table 5.1.2.1-1. If the PDCCH with DCI format 1/1A/2/2A/2B/2C/2D or EPDCCH with DCI format 1/1A/2A/2/2B/2C/2D is validated as an SPS activation PDCCH/EPDCCH, or the PDCCH/EPDCCH with DCI format 1A is validated as an SPS release PDCCH/EPDCCH, then $\delta_{\text{PUCCH}}$ is 0dB.
  - The $\delta_{\text{PUCCH}}$ dB values signalled on PDCCH with DCI format 3/3A are given in Table 5.1.2.1-1 or in Table 5.1.2.1-2 as semi-statically configured by higher layers.
  - If $P_{\text{O_UE_PUCCH}}$ value is changed by higher layers,
    - $g(0) = 0$
  - Else
    - $g(0) = \Delta P_{rampup} + \delta_{msg2}$, where
      - $\delta_{msg2}$ is the TPC command indicated in the random access response corresponding to the random access preamble transmitted in the primary cell, see subclause 6.2 and
      - If UE is transmitting PUCCH in subframe *i*,

$$\Delta P_{rampup} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \begin{pmatrix} P_{0_PUCCH} \\ + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) \\ + \Delta_{F_PUCCH}(F) + \Delta_{TxD}(F') \end{pmatrix}\right)\right\}, \Delta P_{rampuprequested}\right]$$

Otherwise,

$$\Delta P_{rampup} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \left(P_{0_PUCCH} + PL_c\right)\right)\right\}, \Delta P_{rampuprequested}\right]$$

and $\Delta P_{rampuprequested}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last preamble in the primary cell

- If UE has reached $P_{\mathrm{CMAX,c}}(i)$ for the primary cell, positive TPC commands for the primary cell shall not be accumulated
- If UE has reached minimum power, negative TPC commands shall not be accumulated
- UE shall reset accumulation
  - when $P_{\mathrm{O_UE_PUCCH}}$ value is changed by higher layers
  - when the UE receives a random access response message for the primary cell
- $g(i) = g(i-1)$ if $i$ is not an uplink subframe in TDD.

**Table 5.1.2.1-1: Mapping of TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2D/2/3 to $\delta_{\mathrm{PUCCH}}$ values**

| TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2D/2/3 | $\delta_{\mathrm{PUCCH}}$ [dB] |
|---|---|
| 0 | -1 |
| 1 | 0 |
| 2 | 1 |
| 3 | 3 |

**Table 5.1.2.1-2: Mapping of TPC Command Field in DCI format 3A to $\delta_{\mathrm{PUCCH}}$ values**

| TPC Command Field in DCI format 3A | $\delta_{\mathrm{PUCCH}}$ [dB] |
|---|---|
| 0 | -1 |
| 1 | 1 |

## 5.1.3 Sounding Reference Symbol (SRS)

### 5.1.3.1 UE behaviour

The setting of the UE Transmit power $P_{\mathrm{SRS}}$ for the SRS transmitted on subframe *i* for serving cell $c$ is defined by

$$P_{\mathrm{SRS,c}}(i) = \min\left\{ P_{\mathrm{CMAX,c}}(i),\ P_{\mathrm{SRS_OFFSET,c}}(m) + 10\log_{10}(M_{\mathrm{SRS,c}}) + P_{\mathrm{O_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + f_c(i) \right\} \quad \text{[dBm]}$$

where

- $P_{\mathrm{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe *i* for serving cell $c$.
- $P_{\mathrm{SRS_OFFSET,c}}(m)$ is semi-statically configured by higher layers for *m=0* and *m=1* for serving cell $c$. For SRS transmission given trigger type 0 then *m=0* and for SRS transmission given trigger type 1 then *m=1*.
- $M_{\mathrm{SRS,c}}$ is the bandwidth of the SRS transmission in subframe *i* for serving cell $c$ expressed in number of resource blocks.
- $f_c(i)$ is the current PUSCH power control adjustment state for serving cell $c$, see subclause 5.1.1.1.
- $P_{\mathrm{O_PUSCH,c}}(j)$ and $\alpha_c(j)$ are parameters as defined in subclause 5.1.1.1, where $j = 1$.

If the total transmit power of the UE for the Sounding Reference Symbol in an SC-FDMA symbol would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\mathrm{SRS},c}(i)$ for the serving cell $c$ and the SC-FDMA symbol in subframe *i* such that the condition

$$\sum_{c} w(i) \cdot \hat{P}_{\mathrm{SRS},c}(i) \le \hat{P}_{CMAX}(i)$$

is satisfied where $\hat{P}_{\mathrm{SRS},c}(i)$ is the linear value of $P_{\mathrm{SRS},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of $P_{CMAX}$ defined in [6] in subframe *i* and $w(i)$ is a scaling factor of $\hat{P}_{\mathrm{SRS},c}(i)$ for serving cell $c$ where $0 < w(i) \le 1$. Note that $w(i)$ values are the same across serving cells.

If the UE is configured with multiple TAGs and the SRS transmission of the UE in an SC-FDMA symbol for a serving cell in subframe $i$ in a TAG overlaps with the SRS transmission in another SC-FDMA symbol in subframe $i$ for a serving cell in another TAG, and if the total transmit power of the UE for the Sounding Reference Symbol in the overlapped portion would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\mathrm{SRS},c}(i)$ for the serving cell $c$ and each of the overlapped SRS SC-FDMA symbols in subframe $i$ such that the condition

$$\sum_{c} w(i) \cdot \hat{P}_{\mathrm{SRS},c}(i) \le \hat{P}_{CMAX}(i)$$

is satisfied where $\hat{P}_{\mathrm{SRS},c}(i)$ is the linear value of $P_{\mathrm{SRS},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of $P_{CMAX}$ defined in [6] in subframe *i* and $w(i)$ is a scaling factor of $\hat{P}_{\mathrm{SRS},c}(i)$ for serving cell $c$ where $0 < w(i) \le 1$. Note that $w(i)$ values are the same across serving cells.

## 5.2 Downlink power allocation

The eNodeB determines the downlink transmit energy per resource element.

A UE may assume downlink cell-specific RS EPRE is constant across the downlink system bandwidth and constant across all subframes until different cell-specific RS power information is received. The downlink cell-specific reference-signal EPRE can be derived from the downlink reference-signal transmit power given by the parameter *referenceSignalPower* provided by higher layers. The downlink reference-signal transmit power is defined as the linear average over the power contributions (in [W]) of all resource elements that carry cell-specific reference signals within the operating system bandwidth.

The ratio of PDSCH EPRE to cell-specific RS EPRE among PDSCH REs (not applicable to PDSCH REs with zero EPRE) for each OFDM symbol is denoted by either $\rho_A$ or $\rho_B$ according to the OFDM symbol index as given by Table 5.2-2 and Table 5.2-3. In addition, $\rho_A$ and $\rho_B$ are UE-specific.

For a UE in transmission mode 8 - 10 when UE-specific RSs are not present in the PRBs upon which the corresponding PDSCH is mapped or in transmission modes 1 – 7, the UE may assume that for 16 QAM, 64 QAM, spatial multiplexing with more than one layer or for PDSCH transmissions associated with the multi-user MIMO transmission scheme,

- $\rho_A$ is equal to $\delta_{\text{power-offset}} + P_A + 10\log_{10}(2)$ [dB] when the UE receives a PDSCH data transmission using precoding for transmit diversity with 4 cell-specific antenna ports according to subclause 6.3.4.3 of [3];
- $\rho_A$ is equal to $\delta_{\text{power-offset}} + P_A$ [dB] otherwise

where $\delta_{\text{power-offset}}$ is 0 dB for all PDSCH transmission schemes except multi-user MIMO and where $P_A$ is a UE specific parameter provided by higher layers.

For transmission mode 7, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs shall be a constant, and that constant shall be maintained over all the OFDM symbols containing the UE-specific RSs in the corresponding PRBs. In addition, the UE may assume that for 16QAM or 64QAM, this ratio is 0 dB.

For transmission mode 8, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs is 0 dB.

For transmission mode 9 or 10, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RS is 0 dB for number of transmission layers less than or equal to two and -3 dB otherwise.

A UE may assume that downlink positioning reference signal EPRE is constant across the positioning reference signal bandwidth and across all OFDM symbols that contain positioning reference signals in a given positioning reference signal occasion [10].

If CSI-RS is configured in a serving cell then a UE shall assume downlink CSI-RS EPRE is constant across the downlink system bandwidth and constant across all subframes for each CSI-RS resource.

The cell-specific ratio $\rho_B / \rho_A$ is given by Table 5.2-1 according to cell-specific parameter $P_B$ signalled by higher layers and the number of configured eNodeB cell specific antenna ports.

**Table 5.2-1: The cell-specific ratio $\rho_B / \rho_A$ for 1, 2, or 4 cell specific antenna ports**

| $P_B$ | $\rho_B / \rho_A$ | |
|---|---|---|
| | One Antenna Port | Two and Four Antenna Ports |
| 0 | 1 | 5/4 |
| 1 | 4/5 | 1 |
| 2 | 3/5 | 3/4 |
| 3 | 2/5 | 1/2 |

For PMCH with 16QAM or 64QAM, the UE may assume that the ratio of PMCH EPRE to MBSFN RS EPRE is equal to 0 dB.

**Table 5.2-2: OFDM symbol indices within a slot of a non-MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by $\rho_A$ or $\rho_B$**

| Number of antenna ports | OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by $\rho_A$ | | OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by $\rho_B$ | |
|---|---|---|---|---|
| | Normal cyclic prefix | Extended cyclic prefix | Normal cyclic prefix | Extended cyclic prefix |
| One or two | 1, 2, 3, 5, 6 | 1, 2, 4, 5 | 0, 4 | 0, 3 |
| Four | 2, 3, 5, 6 | 2, 4, 5 | 0, 1, 4 | 0, 1, 3 |

**Table 5.2-3: OFDM symbol indices within a slot of an MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by $\rho_A$ or $\rho_B$**

| Number of antenna ports | OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by $\rho_A$ | | | | OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by $\rho_B$ | | | |
|---|---|---|---|---|---|---|---|---|
| | Normal cyclic prefix | | Extended cyclic prefix | | Normal cyclic prefix | | Extended cyclic prefix | |
| | $n_s$ mod 2 = 0 | $n_s$ mod 2 = 1 | $n_s$ mod 2 = 0 | $n_s$ mod 2 = 1 | $n_s$ mod 2 = 0 | $n_s$ mod 2 = 1 | $n_s$ mod 2 = 0 | $n_s$ mod 2 = 1 |
| One or two | 1, 2, 3, 4, 5, 6 | 0, 1, 2, 3, 4, 5, 6 | 1, 2, 3, 4, 5 | 0, 1, 2, 3, 4, 5 | 0 | - | 0 | - |
| Four | 2, 3, 4, 5, 6 | 0, 1, 2, 3, 4, 5, 6 | 2, 4, 3, 5 | 0, 1, 2, 3, 4, 5 | 0, 1 | - | 0, 1 | - |

## 5.2.1 eNodeB Relative Narrowband TX Power (RNTP) restrictions

The determination of reported Relative Narrowband TX Power indication $RNTP(n_{PRB})$ is defined as follows:

$$RNTP(n_{PRB}) = \begin{cases} 0 & \text{if} \quad \dfrac{E_A(n_{PRB})}{E^{(p)}_{\max_nom}} \le RNTP_{threshold} \\ 1 & \text{if} \quad \text{no promise about the upper limit of } \dfrac{E_A(n_{PRB})}{E^{(p)}_{\max_nom}} \text{ is made} \end{cases}$$

where $E_A(n_{PRB})$ is the maximum intended EPRE of UE-specific PDSCH REs in OFDM symbols not containing RS in this physical resource block on antenna port $p$ in the considered future time interval; $n_{PRB}$ is the physical resource block number $n_{PRB} = 0,..., N^{DL}_{RB} - 1$; $RNTP_{threshold}$ takes on one of the following values $RNTP_{threshold} \in \{-\infty,-11,-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,0,+1,+2,+3\}$ [dB] and

$$E^{(p)}_{\max_nom} = \frac{P^{(p)}_{\max} \cdot \dfrac{1}{\Delta f}}{N^{DL}_{RB} \cdot N^{RB}_{SC}}$$

where $P^{(p)}_{\max}$ is the base station maximum output power described in [7], and $\Delta f$, $N^{DL}_{RB}$ and $N^{RB}_{SC}$ are defined in [3].

# 6 Random access procedure

Prior to initiation of the non-synchronized physical random access procedure, Layer 1 shall receive the following information from the higher layers:

1. Random access channel parameters (PRACH configuration and frequency position)
2. Parameters for determining the root sequences and their cyclic shifts in the preamble sequence set for the primary cell (index to logical root sequence table, cyclic shift ( $N_{CS}$ ), and set type (unrestricted or restricted set))

## 6.1 Physical non-synchronized random access procedure

From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble and random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB is not prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission.

The following steps are required for the L1 random access procedure:

1. Layer 1 procedure is triggered upon request of a preamble transmission by higher layers.
2. A preamble index, a target preamble received power (PREAMBLE_RECEIVED_TARGET_POWER), a corresponding RA-RNTI and a PRACH resource are indicated by higher layers as part of the request.
3. A preamble transmission power $P_{PRACH}$ is determined as $P_{PRACH} = \min\{ P_{CMAX,c}(i)$ , PREAMBLE_RECEIVED_TARGET_POWER + $PL_c$ }_[dBm], where $P_{CMAX,c}(i)$ is the configured UE transmit power defined in [6] for subframe *i* of serving cell $c$ and $PL_c$ is the downlink pathloss estimate calculated in the UE for serving cell $c$ .
4. A preamble sequence is selected from the preamble sequence set using the preamble index.
5. A single preamble is transmitted using the selected preamble sequence with transmission power $P_{PRACH}$ on the indicated PRACH resource.
6. Detection of a PDCCH with the indicated RA-RNTI is attempted during a window controlled by higher layers (see [8], subclause 5.1.4). If detected, the corresponding DL-SCH transport block is passed to higher layers. The higher layers parse the transport block and indicate the 20-bit uplink grant to the physical layer, which is processed according to subclause 6.2.

### 6.1.1 Timing

For the L1 random access procedure, UE's uplink transmission timing after a random access preamble transmission is as follows.

a. If a PDCCH with associated RA-RNTI is detected in subframe *n*, and the corresponding DL-SCH transport block contains a response to the transmitted preamble sequence, the UE shall, according to the information in the response, transmit an UL-SCH transport block in the first subframe $n + k_1$ , $k_1 \geq 6$ , if the UL delay field in subclause 6.2 is set to zero where $n + k_1$ is the first available UL subframe for PUSCH transmission. The UE shall postpone the PUSCH transmission to the next available UL subframe after $n + k_1$ if the field is set to 1.

b. If a random access response is received in subframe *n*, and the corresponding DL-SCH transport block does not contain a response to the transmitted preamble sequence, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n + 5$ .

c. If no random access response is received in subframe *n*, where subframe *n* is the last subframe of the random access response window, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n+4$.

In case a random access procedure is initiated by a "PDCCH order" in subframe *n*, the UE shall, if requested by higher layers, transmit random access preamble in the first subframe $n+k_2$, $k_2 \geq 6$, where a PRACH resource is available.

If a UE is configured with multiple TAGs, and if the UE is configured with the carrier indicator field for a given serving cell, the UE shall use the carrier indicator field value from the detected "PDCCH order" to determine the serving cell for the corresponding random access preamble transmission.

## 6.2 Random Access Response Grant

The higher layers indicate the 20-bit UL Grant to the physical layer, as defined in 3GPP TS 36.321 [8].
This is referred to the Random Access Response Grant in the physical layer.
The content of these 20 bits starting with the MSB and ending with the LSB are as follows:

- Hopping flag – 1 bit
- Fixed size resource block assignment – 10 bits
- Truncated modulation and coding scheme – 4 bits
- TPC command for scheduled PUSCH – 3 bits
- UL delay – 1 bit
- CSI request – 1 bit

The UE shall use the single-antenna port uplink transmission scheme for the PUSCH transmission corresponding to the Random Access Response Grant and the PUSCH retransmission for the same transport block.

The UE shall perform PUSCH frequency hopping if the single bit frequency hopping (FH) field in a corresponding Random Access Response Grant is set as 1 and the uplink resource block assignment is type 0, otherwise no PUSCH frequency hopping is performed. When the hopping flag is set, the UE shall perform PUSCH hopping as indicated via the fixed size resource block assignment detailed below.

The fixed size resource block assignment field is interpreted as follows:

if $N_{\mathrm{RB}}^{\mathrm{UL}} \leq 44$

Truncate the fixed size resource block assignment to its *b* least significant bits, where $b = \left\lceil \log_2\left(N_{\mathrm{RB}}^{\mathrm{UL}} \cdot \left(N_{\mathrm{RB}}^{\mathrm{UL}}+1\right)/2\right)\right\rceil$, and interpret the truncated resource block assignment according to the rules for a regular DCI format 0

else

Insert *b* most significant bits with value set to '0' after the $N_{UL_hop}$ hopping bits in the fixed size resource block assignment, where the number of hopping bits $N_{UL_hop}$ is zero when the hopping flag bit is not set to 1, and is defined in Table 8.4-1 when the hopping flag bit is set to 1, and $b = \left(\left\lceil \log_2\left(N_{\mathrm{RB}}^{\mathrm{UL}} \cdot \left(N_{\mathrm{RB}}^{\mathrm{UL}}+1\right)/2\right)\right\rceil - 10\right)$, and interpret the expanded resource block assignment according to the rules for a regular DCI format 0

end if

The truncated modulation and coding scheme field is interpreted such that the modulation and coding scheme corresponding to the Random Access Response grant is determined from MCS indices 0 through 15 in Table 8.6.1-1.

The TPC command $\delta_{msg2}$ shall be used for setting the power of the PUSCH, and is interpreted according to Table 6.2-1.

**Table 6.2-1: TPC Command $\delta_{msg2}$ for Scheduled PUSCH**

| TPC Command | Value (in dB) |
|---|---|
| 0 | -6 |
| 1 | -4 |
| 2 | -2 |
| 3 | 0 |
| 4 | 2 |
| 5 | 4 |
| 6 | 6 |
| 7 | 8 |

In non-contention based random access procedure, the CSI request field is interpreted to determine whether an aperiodic CQI, PMI, and RI report is included in the corresponding PUSCH transmission according to subclause 7.2.1. In contention based random access procedure, the CSI request field is reserved.

The UL delay applies for both TDD and FDD and this field can be set to 0 or 1 to indicate whether the delay of PUSCH is introduced as shown in subclause 6.1.1.

# 7 Physical downlink shared channel related procedures

For FDD, there shall be a maximum of 8 downlink HARQ processes per serving cell.

For TDD, if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, the maximum number of downlink HARQ processes per serving cell shall be determined by the UL/DL configuration (Table 4.2-2 of [3]), as indicated in Table 7-1.

For TDD, if a UE is configured with more than one serving cell and if the TDD UL/DL configuration of at least two configured serving cells is not the same, the maximum number of downlink HARQ processes for a serving cell shall be determined as indicated in Table 7-1, wherein the "TDD UL/DL configuration" in Table 7-1 refers to the DL-reference UL/DL configuration for the serving cell (as defined in subclause 10.2).

The dedicated broadcast HARQ process defined in [8] is not counted as part of the maximum number of HARQ processes for both FDD and TDD.

**Table 7-1: Maximum number of DL HARQ processes for TDD**

| TDD UL/DL configuration | Maximum number of HARQ processes |
|---|---|
| 0 | 4 |
| 1 | 7 |
| 2 | 10 |
| 3 | 9 |
| 4 | 12 |
| 5 | 15 |
| 6 | 6 |

## 7.1 UE procedure for receiving the physical downlink shared channel

Except the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* of serving cell $c$, a UE shall

- upon detection of a PDCCH of the serving cell with DCI format 1, 1A, 1B, 1C, 1D, 2, 2A, 2B, 2C, or 2D intended for the UE in a subframe, or
- upon detection of an EPDCCH of the serving cell with DCI format 1, 1A, 1B, 1D, 2, 2A, 2B, 2C, or 2D intended for the UE in a subframe

decode the corresponding PDSCH in the same subframe with the restriction of the number of transport blocks defined in the higher layers.

A UE may assume that positioning reference signals are not present in resource blocks in which it shall decode PDSCH according to a detected PDCCH with CRC scrambled by the SI-RNTI or P-RNTI with DCI format 1A or 1C intended for the UE.

A UE configured with the carrier indicator field for a given serving cell shall assume that the carrier indicator field is not present in any PDCCH of the serving cell in the common search space that is described in subclause 9.1. Otherwise, the configured UE shall assume that for the given serving cell the carrier indicator field is present in PDCCH/EPDCCH located in the UE specific search space described in subclause 9.1 when the PDCCH/EPDCCH CRC is scrambled by C-RNTI or SPS C-RNTI.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SI-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-1. The scrambling initialization of PDSCH corresponding to these PDCCHs is by SI-RNTI.

**Table 7.1-1: PDCCH and PDSCH configured by SI-RNTI**

| DCI format | Search Space | Transmission scheme of PDSCH corresponding to PDCCH |
|---|---|---|
| DCI format 1C | Common | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2). |
| DCI format 1A | Common | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2). |

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the P-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-2.
The scrambling initialization of PDSCH corresponding to these PDCCHs is by P-RNTI.

**Table 7.1-2: PDCCH and PDSCH configured by P-RNTI**

| DCI format | Search Space | Transmission scheme of PDSCH corresponding to PDCCH |
|---|---|---|
| DCI format 1C | Common | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |
| DCI format 1A | Common | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the RA-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-3. The scrambling initialization of PDSCH corresponding to these PDCCHs is by RA-RNTI.

When RA-RNTI and either C-RNTI or SPS C-RNTI are assigned in the same subframe, the UE is not required to decode a PDSCH on the primary cell indicated by a PDCCH/EPDCCH with a CRC scrambled by C-RNTI or SPS C-RNTI.

**Table 7.1-3: PDCCH and PDSCH configured by RA-RNTI**

| DCI format | Search Space | Transmission scheme of PDSCH corresponding to PDCCH |
|---|---|---|
| DCI format 1C | Common | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |
| DCI format 1A | Common | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |

The UE is semi-statically configured via higher layer signalling to receive PDSCH data transmissions signalled via PDCCH/EPDCCH according to one of the transmission modes, denoted mode 1 to mode 10.

For frame structure type 1,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5, 7, 8, 9, 10, 11, 12, 13 or 14 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of either PBCH or primary or secondary synchronization signals in the same subframe;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7 for which distributed VRB resource allocation is assigned.
- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

For frame structure type 2,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of PBCH in the same subframe;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7, 8, 9, 10, 11, 12, 13 or 14 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of primary or secondary synchronization signals in the same subframe;
- with normal CP configuration, the UE is not expected to receive PDSCH on antenna port 5 for which distributed VRB resource allocation is assigned in the special subframe with configuration #1 or #6;
- the UE is not expected to receive PDSCH on antenna port 7 for which distributed VRB resource allocation is assigned;
- with normal cyclic prefix, the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in DwPTS when the UE is configured with special subframe configuration 9.
- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and any corresponding PDSCH according to the respective combinations defined in Table 7.1-5. The scrambling initialization of PDSCH corresponding to these PDCCHs is by C-RNTI.

If a UE is configured by higher layers to decode EPDCCH with CRC scrambled by the C-RNTI, the UE shall decode the EPDCCH and any corresponding PDSCH according to the respective combinations defined in Table 7.1-5A. The scrambling initialization of PDSCH corresponding to these EPDCCHs is by C-RNTI.

If the UE is configured with the carrier indicator field for a given serving cell and, if the UE is configured by higher layers to decode PDCCH/EPDCCH with CRC scrambled by the C-RNTI, then the UE shall decode PDSCH of the serving cell indicated by the carrier indicator field value in the decoded PDCCH/EPDCCH.

When a UE configured in transmission mode 3, 4, 8, 9 or 10 receives a DCI Format 1A assignment, it shall assume that the PDSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals corresponding to these PDCCHs/EPDCCHs is by C-RNTI.

The UE does not support transmission mode 8 if extended cyclic prefix is used in the downlink.

When a UE is configured in transmission mode 9 or 10, in the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* of serving cell $c$ except in subframes for the serving cell

- indicated by higher layers to decode PMCH or,
- configured by higher layers to be part of a positioning reference signal occasion and the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix,

the UE shall upon detection of a PDCCH with CRC scrambled by the C-RNTI with DCI format 1A/2C/2D intended for the UE or, upon detection of an EPDCCH with CRC scrambled by the C-RNTI with DCI format 1A/2C/2D intended for the UE, decode the corresponding PDSCH in the same subframe.

A UE configured in transmission mode 10 can be configured with scrambling identities, $n_{\mathrm{ID}}^{\mathrm{DMRS},i}$, $i = 0,1$ by higher layers for UE-specific reference signal generation as defined in subclause 6.10.3.1 of [3] to decode PDSCH according to a detected PDCCH/EPDCCH with CRC scrambled by the C-RNTI with DCI format 2D intended for the UE.

**Table 7.1-5: PDCCH and PDSCH configured by C-RNTI**

| Transmission mode | DCI format | Search Space | Transmission scheme of PDSCH corresponding to PDCCH |
|---|---|---|---|
| **Mode 1** | DCI format 1A | Common and UE specific by C-RNTI | Single-antenna port, port 0 (see subclause 7.1.1) |
| | DCI format 1 | UE specific by C-RNTI | Single-antenna port, port 0 (see subclause 7.1.1) |
| **Mode 2** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 1 | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 3** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 2A | UE specific by C-RNTI | Large delay CDD (see subclause 7.1.3) or Transmit diversity (see subclause 7.1.2) |
| **Mode 4** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 2 | UE specific by C-RNTI | Closed-loop spatial multiplexing (see subclause 7.1.4)or Transmit diversity (see subclause 7.1.2) |
| **Mode 5** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 1D | UE specific by C-RNTI | Multi-user MIMO (see subclause 7.1.5) |
| **Mode 6** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 1B | UE specific by C-RNTI | Closed-loop spatial multiplexing (see subclause 7.1.4) using a single transmission layer |
| **Mode 7** | DCI format 1A | Common and UE specific by C-RNTI | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |
| | DCI format 1 | UE specific by C-RNTI | Single-antenna port, port 5 (see subclause 7.1.1) |
| **Mode 8** | DCI format 1A | Common and UE specific by C-RNTI | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |
| | DCI format 2B | UE specific by C-RNTI | Dual layer transmission, port 7 and 8 (see subclause 7.1.5A) or single-antenna port, port 7 or 8 (see subclause 7.1.1) |
| **Mode 9** | DCI format 1A | Common andUE specific by C-RNTI | • Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)<br>• MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1) |
| | DCI format 2C | UE specific by C-RNTI | Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) or single-antenna port, port 7 or 8 (see subclause 7.1.1) |
| **Mode 10** | DCI format 1A | Common andUE specific by C-RNTI | • Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)<br>• MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1) |
| | DCI format 2D | UE specific by C-RNTI | Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) or single-antenna port, port 7 or 8 (see subclause 7.1.1) |

**Table 7.1-5A: EPDCCH and PDSCH configured by C-RNTI**

| Transmission mode | DCI format | Search Space | Transmission scheme of PDSCH corresponding to EPDCCH |
|---|---|---|---|
| **Mode 1** | DCI format 1A | UE specific by C-RNTI | Single-antenna port, port 0 (see subclause 7.1.1) |
| | DCI format 1 | UE specific by C-RNTI | Single-antenna port, port 0 (see subclause 7.1.1) |
| **Mode 2** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 1 | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 3** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 2A | UE specific by C-RNTI | Large delay CDD (see subclause 7.1.3) or Transmit diversity (see subclause 7.1.2) |
| **Mode 4** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 2 | UE specific by C-RNTI | Closed-loop spatial multiplexing (see subclause 7.1.4)or Transmit diversity (see subclause 7.1.2) |
| **Mode 5** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 1D | UE specific by C-RNTI | Multi-user MIMO (see subclause 7.1.5) |
| **Mode 6** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 1B | UE specific by C-RNTI | Closed-loop spatial multiplexing (see subclause 7.1.4) using a single transmission layer |
| **Mode 7** | DCI format 1A | UE specific by C-RNTI | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |
| | DCI format 1 | UE specific by C-RNTI | Single-antenna port, port 5 (see subclause 7.1.1) |
| **Mode 8** | DCI format 1A | UE specific by C-RNTI | If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |
| | DCI format 2B | UE specific by C-RNTI | Dual layer transmission, port 7 and 8 (see subclause 7.1.5A) or single-antenna port, port 7 or 8 (see subclause 7.1.1) |
| **Mode 9** | DCI format 1A | UE specific by C-RNTI | • Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)<br>• MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1) |
| | DCI format 2C | UE specific by C-RNTI | Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) or single-antenna port, port 7 or 8 (see subclause 7.1.1) |
| **Mode 10** | DCI format 1A | UE specific by C-RNTI | • Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)<br>• MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1) |
| | DCI format 2D | UE specific by C-RNTI | Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) or single-antenna port, port 7 or 8 (see subclause 7.1.1) |

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH on the primary cell and any corresponding PDSCH on the primary cell according to the respective combinations defined in Table 7.1-6. The same PDSCH related configuration applies in the case that a PDSCH is transmitted without a corresponding PDCCH. The scrambling initialization of PDSCH corresponding to these PDCCHs and PDSCH without a corresponding PDCCH is by SPS C-RNTI.

If a UE is configured by higher layers to decode EPDCCH with CRC scrambled by the SPS C-RNTI, the UE shall decode the EPDCCH on the primary cell and any corresponding PDSCH on the primary cell according to the respective combinations defined in Table 7.1-6A. The same PDSCH related configuration applies in the case that a PDSCH is transmitted without a corresponding EPDCCH. The scrambling initialization of PDSCH corresponding to these EPDCCHs and PDSCH without a corresponding EPDCCH is by SPS C-RNTI.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals for PDSCH corresponding to these PDCCHs/EPDCCHs and for PDSCH without a corresponding PDCCH/EPDCCH is by SPS C-RNTI.

When a UE is configured in transmission mode 9 or 10, in the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* of serving cell *c* except in subframes for the serving cell

- indicated by higher layers to decode PMCH or,
- configured by higher layers to be part of a positioning reference signal occasion and the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix,

the UE shall upon detection of a PDCCH with CRC scrambled by the SPS C-RNTI with DCI format 1A/2C/2D, or upon detection of a EPDCCH with CRC scrambled by the SPS C-RNTI with DCI format 1A/2C/2D, or for a configured PDSCH without PDCCH intended for the UE, decode the corresponding PDSCH in the same subframe.

A UE configured in transmission mode 10 can be configured with scrambling identities, $n_{\mathrm{ID}}^{\mathrm{DMRS},i}$, $i = 0,1$ by higher layers for UE-specific reference signal generation as defined in subclause 6.10.3.1 of [3] to decode PDSCH according to a detected PDCCH/EPDCCH with CRC scrambled by the SPS C-RNTI with DCI format 2D intended for the UE.

For PDSCH without a corresponding PDCCH/EPDCCH, the UE shall use the value of $n_{\mathrm{SCID}}$ and the scrambling identity of $n_{\mathrm{ID}}^{(n_{\mathrm{SCID}})}$ (as defined in subclause 6.10.3.1 of [3]) derived from the DCI format 2D corresponding to the associated SPS activation for UE-specific reference signal generation.

**Table 7.1-6: PDCCH and PDSCH configured by SPS C-RNTI**

| Transmission mode | DCI format | Search Space | Transmission scheme of PDSCH corresponding to PDCCH |
|---|---|---|---|
| **Mode 1** | DCI format 1A | Common and UE specific by C-RNTI | Single-antenna port, port 0 (see subclause 7.1.1) |
| | DCI format 1 | UE specific by C-RNTI | Single-antenna port, port 0 (see subclause 7.1.1) |
| **Mode 2** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 1 | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 3** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 2A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 4** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 2 | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 5** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 6** | DCI format 1A | Common and UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 7** | DCI format 1A | Common and UE specific by C-RNTI | Single-antenna port, port 5 (see subclause 7.1.1) |
| | DCI format 1 | UE specific by C-RNTI | Single-antenna port, port 5 (see subclause 7.1.1) |
| **Mode 8** | DCI format 1A | Common and UE specific by C-RNTI | Single-antenna port, port 7(see subclause 7.1.1) |
| | DCI format 2B | UE specific by C-RNTI | Single-antenna port, port 7 or 8 (see subclause 7.1.1) |
| **Mode 9** | DCI format 1A | Common and UE specific by C-RNTI | Single-antenna port, port 7 (see subclause 7.1.1) |
| | DCI format 2C | UE specific by C-RNTI | Single-antenna port, port 7 or 8, (see subclause 7.1.1) |
| **Mode 10** | DCI format 1A | Common and UE specific by C-RNTI | Single-antenna port, port 7 (see subclause 7.1.1) |
| | DCI format 2D | UE specific by C-RNTI | Single-antenna port, port 7 or 8, (see subclause 7.1.1) |

**Table 7.1-6A: EPDCCH and PDSCH configured by SPS C-RNTI**

| Transmission mode | DCI format | Search Space | Transmission scheme of PDSCH corresponding to EPDCCH |
|---|---|---|---|
| **Mode 1** | DCI format 1A | UE specific by C-RNTI | Single-antenna port, port 0 (see subclause 7.1.1) |
| | DCI format 1 | UE specific by C-RNTI | Single-antenna port, port 0 (see subclause 7.1.1) |
| **Mode 2** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 1 | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 3** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 2A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 4** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| | DCI format 2 | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 5** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 6** | DCI format 1A | UE specific by C-RNTI | Transmit diversity (see subclause 7.1.2) |
| **Mode 7** | DCI format 1A | UE specific by C-RNTI | Single-antenna port, port 5 (see subclause 7.1.1) |
| | DCI format 1 | UE specific by C-RNTI | Single-antenna port, port 5 (see subclause 7.1.1) |
| **Mode 8** | DCI format 1A | UE specific by C-RNTI | Single-antenna port, port 7(see subclause 7.1.1) |
| | DCI format 2B | UE specific by C-RNTI | Single-antenna port, port 7 or 8 (see subclause 7.1.1) |
| **Mode 9** | DCI format 1A | UE specific by C-RNTI | Single-antenna port, port 7 (see subclause 7.1.1) |
| | DCI format 2C | UE specific by C-RNTI | Single-antenna port, port 7 or 8, (see subclause 7.1.1) |
| **Mode 10** | DCI format 1A | UE specific by C-RNTI | Single-antenna port, port 7 (see subclause 7.1.1) |
| | DCI format 2D | UE specific by C-RNTI | Single-antenna port, port 7 or 8, (see subclause 7.1.1) |

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the Temporary C-RNTI and is not configured to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to the combination defined in Table 7.1-7. The scrambling initialization of PDSCH corresponding to these PDCCHs is by Temporary C-RNTI.

**Table 7.1-7: PDCCH and PDSCH configured by Temporary C-RNTI**

| DCI format | Search Space | Transmission scheme of PDSCH corresponding to PDCCH |
|---|---|---|
| DCI format 1A | Common and UE specific by Temporary C-RNTI | If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |
| DCI format 1 | UE specific by Temporary C-RNTI | If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) |

The transmission schemes of the PDSCH are described in the following sub-subclauses.

## 7.1.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 0, port 5, port 7 or port 8) of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to subclause 6.3.4.1 of [3].

In case an antenna port $p \in \{7,8\}$ is used, the UE cannot assume that the other antenna port in the set $\{7,8\}$ is not associated with transmission of PDSCH to another UE.

### 7.1.2 Transmit diversity scheme

For the transmit diversity transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to subclause 6.3.4.3 of [3]

### 7.1.3 Large delay CDD scheme

For the large delay CDD transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to large delay CDD as defined in subclause 6.3.4.2.2 of [3].

### 7.1.4 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to the applicable number of transmission layers as defined in subclause 6.3.4.2.1 of [3].

### 7.1.5 Multi-user MIMO scheme

For the multi-user MIMO transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed on one layer and according to subclause 6.3.4.2.1 of [3]. The $\delta_{\text{power-offset}}$ dB value signalled on PDCCH/EPDCCH with DCI format 1D using the downlink power offset field is given in Table 7.1.5-1.

**Table 7.1.5-1: Mapping of downlink power offset field in DCI format 1D to the $\delta_{\text{power-offset}}$ value.**

| Downlink power offset field | $\delta_{\text{power-offset}}$ [dB] |
|---|---|
| 0 | $-10\log_{10}(2)$ |
| 1 | 0 |

### 7.1.5A Dual layer scheme

For the dual layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with two transmission layers on antenna ports 7 and 8 as defined in subclause 6.3.4.4 of [3].

### 7.1.5B Up to 8 layer transmission scheme

For the up to 8 layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with up to 8 transmission layers on antenna ports 7 - 14 as defined in subclause 6.3.4.4 of [3].

### 7.1.6 Resource allocation

The UE shall interpret the resource allocation field depending on the PDCCH/EPDCCH DCI format detected.
A resource allocation field in each PDCCH/EPDCCH includes two parts, a resource allocation header field and information consisting of the actual resource block assignment.

PDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 0 and PDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 1 resource allocation have the same format and are distinguished from each other via the single bit resource allocation header field which exists depending on the downlink system bandwidth (subclause 5.3.3.1 of [4]), where type 0 is indicated by 0 value and type 1 is indicated otherwise. PDCCH with DCI format 1A, 1B, 1C and 1D have a type 2 resource allocation while PDCCH with DCI format 1, 2, 2A, 2B, 2C and 2D have type 0 or type 1 resource allocation. PDCCH DCI formats with a type 2 resource allocation do not have a resource allocation header field.

EPDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 0 and EPDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 1 resource allocation have the same format and are distinguished from each other via the single bit resource allocation header field which exists depending on the downlink system bandwidth (subclause 5.3.3.1 of [4]), where type 0 is indicated by 0 value and type 1 is indicated otherwise. EPDCCH with DCI format 1A, 1B, and 1D have a type 2 resource allocation while EPDCCH with DCI format 1, 2, 2A, 2B, 2C and 2D have type 0 or type 1 resource allocation. EPDCCH DCI formats with a type 2 resource allocation do not have a resource allocation header field.

### 7.1.6.1 Resource allocation type 0

In resource allocations of type 0, resource block assignment information includes a bitmap indicating the Resource Block Groups (RBGs) that are allocated to the scheduled UE where a RBG is a set of consecutive virtual resource blocks (VRBs) of localized type as defined in subclause 6.2.3.1 of [3]. Resource block group size (*P*) is a function of the system bandwidth as shown in Table 7.1.6.1-1. The total number of RBGs ( $N_{\text{RBG}}$ ) for downlink system bandwidth of $N_{\text{RB}}^{\text{DL}}$ is given by $N_{RBG} = \lceil N_{\text{RB}}^{\text{DL}} / P \rceil$ where $\lfloor N_{\text{RB}}^{\text{DL}} / P \rfloor$ of the RBGs are of size P and if $N_{\text{RB}}^{\text{DL}} \bmod P > 0$ then one of the RBGs is of size $N_{\text{RB}}^{\text{DL}} - P \cdot \lfloor N_{\text{RB}}^{\text{DL}} / P \rfloor$. The bitmap is of size $N_{\text{RBG}}$ bits with one bitmap bit per RBG such that each RBG is addressable. The RBGs shall be indexed in the order of increasing frequency and non-increasing RBG sizes starting at the lowest frequency. The order of RBG to bitmap bit mapping is in such way that RBG 0 to RBG $N_{\text{RBG}} - 1$ are mapped to MSB to LSB of the bitmap. The RBG is allocated to the UE if the corresponding bit value in the bitmap is 1, the RBG is not allocated to the UE otherwise.

**Table 7.1.6.1-1: Type 0 resource allocation RBG size vs. Downlink System Bandwidth**

| System Bandwidth $N_{\text{RB}}^{\text{DL}}$ | RBG Size (*P*) |
|---|---|
| ≤10 | 1 |
| 11 – 26 | 2 |
| 27 – 63 | 3 |
| 64 – 110 | 4 |

### 7.1.6.2 Resource allocation type 1

In resource allocations of type 1, a resource block assignment information of size $N_{\text{RBG}}$ indicates to a scheduled UE the VRBs from the set of VRBs from one of *P* RBG subsets. The virtual resource blocks used are of localized type as defined in subclause 6.2.3.1 of [3]. Also *P* is the RBG size associated with the system bandwidth as shown in Table 7.1.6.1-1. A RBG subset $p$, where $0 \le p < P$, consists of every $P$ th RBG starting from RBG $p$. The resource block assignment information consists of three fields [4].

The first field with $\lceil \log_2(P) \rceil$ bits is used to indicate the selected RBG subset among $P$ RBG subsets.

The second field with one bit is used to indicate a shift of the resource allocation span within a subset. A bit value of 1 indicates shift is triggered. Shift is not triggered otherwise.

The third field includes a bitmap, where each bit of the bitmap addresses a single VRB in the selected RBG subset in such a way that MSB to LSB of the bitmap are mapped to the VRBs in the increasing frequency order. The VRB is allocated to the UE if the corresponding bit value in the bit field is 1, the VRB is not allocated to the UE otherwise. The portion of the bitmap used to address VRBs in a selected RBG subset has size $N_{\text{RB}}^{\text{TYPE1}}$ and is defined as

$$N_{\text{RB}}^{\text{TYPE1}} = \lceil N_{\text{RB}}^{\text{DL}} / P \rceil - \lceil \log_2(P) \rceil - 1$$

The addressable VRB numbers of a selected RBG subset start from an offset, $\Delta_{\text{shift}}(p)$ to the smallest VRB number within the selected RBG subset, which is mapped to the MSB of the bitmap. The offset is in terms of the number of VRBs and is done within the selected RBG subset. If the value of the bit in the second field for shift of the resource allocation span is set to 0, the offset for RBG subset $p$ is given by $\Delta_{\text{shift}}(p) = 0$. Otherwise, the offset for RBG subset $p$ is given by $\Delta_{\text{shift}}(p) = N_{\text{RB}}^{\text{RBG subset}}(p) - N_{\text{RB}}^{\text{TYPE1}}$, where the LSB of the bitmap is justified with the highest VRB number within the selected RBG subset. $N_{\text{RB}}^{\text{RBG subset}}(p)$ is the number of VRBs in RBG subset $p$ and can be calculated by the following equation,

$$N_{\mathrm{RB}}^{\mathrm{RBG\ subset}}(p)=\begin{cases}\left\lfloor\frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P^2}\right\rfloor\cdot P+P & ,p<\left\lfloor\frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P}\right\rfloor \bmod P\\ \left\lfloor\frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P^2}\right\rfloor\cdot P+(N_{\mathrm{RB}}^{\mathrm{DL}}-1)\bmod P+1 & ,p=\left\lfloor\frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P}\right\rfloor \bmod P\\ \left\lfloor\frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P^2}\right\rfloor\cdot P & ,p>\left\lfloor\frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P}\right\rfloor \bmod P\end{cases}$$

Consequently, when RBG subset $p$ is indicated, bit $i$ for $i=0,1,\cdots,N_{\mathrm{RB}}^{\mathrm{TYPE1}}-1$ in the bitmap field indicates VRB number,

$$n_{\mathrm{VRB}}^{\mathrm{RBG\ subset}}(p)=\left\lfloor\frac{i+\Delta_{\mathrm{shift}}(p)}{P}\right\rfloor P^2+p\cdot P+\left(i+\Delta_{\mathrm{shift}}(p)\right)\bmod P\,.$$

### 7.1.6.3 Resource allocation type 2

In resource allocations of type 2, the resource block assignment information indicates to a scheduled UE a set of contiguously allocated localized virtual resource blocks or distributed virtual resource blocks. In case of resource allocation signalled with PDCCH DCI format 1A, 1B or 1D, or for resource allocation signalled with EPDCCH DCI format 1A, 1B, or 1D, one bit flag indicates whether localized virtual resource blocks or distributed virtual resource blocks are assigned (value 0 indicates Localized and value 1 indicates Distributed VRB assignment) while distributed virtual resource blocks are always assigned in case of resource allocation signalled with PDCCH DCI format 1C. Localized VRB allocations for a UE vary from a single VRB up to a maximum number of VRBs spanning the system bandwidth. For DCI format 1A the distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs, where $N_{\mathrm{VRB}}^{\mathrm{DL}}$ is defined in [3], if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI. With PDCCH DCI format 1B, 1D with a CRC scrambled by C-RNTI, or with DCI format 1A with a CRC scrambled with C-RNTI, SPS C-RNTI or Temporary C-RNTI distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 6-49 and vary from a single VRB up to 16 if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 50-110. With EPDCCH DCI format 1B, 1D with a CRC scrambled by C-RNTI, or with DCI format 1A with a CRC scrambled with C-RNTI, SPS C-RNTI distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 6-49 and vary from a single VRB up to 16 if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 50-110. With PDCCH DCI format 1C, distributed VRB allocations for a UE vary from $N_{\mathrm{RB}}^{\mathrm{step}}$ VRB(s) up to $\left\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}}/N_{\mathrm{RB}}^{\mathrm{step}}\right\rfloor\cdot N_{\mathrm{RB}}^{\mathrm{step}}$ VRBs with an increment step of $N_{\mathrm{RB}}^{\mathrm{step}}$, where $N_{\mathrm{RB}}^{\mathrm{step}}$ value is determined depending on the downlink system bandwidth as shown in Table 7.1.6.3-1.

**Table 7.1.6.3-1: $N_{\mathrm{RB}}^{\mathrm{step}}$ values vs. Downlink System Bandwidth**

| System BW ( $N_{\mathrm{RB}}^{\mathrm{DL}}$ ) | $N_{\mathrm{RB}}^{\mathrm{step}}$ |
|---|---|
| | DCI format 1C |
| 6-49 | 2 |
| 50-110 | 4 |

For PDCCH DCI format 1A, 1B or 1D, or for EPDCCH DCI format 1A, 1B, or 1D, a type 2 resource allocation field consists of a resource indication value (*RIV*) corresponding to a starting resource block ( $RB_{start}$ ) and a length in terms of virtually contiguously allocated resource blocks $L_{CRBs}$. The resource indication value is defined by

if $(L_{CRBs}-1)\le\lfloor N_{RB}^{DL}/2\rfloor$ then

$$RIV=N_{RB}^{DL}(L_{CRBs}-1)+RB_{start}$$

else

$$RIV = N_{RB}^{DL}(N_{RB}^{DL} - L_{CRBs} + 1) + (N_{RB}^{DL} - 1 - RB_{start})$$

where $L_{CRBs} \geq 1$ and shall not exceed $N_{VRB}^{DL} - RB_{start}$.

For PDCCH DCI format 1C, a type 2 resource block assignment field consists of a resource indication value (*RIV*) corresponding to a starting resource block ( $RB_{start} = 0,\ N_{\mathrm{RB}}^{\mathrm{step}},\ 2N_{\mathrm{RB}}^{\mathrm{step}},\ldots,\ (\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}} / N_{\mathrm{RB}}^{\mathrm{step}} \rfloor - 1)N_{\mathrm{RB}}^{\mathrm{step}}$ ) and a length in terms of virtually contiguously allocated resource blocks ( $L_{CRBs} = N_{\mathrm{RB}}^{\mathrm{step}},\ 2N_{\mathrm{RB}}^{\mathrm{step}},\ldots,\ \lfloor N_{\mathrm{VRB}}^{\mathrm{DL}} / N_{\mathrm{RB}}^{\mathrm{step}} \rfloor \cdot N_{\mathrm{RB}}^{\mathrm{step}}$ ).
The resource indication value is defined by:

if $(L'_{CRBs} - 1) \leq \lfloor N'^{DL}_{VRB} / 2 \rfloor$ then

$$RIV = N'^{DL}_{VRB}(L'_{CRBs} - 1) + RB'_{start}$$

else

$$RIV = N'^{DL}_{VRB}(N'^{DL}_{VRB} - L'_{CRBs} + 1) + (N'^{DL}_{VRB} - 1 - RB'_{start})$$

where $L'_{CRBs} = L_{CRBs} / N_{RB}^{step}$, $RB'_{start} = RB_{start} / N_{RB}^{step}$ and $N'^{DL}_{VRB} = \lfloor N_{VRB}^{DL} / N_{RB}^{step} \rfloor$. Here,

$L'_{CRBs} \geq 1$ and shall not exceed $N'^{DL}_{VRB} - RB'_{start}$.

### 7.1.6.4 PDSCH starting position

The starting OFDM symbol for the PDSCH of each activated serving cell is given by index $l_{\mathrm{DataStart}}$ in the first slot in a subframe.

For a UE configured in transmission mode 1-9, for a given activated serving cell

- if the PDSCH is assigned by EPDCCH received in the same serving cell, or if the UE is configured to monitor EPDCCH in the subframe and the PDSCH is not assigned by a PDCCH/EPDCCH, and if the UE is configured with the higher layer parameter *epdcch-StartSymbol-r11*
  - $l_{\mathrm{DataStart}}$ is given by the higher-layer parameter *epdcch-StartSymbol-r11*.
- else if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells
  - $l_{\mathrm{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received,
- Otherwise
  - $l_{\mathrm{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, and $l_{\mathrm{DataStart}}$ is given by the CFI value + 1 in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 10$.

For a UE configured in transmission mode 10, for a given activated serving cell

- if the PDSCH is assigned by a PDCCH with DCI format 1C or by a PDCCH with DCI format 1A and with CRC scrambled with P-RNTI/RA-RNTI/SI-RNTI/Temporary C-RNTI
  - $l_{\mathrm{DataStart}}$ is given by the span of the DCI given by the CFI value in the subframe of the given serving cell according to subclause 5.3.4 of [4].
- if the PDSCH is assigned by a PDCCH/EPDCCH with DCI format 1A and with CRC scrambled with C-RNTI and if the PDSCH transmission is on antenna ports 0 - 3
  - if the PDSCH is assigned by EPDCCH received in the same serving cell

- $l_{\text{DataStart}}$ is given by $l_{\text{EPDCCHStart}}$ for the EPDCCH-PRB-set where EPDCCH with the DCI format 1A was received ($l_{\text{EPDCCHStart}}$ as defined in subclause 9.1.4.1),

- else if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells
  - $l_{\text{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received.
- otherwise
  - $l_{\text{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{DataStart}}$ is given by the CFI value+1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \le 10$.

– if the PDSCH is assigned by or semi-statically scheduled by a PDCCH/EPDCCH with DCI format 1A and if the PDSCH transmission is on antenna port 7

- if the value of the higher layer parameter *pdsch-Start-r11* determined from parameter set 1 in table 7.1.9-1 for the serving cell on which PDSCH is received belongs to {1,2,3,4},
  - $l'_{\text{DataStart}}$ is given by the higher layer parameter *pdsch-Start-r11* determined from parameter set 1 in table 7.1.9-1 for the serving cell on which PDSCH is received.
- else,
  - if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells,
    - $l'_{\text{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received
  - otherwise
    - $l'_{\text{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{DataStart}}$ is given by the CFI value + 1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \le 10$.
- if the subframe on which PDSCH is received is indicated by the higher layer parameter *mbsfn-SubframeConfigList-r11* determined from parameter set 1 in table 7.1.9-1 for the serving cell on which PDSCH is received, or if the PDSCH is received on subframe 1 or 6 for the frame structure type 2,
  - $l_{\text{DataStart}} = \min(2, l'_{\text{DataStart}})$,
- otherwise
  - $l_{\text{DataStart}} = l'_{\text{DataStart}}$.

– if the PDSCH is assigned by or semi-persistently scheduled by a PDCCH/EPDCCH with DCI format 2D,

- if the value of the higher layer parameter *pdsch-Start-r11* determined from the DCI (according to subclause 7.1.9) for the serving cell on which PDSCH is received belongs to {1,2,3,4},
  - $l'_{\text{DataStart}}$ is given by parameter *pdsch-Start-r11* determined from the DCI (according to subclause 7.1.9) for the serving cell on which PDSCH is received
- else,
  - if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells,
    - $l'_{\text{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received
  - Otherwise

- $l'_{\text{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{DataStart}}$ is given by the CFI value+1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \le 10$.

– if the subframe on which PDSCH is received is indicated by the higher layer parameter *mbsfn-SubframeConfigList-r11* determined from the DCI (according to subclause 7.1.9) for the serving cell on which PDSCH is received, or if the PDSCH is received on subframe 1 or 6 for frame structure type 2,

  ○ $l_{\text{DataStart}} = \min(2, l'_{\text{DataStart}})$,

– otherwise

  ○ $l_{\text{DataStart}} = l'_{\text{DataStart}}$.

### 7.1.6.5 Physical Resource Block (PRB) bundling

A UE configured for transmission mode 9 for a given serving cell *c* may assume that precoding granularity is multiple resource blocks in the frequency domain when PMI/RI reporting is configured.

For a given serving cell c, if a UE is configured for transmission mode 10

- if PMI/RI reporting is configured for all configured CSI processes for the serving cell *c*, the UE may assume that precoding granularity is multiple resource blocks in the frequency domain,
- otherwise, the UE shall assume the precoding granularity is one resource block in the frequency domain.

Fixed system bandwidth dependent Precoding Resource block Groups (PRGs) of size $P'$ partition the system bandwidth and each PRG consists of consecutive PRBs. If $N_{\text{RB}}^{\text{DL}} \bmod P' > 0$ then one of the PRGs is of size $N_{\text{RB}}^{\text{DL}} - P'\lfloor N_{\text{RB}}^{\text{DL}} / P' \rfloor$. The PRG size is non-increasing starting at the lowest frequency. The UE may assume that the same precoder applies on all scheduled PRBs within a PRG.

The PRG size a UE may assume for a given system bandwidth is given by:

**Table 7.1.6.5-1**

| System Bandwidth ($N_{\text{RB}}^{\text{DL}}$) | PRG Size ($P'$) (PRBs) |
|---|---|
| ≤10 | 1 |
| 11 – 26 | 2 |
| 27 – 63 | 3 |
| 64 – 110 | 2 |

## 7.1.7 Modulation order and transport block size determination

To determine the modulation order and transport block size(s) in the physical downlink shared channel, the UE shall first

- read the 5-bit "modulation and coding scheme" field ( $I_{\mathrm{MCS}}$ ) in the DCI

and second if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A:
  - set the Table 7.1.7.2.1-1 column indicator $N_{\mathrm{PRB}}$ to $N_{\mathrm{PRB}}^{1\mathrm{A}}$ from subclause 5.3.3.1.3 in [4]
- for DCI format 1C:
  - use Table 7.1.7.2.3-1 for determining its transport block size.

else

- set $N'_{\mathrm{PRB}}$ to the total number of allocated PRBs based on the procedure defined in subclause 7.1.6.

  if the transport block is transmitted in DwPTS of the special subframe in frame structure type 2, then

  - for special subframe configuration 9 with normal cyclic prefix or special subframe configuration 7 with extended cyclic prefix:
    - set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = \max\left\{\left\lfloor N'_{\mathrm{PRB}} \times 0.375 \right\rfloor, \quad 1\right\}$
  - for other special subframe configurations:
    - set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = \max\left\{\left\lfloor N'_{\mathrm{PRB}} \times 0.75 \right\rfloor, \quad 1\right\}$,

  else, set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = N'_{PRB}$.

The UE may skip decoding a transport block in an initial transmission if the effective channel code rate is higher than 0.930, where the effective channel code rate is defined as the number of downlink information bits (including CRC bits) divided by the number of physical channel bits on PDSCH. If the UE skips decoding, the physical layer indicates to higher layer that the transport block is not successfully decoded. For the special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP, shown in Table 4.2-1 of [3], there shall be no PDSCH transmission in DwPTS of the special subframe.

### 7.1.7.1 Modulation order determination

The UE shall use $Q_m = 2$ if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI, otherwise, the UE shall use $I_{\mathrm{MCS}}$ and Table 7.1.7.1-1 to determine the modulation order ( $Q_m$ ) used in the physical downlink shared channel.

**Table 7.1.7.1-1: Modulation and TBS index table for PDSCH**

| MCS Index $I_{MCS}$ | Modulation Order $Q_m$ | TBS Index $I_{TBS}$ |
|---|---|---|
| **0** | 2 | 0 |
| **1** | 2 | 1 |
| **2** | 2 | 2 |
| **3** | 2 | 3 |
| **4** | 2 | 4 |
| **5** | 2 | 5 |
| **6** | 2 | 6 |
| **7** | 2 | 7 |
| **8** | 2 | 8 |
| **9** | 2 | 9 |
| **10** | 4 | 9 |
| **11** | 4 | 10 |
| **12** | 4 | 11 |
| **13** | 4 | 12 |
| **14** | 4 | 13 |
| **15** | 4 | 14 |
| **16** | 4 | 15 |
| **17** | 6 | 15 |
| **18** | 6 | 16 |
| **19** | 6 | 17 |
| **20** | 6 | 18 |
| **21** | 6 | 19 |
| **22** | 6 | 20 |
| **23** | 6 | 21 |
| **24** | 6 | 22 |
| **25** | 6 | 23 |
| **26** | 6 | 24 |
| **27** | 6 | 25 |
| **28** | 6 | 26 |
| **29** | 2 | reserved |
| **30** | 4 | |
| **31** | 6 | |

### 7.1.7.2 Transport block size determination

If the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A:
  - the UE shall set the TBS index ( $I_{TBS}$ ) equal to $I_{MCS}$ and determine its TBS by the procedure in subclause 7.1.7.2.1.
- for DCI format 1C:
  - the UE shall set the TBS index ( $I_{TBS}$ ) equal to $I_{MCS}$ and determine its TBS from Table 7.1.7.2.3-1.

else

- for $0 \le I_{MCS} \le 28$ , the UE shall first determine the TBS index ( $I_{TBS}$ ) using $I_{MCS}$ and Table 7.1.7.1-1 except if the transport block is disabled in DCI formats 2, 2A, 2B, 2C and 2D as specified below. For a transport block that is not mapped to more than single-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.2. For a transport block that is mapped to three-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.4. For a transport block that is mapped to four-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.5.

– for $29 \le I_{MCS} \le 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH/EPDCCH for the same transport block using $0 \le I_{MCS} \le 28$. If there is no PDCCH/EPDCCH for the same transport block using $0 \le I_{MCS} \le 28$, and if the initial PDSCH for the same transport block is semi-persistently scheduled, the TBS shall be determined from the most recent semi-persistent scheduling assignment PDCCH/EPDCCH.

– In DCI formats 2, 2A, 2B, 2C and 2D a transport block is disabled if $I_{MCS} = 0$ and if $rv_{idx} = 1$ otherwise the transport block is enabled.

The NDI and HARQ process ID, as signalled on PDCCH/EPDCCH, and the TBS, as determined above, shall be delivered to higher layers.

#### 7.1.7.2.1 Transport blocks not mapped to two or more layer spatial multiplexing

For $1 \le N_{PRB} \le 110$, the TBS is given by the ( $I_{TBS}$ , $N_{PRB}$ ) entry of Table 7.1.7.2.1-1.

**Table 7.1.7.2.1-1: Transport block size table (dimension 27×110)**

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| 0 | 16 | 32 | 56 | 88 | 120 | 152 | 176 | 208 | 224 | 256 |
| 1 | 24 | 56 | 88 | 144 | 176 | 208 | 224 | 256 | 328 | 344 |
| 2 | 32 | 72 | 144 | 176 | 208 | 256 | 296 | 328 | 376 | 424 |
| 3 | 40 | 104 | 176 | 208 | 256 | 328 | 392 | 440 | 504 | 568 |
| 4 | 56 | 120 | 208 | 256 | 328 | 408 | 488 | 552 | 632 | 696 |
| 5 | 72 | 144 | 224 | 328 | 424 | 504 | 600 | 680 | 776 | 872 |
| 6 | 328 | 176 | 256 | 392 | 504 | 600 | 712 | 808 | 936 | 1032 |
| 7 | 104 | 224 | 328 | 472 | 584 | 712 | 840 | 968 | 1096 | 1224 |
| 8 | 120 | 256 | 392 | 536 | 680 | 808 | 968 | 1096 | 1256 | 1384 |
| 9 | 136 | 296 | 456 | 616 | 776 | 936 | 1096 | 1256 | 1416 | 1544 |
| 10 | 144 | 328 | 504 | 680 | 872 | 1032 | 1224 | 1384 | 1544 | 1736 |
| 11 | 176 | 376 | 584 | 776 | 1000 | 1192 | 1384 | 1608 | 1800 | 2024 |
| 12 | 208 | 440 | 680 | 904 | 1128 | 1352 | 1608 | 1800 | 2024 | 2280 |
| 13 | 224 | 488 | 744 | 1000 | 1256 | 1544 | 1800 | 2024 | 2280 | 2536 |
| 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 1992 | 2280 | 2600 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2152 | 2472 | 2728 | 3112 |
| 16 | 328 | 632 | 968 | 1288 | 1608 | 1928 | 2280 | 2600 | 2984 | 3240 |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 | 2536 | 2856 | 3240 | 3624 |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 | 2792 | 3112 | 3624 | 4008 |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | 2600 | 2984 | 3496 | 3880 | 4264 |
| 20 | 440 | 904 | 1384 | 1864 | 2344 | 2792 | 3240 | 3752 | 4136 | 4584 |
| 21 | 488 | 1000 | 1480 | 1992 | 2472 | 2984 | 3496 | 4008 | 4584 | 4968 |
| 22 | 520 | 1064 | 1608 | 2152 | 2664 | 3240 | 3752 | 4264 | 4776 | 5352 |
| 23 | 552 | 1128 | 1736 | 2280 | 2856 | 3496 | 4008 | 4584 | 5160 | 5736 |
| 24 | 584 | 1192 | 1800 | 2408 | 2984 | 3624 | 4264 | 4968 | 5544 | 5992 |
| 25 | 616 | 1256 | 1864 | 2536 | 3112 | 3752 | 4392 | 5160 | 5736 | 6200 |
| 26 | 712 | 1480 | 2216 | 2984 | 3752 | 4392 | 5160 | 5992 | 6712 | 7480 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| 0 | 288 | 328 | 344 | 376 | 392 | 424 | 456 | 488 | 504 | 536 |
| 1 | 376 | 424 | 456 | 488 | 520 | 568 | 600 | 632 | 680 | 712 |
| 2 | 472 | 520 | 568 | 616 | 648 | 696 | 744 | 776 | 840 | 872 |
| 3 | 616 | 680 | 744 | 808 | 872 | 904 | 968 | 1032 | 1096 | 1160 |
| 4 | 776 | 840 | 904 | 1000 | 1064 | 1128 | 1192 | 1288 | 1352 | 1416 |
| 5 | 968 | 1032 | 1128 | 1224 | 1320 | 1384 | 1480 | 1544 | 1672 | 1736 |
| 6 | 1128 | 1224 | 1352 | 1480 | 1544 | 1672 | 1736 | 1864 | 1992 | 2088 |
| 7 | 1320 | 1480 | 1608 | 1672 | 1800 | 1928 | 2088 | 2216 | 2344 | 2472 |
| 8 | 1544 | 1672 | 1800 | 1928 | 2088 | 2216 | 2344 | 2536 | 2664 | 2792 |
| 9 | 1736 | 1864 | 2024 | 2216 | 2344 | 2536 | 2664 | 2856 | 2984 | 3112 |
| 10 | 1928 | 2088 | 2280 | 2472 | 2664 | 2792 | 2984 | 3112 | 3368 | 3496 |
| 11 | 2216 | 2408 | 2600 | 2792 | 2984 | 3240 | 3496 | 3624 | 3880 | 4008 |
| 12 | 2472 | 2728 | 2984 | 3240 | 3368 | 3624 | 3880 | 4136 | 4392 | 4584 |
| 13 | 2856 | 3112 | 3368 | 3624 | 3880 | 4136 | 4392 | 4584 | 4968 | 5160 |
| 14 | 3112 | 3496 | 3752 | 4008 | 4264 | 4584 | 4968 | 5160 | 5544 | 5736 |
| 15 | 3368 | 3624 | 4008 | 4264 | 4584 | 4968 | 5160 | 5544 | 5736 | 6200 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 3624 | 3880 | 4264 | 4584 | 4968 | 5160 | 5544 | 5992 | 6200 | 6456 |
| 17 | 4008 | 4392 | 4776 | 5160 | 5352 | 5736 | 6200 | 6456 | 6712 | 7224 |
| 18 | 4392 | 4776 | 5160 | 5544 | 5992 | 6200 | 6712 | 7224 | 7480 | 7992 |
| 19 | 4776 | 5160 | 5544 | 5992 | 6456 | 6968 | 7224 | 7736 | 8248 | 8504 |
| 20 | 5160 | 5544 | 5992 | 6456 | 6968 | 7480 | 7992 | 8248 | 8760 | 9144 |
| 21 | 5544 | 5992 | 6456 | 6968 | 7480 | 7992 | 8504 | 9144 | 9528 | 9912 |
| 22 | 5992 | 6456 | 6968 | 7480 | 7992 | 8504 | 9144 | 9528 | 10296 | 10680 |
| 23 | 6200 | 6968 | 7480 | 7992 | 8504 | 9144 | 9912 | 10296 | 11064 | 11448 |
| 24 | 6712 | 7224 | 7992 | 8504 | 9144 | 9912 | 10296 | 11064 | 11448 | 12216 |
| 25 | 6968 | 7480 | 8248 | 8760 | 9528 | 10296 | 10680 | 11448 | 12216 | 12576 |
| 26 | 8248 | 8760 | 9528 | 10296 | 11064 | 11832 | 12576 | 13536 | 14112 | 14688 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** |
| 0 | 568 | 600 | 616 | 648 | 680 | 712 | 744 | 776 | 776 | 808 |
| 1 | 744 | 776 | 808 | 872 | 904 | 936 | 968 | 1000 | 1032 | 1064 |
| 2 | 936 | 968 | 1000 | 1064 | 1096 | 1160 | 1192 | 1256 | 1288 | 1320 |
| 3 | 1224 | 1256 | 1320 | 1384 | 1416 | 1480 | 1544 | 1608 | 1672 | 1736 |
| 4 | 1480 | 1544 | 1608 | 1736 | 1800 | 1864 | 1928 | 1992 | 2088 | 2152 |
| 5 | 1864 | 1928 | 2024 | 2088 | 2216 | 2280 | 2344 | 2472 | 2536 | 2664 |
| 6 | 2216 | 2280 | 2408 | 2472 | 2600 | 2728 | 2792 | 2984 | 2984 | 3112 |
| 7 | 2536 | 2664 | 2792 | 2984 | 3112 | 3240 | 3368 | 3368 | 3496 | 3624 |
| 8 | 2984 | 3112 | 3240 | 3368 | 3496 | 3624 | 3752 | 3880 | 4008 | 4264 |
| 9 | 3368 | 3496 | 3624 | 3752 | 4008 | 4136 | 4264 | 4392 | 4584 | 4776 |
| 10 | 3752 | 3880 | 4008 | 4264 | 4392 | 4584 | 4776 | 4968 | 5160 | 5352 |
| 11 | 4264 | 4392 | 4584 | 4776 | 4968 | 5352 | 5544 | 5736 | 5992 | 5992 |
| 12 | 4776 | 4968 | 5352 | 5544 | 5736 | 5992 | 6200 | 6456 | 6712 | 6712 |
| 13 | 5352 | 5736 | 5992 | 6200 | 6456 | 6712 | 6968 | 7224 | 7480 | 7736 |
| 14 | 5992 | 6200 | 6456 | 6968 | 7224 | 7480 | 7736 | 7992 | 8248 | 8504 |
| 15 | 6456 | 6712 | 6968 | 7224 | 7736 | 7992 | 8248 | 8504 | 8760 | 9144 |
| 16 | 6712 | 7224 | 7480 | 7736 | 7992 | 8504 | 8760 | 9144 | 9528 | 9912 |
| 17 | 7480 | 7992 | 8248 | 8760 | 9144 | 9528 | 9912 | 10296 | 10296 | 10680 |
| 18 | 8248 | 8760 | 9144 | 9528 | 9912 | 10296 | 10680 | 11064 | 11448 | 11832 |
| 19 | 9144 | 9528 | 9912 | 10296 | 10680 | 11064 | 11448 | 12216 | 12576 | 12960 |
| 20 | 9912 | 10296 | 10680 | 11064 | 11448 | 12216 | 12576 | 12960 | 13536 | 14112 |
| 21 | 10680 | 11064 | 11448 | 12216 | 12576 | 12960 | 13536 | 14112 | 14688 | 15264 |
| 22 | 11448 | 11832 | 12576 | 12960 | 13536 | 14112 | 14688 | 15264 | 15840 | 16416 |
| 23 | 12216 | 12576 | 12960 | 13536 | 14112 | 14688 | 15264 | 15840 | 16416 | 16992 |
| 24 | 12960 | 13536 | 14112 | 14688 | 15264 | 15840 | 16416 | 16992 | 17568 | 18336 |
| 25 | 13536 | 14112 | 14688 | 15264 | 15840 | 16416 | 16992 | 17568 | 18336 | 19080 |
| 26 | 15264 | 16416 | 16992 | 17568 | 18336 | 19080 | 19848 | 20616 | 21384 | 22152 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **31** | **32** | **33** | **34** | **35** | **36** | **37** | **38** | **39** | **40** |
| 0 | 840 | 872 | 904 | 936 | 968 | 1000 | 1032 | 1032 | 1064 | 1096 |
| 1 | 1128 | 1160 | 1192 | 1224 | 1256 | 1288 | 1352 | 1384 | 1416 | 1416 |
| 2 | 1384 | 1416 | 1480 | 1544 | 1544 | 1608 | 1672 | 1672 | 1736 | 1800 |
| 3 | 1800 | 1864 | 1928 | 1992 | 2024 | 2088 | 2152 | 2216 | 2280 | 2344 |
| 4 | 2216 | 2280 | 2344 | 2408 | 2472 | 2600 | 2664 | 2728 | 2792 | 2856 |
| 5 | 2728 | 2792 | 2856 | 2984 | 3112 | 3112 | 3240 | 3368 | 3496 | 3496 |
| 6 | 3240 | 3368 | 3496 | 3496 | 3624 | 3752 | 3880 | 4008 | 4136 | 4136 |
| 7 | 3752 | 3880 | 4008 | 4136 | 4264 | 4392 | 4584 | 4584 | 4776 | 4968 |
| 8 | 4392 | 4584 | 4584 | 4776 | 4968 | 4968 | 5160 | 5352 | 5544 | 5544 |
| 9 | 4968 | 5160 | 5160 | 5352 | 5544 | 5736 | 5736 | 5992 | 6200 | 6200 |
| 10 | 5544 | 5736 | 5736 | 5992 | 6200 | 6200 | 6456 | 6712 | 6712 | 6968 |
| 11 | 6200 | 6456 | 6712 | 6968 | 6968 | 7224 | 7480 | 7736 | 7736 | 7992 |
| 12 | 6968 | 7224 | 7480 | 7736 | 7992 | 8248 | 8504 | 8760 | 8760 | 9144 |
| 13 | 7992 | 8248 | 8504 | 8760 | 9144 | 9144 | 9528 | 9912 | 9912 | 10296 |
| 14 | 8760 | 9144 | 9528 | 9912 | 9912 | 10296 | 10680 | 11064 | 11064 | 11448 |
| 15 | 9528 | 9912 | 10296 | 10296 | 10680 | 11064 | 11448 | 11832 | 11832 | 12216 |
| 16 | 9912 | 10296 | 10680 | 11064 | 11448 | 11832 | 12216 | 12216 | 12576 | 12960 |
| 17 | 11064 | 11448 | 11832 | 12216 | 12576 | 12960 | 13536 | 13536 | 14112 | 14688 |
| 18 | 12216 | 12576 | 12960 | 13536 | 14112 | 14112 | 14688 | 15264 | 15264 | 15840 |
| 19 | 13536 | 13536 | 14112 | 14688 | 15264 | 15264 | 15840 | 16416 | 16992 | 16992 |
| 20 | 14688 | 14688 | 15264 | 15840 | 16416 | 16992 | 16992 | 17568 | 18336 | 18336 |
| 21 | 15840 | 15840 | 16416 | 16992 | 17568 | 18336 | 18336 | 19080 | 19848 | 19848 |
| 22 | 16992 | 16992 | 17568 | 18336 | 19080 | 19080 | 19848 | 20616 | 21384 | 21384 |
| 23 | 17568 | 18336 | 19080 | 19848 | 19848 | 20616 | 21384 | 22152 | 22152 | 22920 |
| 24 | 19080 | 19848 | 19848 | 20616 | 21384 | 22152 | 22920 | 22920 | 23688 | 24496 |
| 25 | 19848 | 20616 | 20616 | 21384 | 22152 | 22920 | 23688 | 24496 | 24496 | 25456 |
| 26 | 22920 | 23688 | 24496 | 25456 | 25456 | 26416 | 27376 | 28336 | 29296 | 29296 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
| 0 | 1128 | 1160 | 1192 | 1224 | 1256 | 1256 | 1288 | 1320 | 1352 | 1384 |
| 1 | 1480 | 1544 | 1544 | 1608 | 1608 | 1672 | 1736 | 1736 | 1800 | 1800 |
| 2 | 1800 | 1864 | 1928 | 1992 | 2024 | 2088 | 2088 | 2152 | 2216 | 2216 |
| 3 | 2408 | 2472 | 2536 | 2536 | 2600 | 2664 | 2728 | 2792 | 2856 | 2856 |
| 4 | 2984 | 2984 | 3112 | 3112 | 3240 | 3240 | 3368 | 3496 | 3496 | 3624 |
| 5 | 3624 | 3752 | 3752 | 3880 | 4008 | 4008 | 4136 | 4264 | 4392 | 4392 |
| 6 | 4264 | 4392 | 4584 | 4584 | 4776 | 4776 | 4968 | 4968 | 5160 | 5160 |
| 7 | 4968 | 5160 | 5352 | 5352 | 5544 | 5736 | 5736 | 5992 | 5992 | 6200 |
| 8 | 5736 | 5992 | 5992 | 6200 | 6200 | 6456 | 6456 | 6712 | 6968 | 6968 |
| 9 | 6456 | 6712 | 6712 | 6968 | 6968 | 7224 | 7480 | 7480 | 7736 | 7992 |
| 10 | 7224 | 7480 | 7480 | 7736 | 7992 | 7992 | 8248 | 8504 | 8504 | 8760 |
| 11 | 8248 | 8504 | 8760 | 8760 | 9144 | 9144 | 9528 | 9528 | 9912 | 9912 |
| 12 | 9528 | 9528 | 9912 | 9912 | 10296 | 10680 | 10680 | 11064 | 11064 | 11448 |
| 13 | 10680 | 10680 | 11064 | 11448 | 11448 | 11832 | 12216 | 12216 | 12576 | 12960 |
| 14 | 11832 | 12216 | 12216 | 12576 | 12960 | 12960 | 13536 | 13536 | 14112 | 14112 |
| 15 | 12576 | 12960 | 12960 | 13536 | 13536 | 14112 | 14688 | 14688 | 15264 | 15264 |
| 16 | 13536 | 13536 | 14112 | 14112 | 14688 | 14688 | 15264 | 15840 | 15840 | 16416 |
| 17 | 14688 | 15264 | 15264 | 15840 | 16416 | 16416 | 16992 | 17568 | 17568 | 18336 |
| 18 | 16416 | 16416 | 16992 | 17568 | 17568 | 18336 | 18336 | 19080 | 19080 | 19848 |
| 19 | 17568 | 18336 | 18336 | 19080 | 19080 | 19848 | 20616 | 20616 | 21384 | 21384 |
| 20 | 19080 | 19848 | 19848 | 20616 | 20616 | 21384 | 22152 | 22152 | 22920 | 22920 |
| 21 | 20616 | 21384 | 21384 | 22152 | 22920 | 22920 | 23688 | 24496 | 24496 | 25456 |
| 22 | 22152 | 22920 | 22920 | 23688 | 24496 | 24496 | 25456 | 25456 | 26416 | 27376 |
| 23 | 23688 | 24496 | 24496 | 25456 | 25456 | 26416 | 27376 | 27376 | 28336 | 28336 |
| 24 | 25456 | 25456 | 26416 | 26416 | 27376 | 28336 | 28336 | 29296 | 29296 | 30576 |
| 25 | 26416 | 26416 | 27376 | 28336 | 28336 | 29296 | 29296 | 30576 | 31704 | 31704 |
| 26 | 30576 | 30576 | 31704 | 32856 | 32856 | 34008 | 35160 | 35160 | 36696 | 36696 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| 0 | 1416 | 1416 | 1480 | 1480 | 1544 | 1544 | 1608 | 1608 | 1608 | 1672 |
| 1 | 1864 | 1864 | 1928 | 1992 | 1992 | 2024 | 2088 | 2088 | 2152 | 2152 |
| 2 | 2280 | 2344 | 2344 | 2408 | 2472 | 2536 | 2536 | 2600 | 2664 | 2664 |
| 3 | 2984 | 2984 | 3112 | 3112 | 3240 | 3240 | 3368 | 3368 | 3496 | 3496 |
| 4 | 3624 | 3752 | 3752 | 3880 | 4008 | 4008 | 4136 | 4136 | 4264 | 4264 |
| 5 | 4584 | 4584 | 4776 | 4776 | 4776 | 4968 | 4968 | 5160 | 5160 | 5352 |
| 6 | 5352 | 5352 | 5544 | 5736 | 5736 | 5992 | 5992 | 5992 | 6200 | 6200 |
| 7 | 6200 | 6456 | 6456 | 6712 | 6712 | 6712 | 6968 | 6968 | 7224 | 7224 |
| 8 | 7224 | 7224 | 7480 | 7480 | 7736 | 7736 | 7992 | 7992 | 8248 | 8504 |
| 9 | 7992 | 8248 | 8248 | 8504 | 8760 | 8760 | 9144 | 9144 | 9144 | 9528 |
| 10 | 9144 | 9144 | 9144 | 9528 | 9528 | 9912 | 9912 | 10296 | 10296 | 10680 |
| 11 | 10296 | 10680 | 10680 | 11064 | 11064 | 11448 | 11448 | 11832 | 11832 | 12216 |
| 12 | 11832 | 11832 | 12216 | 12216 | 12576 | 12576 | 12960 | 12960 | 13536 | 13536 |
| 13 | 12960 | 13536 | 13536 | 14112 | 14112 | 14688 | 14688 | 14688 | 15264 | 15264 |
| 14 | 14688 | 14688 | 15264 | 15264 | 15840 | 15840 | 16416 | 16416 | 16992 | 16992 |
| 15 | 15840 | 15840 | 16416 | 16416 | 16992 | 16992 | 17568 | 17568 | 18336 | 18336 |
| 16 | 16416 | 16992 | 16992 | 17568 | 17568 | 18336 | 18336 | 19080 | 19080 | 19848 |
| 17 | 18336 | 19080 | 19080 | 19848 | 19848 | 20616 | 20616 | 20616 | 21384 | 21384 |
| 18 | 19848 | 20616 | 21384 | 21384 | 22152 | 22152 | 22920 | 22920 | 23688 | 23688 |
| 19 | 22152 | 22152 | 22920 | 22920 | 23688 | 24496 | 24496 | 25456 | 25456 | 25456 |
| 20 | 23688 | 24496 | 24496 | 25456 | 25456 | 26416 | 26416 | 27376 | 27376 | 28336 |
| 21 | 25456 | 26416 | 26416 | 27376 | 27376 | 28336 | 28336 | 29296 | 29296 | 30576 |
| 22 | 27376 | 28336 | 28336 | 29296 | 29296 | 30576 | 30576 | 31704 | 31704 | 32856 |
| 23 | 29296 | 29296 | 30576 | 30576 | 31704 | 31704 | 32856 | 32856 | 34008 | 34008 |
| 24 | 31704 | 31704 | 32856 | 32856 | 34008 | 34008 | 35160 | 35160 | 36696 | 36696 |
| 25 | 32856 | 32856 | 34008 | 34008 | 35160 | 35160 | 36696 | 36696 | 37888 | 37888 |
| 26 | 37888 | 37888 | 39232 | 40576 | 40576 | 40576 | 42368 | 42368 | 43816 | 43816 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
| 0 | 1672 | 1736 | 1736 | 1800 | 1800 | 1800 | 1864 | 1864 | 1928 | 1928 |
| 1 | 2216 | 2280 | 2280 | 2344 | 2344 | 2408 | 2472 | 2472 | 2536 | 2536 |
| 2 | 2728 | 2792 | 2856 | 2856 | 2856 | 2984 | 2984 | 3112 | 3112 | 3112 |
| 3 | 3624 | 3624 | 3624 | 3752 | 3752 | 3880 | 3880 | 4008 | 4008 | 4136 |
| 4 | 4392 | 4392 | 4584 | 4584 | 4584 | 4776 | 4776 | 4968 | 4968 | 4968 |
| 5 | 5352 | 5544 | 5544 | 5736 | 5736 | 5736 | 5992 | 5992 | 5992 | 6200 |
| 6 | 6456 | 6456 | 6456 | 6712 | 6712 | 6968 | 6968 | 6968 | 7224 | 7224 |
| 7 | 7480 | 7480 | 7736 | 7736 | 7992 | 7992 | 8248 | 8248 | 8504 | 8504 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 8504 | 8760 | 8760 | 9144 | 9144 | 9144 | 9528 | 9528 | 9528 | 9912 |
| 9 | 9528 | 9912 | 9912 | 10296 | 10296 | 10296 | 10680 | 10680 | 11064 | 11064 |
| 10 | 10680 | 11064 | 11064 | 11448 | 11448 | 11448 | 11832 | 11832 | 12216 | 12216 |
| 11 | 12216 | 12576 | 12576 | 12960 | 12960 | 13536 | 13536 | 13536 | 14112 | 14112 |
| 12 | 14112 | 14112 | 14112 | 14688 | 14688 | 15264 | 15264 | 15264 | 15840 | 15840 |
| 13 | 15840 | 15840 | 16416 | 16416 | 16992 | 16992 | 16992 | 17568 | 17568 | 18336 |
| 14 | 17568 | 17568 | 18336 | 18336 | 18336 | 19080 | 19080 | 19848 | 19848 | 19848 |
| 15 | 18336 | 19080 | 19080 | 19848 | 19848 | 20616 | 20616 | 20616 | 21384 | 21384 |
| 16 | 19848 | 19848 | 20616 | 20616 | 21384 | 21384 | 22152 | 22152 | 22152 | 22920 |
| 17 | 22152 | 22152 | 22920 | 22920 | 23688 | 23688 | 24496 | 24496 | 24496 | 25456 |
| 18 | 24496 | 24496 | 24496 | 25456 | 25456 | 26416 | 26416 | 27376 | 27376 | 27376 |
| 19 | 26416 | 26416 | 27376 | 27376 | 28336 | 28336 | 29296 | 29296 | 29296 | 30576 |
| 20 | 28336 | 29296 | 29296 | 29296 | 30576 | 30576 | 31704 | 31704 | 31704 | 32856 |
| 21 | 30576 | 31704 | 31704 | 31704 | 32856 | 32856 | 34008 | 34008 | 35160 | 35160 |
| 22 | 32856 | 34008 | 34008 | 34008 | 35160 | 35160 | 36696 | 36696 | 36696 | 37888 |
| 23 | 35160 | 35160 | 36696 | 36696 | 37888 | 37888 | 37888 | 39232 | 39232 | 40576 |
| 24 | 36696 | 37888 | 37888 | 39232 | 39232 | 40576 | 40576 | 42368 | 42368 | 42368 |
| 25 | 39232 | 39232 | 40576 | 40576 | 40576 | 42368 | 42368 | 43816 | 43816 | 43816 |
| 26 | 45352 | 45352 | 46888 | 46888 | 48936 | 48936 | 48936 | 51024 | 51024 | 52752 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **71** | **72** | **73** | **74** | **75** | **76** | **77** | **78** | **79** | **80** |
| 0 | 1992 | 1992 | 2024 | 2088 | 2088 | 2088 | 2152 | 2152 | 2216 | 2216 |
| 1 | 2600 | 2600 | 2664 | 2728 | 2728 | 2792 | 2792 | 2856 | 2856 | 2856 |
| 2 | 3240 | 3240 | 3240 | 3368 | 3368 | 3368 | 3496 | 3496 | 3496 | 3624 |
| 3 | 4136 | 4264 | 4264 | 4392 | 4392 | 4392 | 4584 | 4584 | 4584 | 4776 |
| 4 | 5160 | 5160 | 5160 | 5352 | 5352 | 5544 | 5544 | 5544 | 5736 | 5736 |
| 5 | 6200 | 6200 | 6456 | 6456 | 6712 | 6712 | 6712 | 6968 | 6968 | 6968 |
| 6 | 7480 | 7480 | 7736 | 7736 | 7736 | 7992 | 7992 | 8248 | 8248 | 8248 |
| 7 | 8760 | 8760 | 8760 | 9144 | 9144 | 9144 | 9528 | 9528 | 9528 | 9912 |
| 8 | 9912 | 9912 | 10296 | 10296 | 10680 | 10680 | 10680 | 11064 | 11064 | 11064 |
| 9 | 11064 | 11448 | 11448 | 11832 | 11832 | 11832 | 12216 | 12216 | 12576 | 12576 |
| 10 | 12576 | 12576 | 12960 | 12960 | 12960 | 13536 | 13536 | 13536 | 14112 | 14112 |
| 11 | 14112 | 14688 | 14688 | 14688 | 15264 | 15264 | 15840 | 15840 | 15840 | 16416 |
| 12 | 16416 | 16416 | 16416 | 16992 | 16992 | 17568 | 17568 | 17568 | 18336 | 18336 |
| 13 | 18336 | 18336 | 19080 | 19080 | 19080 | 19848 | 19848 | 19848 | 20616 | 20616 |
| 14 | 20616 | 20616 | 20616 | 21384 | 21384 | 22152 | 22152 | 22152 | 22920 | 22920 |
| 15 | 22152 | 22152 | 22152 | 22920 | 22920 | 23688 | 23688 | 23688 | 24496 | 24496 |
| 16 | 22920 | 23688 | 23688 | 24496 | 24496 | 24496 | 25456 | 25456 | 25456 | 26416 |
| 17 | 25456 | 26416 | 26416 | 26416 | 27376 | 27376 | 27376 | 28336 | 28336 | 29296 |
| 18 | 28336 | 28336 | 29296 | 29296 | 29296 | 30576 | 30576 | 30576 | 31704 | 31704 |
| 19 | 30576 | 30576 | 31704 | 31704 | 32856 | 32856 | 32856 | 34008 | 34008 | 34008 |
| 20 | 32856 | 34008 | 34008 | 34008 | 35160 | 35160 | 35160 | 36696 | 36696 | 36696 |
| 21 | 35160 | 36696 | 36696 | 36696 | 37888 | 37888 | 39232 | 39232 | 39232 | 40576 |
| 22 | 37888 | 39232 | 39232 | 40576 | 40576 | 40576 | 42368 | 42368 | 42368 | 43816 |
| 23 | 40576 | 40576 | 42368 | 42368 | 43816 | 43816 | 43816 | 45352 | 45352 | 45352 |
| 24 | 43816 | 43816 | 45352 | 45352 | 45352 | 46888 | 46888 | 46888 | 48936 | 48936 |
| 25 | 45352 | 45352 | 46888 | 46888 | 46888 | 48936 | 48936 | 48936 | 51024 | 51024 |
| 26 | 52752 | 52752 | 55056 | 55056 | 55056 | 55056 | 57336 | 57336 | 57336 | 59256 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **81** | **82** | **83** | **84** | **85** | **86** | **87** | **88** | **89** | **90** |
| 0 | 2280 | 2280 | 2280 | 2344 | 2344 | 2408 | 2408 | 2472 | 2472 | 2536 |
| 1 | 2984 | 2984 | 2984 | 3112 | 3112 | 3112 | 3240 | 3240 | 3240 | 3240 |
| 2 | 3624 | 3624 | 3752 | 3752 | 3880 | 3880 | 3880 | 4008 | 4008 | 4008 |
| 3 | 4776 | 4776 | 4776 | 4968 | 4968 | 4968 | 5160 | 5160 | 5160 | 5352 |
| 4 | 5736 | 5992 | 5992 | 5992 | 5992 | 6200 | 6200 | 6200 | 6456 | 6456 |
| 5 | 7224 | 7224 | 7224 | 7480 | 7480 | 7480 | 7736 | 7736 | 7736 | 7992 |
| 6 | 8504 | 8504 | 8760 | 8760 | 8760 | 9144 | 9144 | 9144 | 9144 | 9528 |
| 7 | 9912 | 9912 | 10296 | 10296 | 10296 | 10680 | 10680 | 10680 | 11064 | 11064 |
| 8 | 11448 | 11448 | 11448 | 11832 | 11832 | 12216 | 12216 | 12216 | 12576 | 12576 |
| 9 | 12960 | 12960 | 12960 | 13536 | 13536 | 13536 | 13536 | 14112 | 14112 | 14112 |
| 10 | 14112 | 14688 | 14688 | 14688 | 14688 | 15264 | 15264 | 15264 | 15840 | 15840 |
| 11 | 16416 | 16416 | 16992 | 16992 | 16992 | 17568 | 17568 | 17568 | 18336 | 18336 |
| 12 | 18336 | 19080 | 19080 | 19080 | 19080 | 19848 | 19848 | 19848 | 20616 | 20616 |
| 13 | 20616 | 21384 | 21384 | 21384 | 22152 | 22152 | 22152 | 22920 | 22920 | 22920 |
| 14 | 22920 | 23688 | 23688 | 24496 | 24496 | 24496 | 25456 | 25456 | 25456 | 25456 |
| 15 | 24496 | 25456 | 25456 | 25456 | 26416 | 26416 | 26416 | 27376 | 27376 | 27376 |
| 16 | 26416 | 26416 | 27376 | 27376 | 27376 | 28336 | 28336 | 28336 | 29296 | 29296 |
| 17 | 29296 | 29296 | 30576 | 30576 | 30576 | 30576 | 31704 | 31704 | 31704 | 32856 |
| 18 | 31704 | 32856 | 32856 | 32856 | 34008 | 34008 | 34008 | 35160 | 35160 | 35160 |
| 19 | 35160 | 35160 | 35160 | 36696 | 36696 | 36696 | 37888 | 37888 | 37888 | 39232 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 37888 | 37888 | 39232 | 39232 | 39232 | 40576 | 40576 | 40576 | 42368 | 42368 |
| 21 | 40576 | 40576 | 42368 | 42368 | 42368 | 43816 | 43816 | 43816 | 45352 | 45352 |
| 22 | 43816 | 43816 | 45352 | 45352 | 45352 | 46888 | 46888 | 46888 | 48936 | 48936 |
| 23 | 46888 | 46888 | 46888 | 48936 | 48936 | 48936 | 51024 | 51024 | 51024 | 51024 |
| 24 | 48936 | 51024 | 51024 | 51024 | 52752 | 52752 | 52752 | 52752 | 55056 | 55056 |
| 25 | 51024 | 52752 | 52752 | 52752 | 55056 | 55056 | 55056 | 55056 | 57336 | 57336 |
| 26 | 59256 | 59256 | 61664 | 61664 | 61664 | 63776 | 63776 | 63776 | 66592 | 66592 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **91** | **92** | **93** | **94** | **95** | **96** | **97** | **98** | **99** | **100** |
| 0 | 2536 | 2536 | 2600 | 2600 | 2664 | 2664 | 2728 | 2728 | 2728 | 2792 |
| 1 | 3368 | 3368 | 3368 | 3496 | 3496 | 3496 | 3496 | 3624 | 3624 | 3624 |
| 2 | 4136 | 4136 | 4136 | 4264 | 4264 | 4264 | 4392 | 4392 | 4392 | 4584 |
| 3 | 5352 | 5352 | 5352 | 5544 | 5544 | 5544 | 5736 | 5736 | 5736 | 5736 |
| 4 | 6456 | 6456 | 6712 | 6712 | 6712 | 6968 | 6968 | 6968 | 6968 | 7224 |
| 5 | 7992 | 7992 | 8248 | 8248 | 8248 | 8504 | 8504 | 8760 | 8760 | 8760 |
| 6 | 9528 | 9528 | 9528 | 9912 | 9912 | 9912 | 10296 | 10296 | 10296 | 10296 |
| 7 | 11064 | 11448 | 11448 | 11448 | 11448 | 11832 | 11832 | 11832 | 12216 | 12216 |
| 8 | 12576 | 12960 | 12960 | 12960 | 13536 | 13536 | 13536 | 13536 | 14112 | 14112 |
| 9 | 14112 | 14688 | 14688 | 14688 | 15264 | 15264 | 15264 | 15264 | 15840 | 15840 |
| 10 | 15840 | 16416 | 16416 | 16416 | 16992 | 16992 | 16992 | 16992 | 17568 | 17568 |
| 11 | 18336 | 18336 | 19080 | 19080 | 19080 | 19080 | 19848 | 19848 | 19848 | 19848 |
| 12 | 20616 | 21384 | 21384 | 21384 | 21384 | 22152 | 22152 | 22152 | 22920 | 22920 |
| 13 | 23688 | 23688 | 23688 | 24496 | 24496 | 24496 | 25456 | 25456 | 25456 | 25456 |
| 14 | 26416 | 26416 | 26416 | 27376 | 27376 | 27376 | 28336 | 28336 | 28336 | 28336 |
| 15 | 28336 | 28336 | 28336 | 29296 | 29296 | 29296 | 29296 | 30576 | 30576 | 30576 |
| 16 | 29296 | 30576 | 30576 | 30576 | 30576 | 31704 | 31704 | 31704 | 31704 | 32856 |
| 17 | 32856 | 32856 | 34008 | 34008 | 34008 | 35160 | 35160 | 35160 | 35160 | 36696 |
| 18 | 36696 | 36696 | 36696 | 37888 | 37888 | 37888 | 37888 | 39232 | 39232 | 39232 |
| 19 | 39232 | 39232 | 40576 | 40576 | 40576 | 40576 | 42368 | 42368 | 42368 | 43816 |
| 20 | 42368 | 42368 | 43816 | 43816 | 43816 | 45352 | 45352 | 45352 | 46888 | 46888 |
| 21 | 45352 | 46888 | 46888 | 46888 | 46888 | 48936 | 48936 | 48936 | 48936 | 51024 |
| 22 | 48936 | 48936 | 51024 | 51024 | 51024 | 51024 | 52752 | 52752 | 52752 | 55056 |
| 23 | 52752 | 52752 | 52752 | 55056 | 55056 | 55056 | 55056 | 57336 | 57336 | 57336 |
| 24 | 55056 | 57336 | 57336 | 57336 | 57336 | 59256 | 59256 | 59256 | 61664 | 61664 |
| 25 | 57336 | 59256 | 59256 | 59256 | 61664 | 61664 | 61664 | 61664 | 63776 | 63776 |
| 26 | 66592 | 68808 | 68808 | 68808 | 71112 | 71112 | 71112 | 73712 | 73712 | 75376 |

| $I_{TBS}$ | $N_{PRB}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **101** | **102** | **103** | **104** | **105** | **106** | **107** | **108** | **109** | **110** |
| 0 | 2792 | 2856 | 2856 | 2856 | 2984 | 2984 | 2984 | 2984 | 2984 | 3112 |
| 1 | 3752 | 3752 | 3752 | 3752 | 3880 | 3880 | 3880 | 4008 | 4008 | 4008 |
| 2 | 4584 | 4584 | 4584 | 4584 | 4776 | 4776 | 4776 | 4776 | 4968 | 4968 |
| 3 | 5992 | 5992 | 5992 | 5992 | 6200 | 6200 | 6200 | 6200 | 6456 | 6456 |
| 4 | 7224 | 7224 | 7480 | 7480 | 7480 | 7480 | 7736 | 7736 | 7736 | 7992 |
| 5 | 8760 | 9144 | 9144 | 9144 | 9144 | 9528 | 9528 | 9528 | 9528 | 9528 |
| 6 | 10680 | 10680 | 10680 | 10680 | 11064 | 11064 | 11064 | 11448 | 11448 | 11448 |
| 7 | 12216 | 12576 | 12576 | 12576 | 12960 | 12960 | 12960 | 12960 | 13536 | 13536 |
| 8 | 14112 | 14112 | 14688 | 14688 | 14688 | 14688 | 15264 | 15264 | 15264 | 15264 |
| 9 | 15840 | 16416 | 16416 | 16416 | 16416 | 16992 | 16992 | 16992 | 16992 | 17568 |
| 10 | 17568 | 18336 | 18336 | 18336 | 18336 | 18336 | 19080 | 19080 | 19080 | 19080 |
| 11 | 20616 | 20616 | 20616 | 21384 | 21384 | 21384 | 21384 | 22152 | 22152 | 22152 |
| 12 | 22920 | 23688 | 23688 | 23688 | 23688 | 24496 | 24496 | 24496 | 24496 | 25456 |
| 13 | 26416 | 26416 | 26416 | 26416 | 27376 | 27376 | 27376 | 27376 | 28336 | 28336 |
| 14 | 29296 | 29296 | 29296 | 29296 | 30576 | 30576 | 30576 | 30576 | 31704 | 31704 |
| 15 | 30576 | 31704 | 31704 | 31704 | 31704 | 32856 | 32856 | 32856 | 34008 | 34008 |
| 16 | 32856 | 32856 | 34008 | 34008 | 34008 | 34008 | 35160 | 35160 | 35160 | 35160 |
| 17 | 36696 | 36696 | 36696 | 37888 | 37888 | 37888 | 39232 | 39232 | 39232 | 39232 |
| 18 | 40576 | 40576 | 40576 | 40576 | 42368 | 42368 | 42368 | 42368 | 43816 | 43816 |
| 19 | 43816 | 43816 | 43816 | 45352 | 45352 | 45352 | 46888 | 46888 | 46888 | 46888 |
| 20 | 46888 | 46888 | 48936 | 48936 | 48936 | 48936 | 48936 | 51024 | 51024 | 51024 |
| 21 | 51024 | 51024 | 51024 | 52752 | 52752 | 52752 | 52752 | 55056 | 55056 | 55056 |
| 22 | 55056 | 55056 | 55056 | 57336 | 57336 | 57336 | 57336 | 59256 | 59256 | 59256 |
| 23 | 57336 | 59256 | 59256 | 59256 | 59256 | 61664 | 61664 | 61664 | 61664 | 63776 |
| 24 | 61664 | 61664 | 63776 | 63776 | 63776 | 63776 | 66592 | 66592 | 66592 | 66592 |
| 25 | 63776 | 63776 | 66592 | 66592 | 66592 | 66592 | 68808 | 68808 | 68808 | 71112 |
| 26 | 75376 | 75376 | 75376 | 75376 | 75376 | 75376 | 75376 | 75376 | 75376 | 75376 |

#### 7.1.7.2.2 Transport blocks mapped to two-layer spatial multiplexing

For $1 \le N_{PRB} \le 55$, the TBS is given by the ( $I_{TBS}$ , $2 \cdot N_{PRB}$ ) entry of Table 7.1.7.2.1-1.

For $56 \le N_{PRB} \le 110$, a baseline TBS_L1 is taken from the ( $I_{TBS}$ , $N_{PRB}$ ) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L2 using the mapping rule shown in Table 7.1.7.2.2-1. The TBS is given by TBS_L2.

**Table 7.1.7.2.2-1: One-layer to two-layer TBS translation table**

| TBS_L1 | TBS_L2 | TBS_L1 | TBS_L2 | TBS_L1 | TBS_L2 | TBS_L1 | TBS_L2 |
|---|---|---|---|---|---|---|---|
| 1544 | 3112 | 3752 | 7480 | 10296 | 20616 | 28336 | 57336 |
| 1608 | 3240 | 3880 | 7736 | 10680 | 21384 | 29296 | 59256 |
| 1672 | 3368 | 4008 | 7992 | 11064 | 22152 | 30576 | 61664 |
| 1736 | 3496 | 4136 | 8248 | 11448 | 22920 | 31704 | 63776 |
| 1800 | 3624 | 4264 | 8504 | 11832 | 23688 | 32856 | 66592 |
| 1864 | 3752 | 4392 | 8760 | 12216 | 24496 | 34008 | 68808 |
| 1928 | 3880 | 4584 | 9144 | 12576 | 25456 | 35160 | 71112 |
| 1992 | 4008 | 4776 | 9528 | 12960 | 25456 | 36696 | 73712 |
| 2024 | 4008 | 4968 | 9912 | 13536 | 27376 | 37888 | 76208 |
| 2088 | 4136 | 5160 | 10296 | 14112 | 28336 | 39232 | 78704 |
| 2152 | 4264 | 5352 | 10680 | 14688 | 29296 | 40576 | 81176 |
| 2216 | 4392 | 5544 | 11064 | 15264 | 30576 | 42368 | 84760 |
| 2280 | 4584 | 5736 | 11448 | 15840 | 31704 | 43816 | 87936 |
| 2344 | 4776 | 5992 | 11832 | 16416 | 32856 | 45352 | 90816 |
| 2408 | 4776 | 6200 | 12576 | 16992 | 34008 | 46888 | 93800 |
| 2472 | 4968 | 6456 | 12960 | 17568 | 35160 | 48936 | 97896 |
| 2536 | 5160 | 6712 | 13536 | 18336 | 36696 | 51024 | 101840 |
| 2600 | 5160 | 6968 | 14112 | 19080 | 37888 | 52752 | 105528 |
| 2664 | 5352 | 7224 | 14688 | 19848 | 39232 | 55056 | 110136 |
| 2728 | 5544 | 7480 | 14688 | 20616 | 40576 | 57336 | 115040 |
| 2792 | 5544 | 7736 | 15264 | 21384 | 42368 | 59256 | 119816 |
| 2856 | 5736 | 7992 | 15840 | 22152 | 43816 | 61664 | 124464 |
| 2984 | 5992 | 8248 | 16416 | 22920 | 45352 | 63776 | 128496 |
| 3112 | 6200 | 8504 | 16992 | 23688 | 46888 | 66592 | 133208 |
| 3240 | 6456 | 8760 | 17568 | 24496 | 48936 | 68808 | 137792 |
| 3368 | 6712 | 9144 | 18336 | 25456 | 51024 | 71112 | 142248 |
| 3496 | 6968 | 9528 | 19080 | 26416 | 52752 | 73712 | 146856 |
| 3624 | 7224 | 9912 | 19848 | 27376 | 55056 | 75376 | 149776 |

#### 7.1.7.2.3 Transport blocks mapped for DCI Format 1C

The TBS is given by the $I_{TBS}$ entry of Table 7.1.7.2.3-1.

**Table 7.1.7.2.3-1: Transport Block Size (TBS) table for DCI format 1C**

| $I_{TBS}$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TBS** | 40 | 56 | 72 | 120 | 136 | 144 | 176 | 208 | 224 | 256 | 280 | 296 | 328 | 336 | 392 | 488 |
| $I_{TBS}$ | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| **TBS** | 552 | 600 | 632 | 696 | 776 | 840 | 904 | 1000 | 1064 | 1128 | 1224 | 1288 | 1384 | 1480 | 1608 | 1736 |

#### 7.1.7.2.4 Transport blocks mapped to three-layer spatial multiplexing

For $1 \le N_{PRB} \le 36$, the TBS is given by the ( $I_{TBS}$ , $3 \cdot N_{PRB}$ ) entry of Table 7.1.7.2.1-1.

For $37 \le N_{PRB} \le 110$, a baseline TBS_L1 is taken from the ( $I_{TBS}$ , $N_{PRB}$ ) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L3 using the mapping rule shown in Table 7.1.7.2.4-1. The TBS is given by TBS_L3.

**Table 7.1.7.2.4-1: One-layer to three-layer TBS translation table**

| TBS_L1 | TBS_L3 | TBS_L1 | TBS_L3 | TBS_L1 | TBS_L3 | TBS_L1 | TBS_L3 |
|---|---|---|---|---|---|---|---|
| 1032 | 3112 | 2664 | 7992 | 8248 | 24496 | 26416 | 78704 |
| 1064 | 3240 | 2728 | 8248 | 8504 | 25456 | 27376 | 81176 |
| 1096 | 3240 | 2792 | 8248 | 8760 | 26416 | 28336 | 84760 |
| 1128 | 3368 | 2856 | 8504 | 9144 | 27376 | 29296 | 87936 |
| 1160 | 3496 | 2984 | 8760 | 9528 | 28336 | 30576 | 90816 |
| 1192 | 3624 | 3112 | 9144 | 9912 | 29296 | 31704 | 93800 |
| 1224 | 3624 | 3240 | 9528 | 10296 | 30576 | 32856 | 97896 |
| 1256 | 3752 | 3368 | 9912 | 10680 | 31704 | 34008 | 101840 |
| 1288 | 3880 | 3496 | 10296 | 11064 | 32856 | 35160 | 105528 |
| 1320 | 4008 | 3624 | 10680 | 11448 | 34008 | 36696 | 110136 |
| 1352 | 4008 | 3752 | 11064 | 11832 | 35160 | 37888 | 115040 |
| 1384 | 4136 | 3880 | 11448 | 12216 | 36696 | 39232 | 119816 |
| 1416 | 4264 | 4008 | 11832 | 12576 | 37888 | 40576 | 119816 |
| 1480 | 4392 | 4136 | 12576 | 12960 | 39232 | 42368 | 128496 |
| 1544 | 4584 | 4264 | 12960 | 13536 | 40576 | 43816 | 133208 |
| 1608 | 4776 | 4392 | 12960 | 14112 | 42368 | 45352 | 137792 |
| 1672 | 4968 | 4584 | 13536 | 14688 | 43816 | 46888 | 142248 |
| 1736 | 5160 | 4776 | 14112 | 15264 | 45352 | 48936 | 146856 |
| 1800 | 5352 | 4968 | 14688 | 15840 | 46888 | 51024 | 152976 |
| 1864 | 5544 | 5160 | 15264 | 16416 | 48936 | 52752 | 157432 |
| 1928 | 5736 | 5352 | 15840 | 16992 | 51024 | 55056 | 165216 |
| 1992 | 5992 | 5544 | 16416 | 17568 | 52752 | 57336 | 171888 |
| 2024 | 5992 | 5736 | 16992 | 18336 | 55056 | 59256 | 177816 |
| 2088 | 6200 | 5992 | 18336 | 19080 | 57336 | 61664 | 185728 |
| 2152 | 6456 | 6200 | 18336 | 19848 | 59256 | 63776 | 191720 |
| 2216 | 6712 | 6456 | 19080 | 20616 | 61664 | 66592 | 199824 |
| 2280 | 6712 | 6712 | 19848 | 21384 | 63776 | 68808 | 205880 |
| 2344 | 6968 | 6968 | 20616 | 22152 | 66592 | 71112 | 214176 |
| 2408 | 7224 | 7224 | 21384 | 22920 | 68808 | 73712 | 221680 |
| 2472 | 7480 | 7480 | 22152 | 23688 | 71112 | 75376 | 226416 |
| 2536 | 7480 | 7736 | 22920 | 24496 | 73712 | | |
| 2600 | 7736 | 7992 | 23688 | 25456 | 76208 | | |

### 7.1.7.2.5 Transport blocks mapped to four-layer spatial multiplexing

For $1 \le N_{PRB} \le 27$, the TBS is given by the ($I_{TBS}$, $4 \cdot N_{PRB}$) entry of Table 7.1.7.2.1-1.

For $28 \le N_{PRB} \le 110$, a baseline TBS_L1 is taken from the ($I_{TBS}$, $N_{PRB}$) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L4 using the mapping rule shown in Table 7.1.7.2.5-1. The TBS is given by TBS_L4.

**Table 7.1.7.2.5-1: One-layer to four-layer TBS translation table**

| TBS_L1 | TBS_L4 | TBS_L1 | TBS_L4 | TBS_L1 | TBS_L4 | TBS_L1 | TBS_L4 |
|---|---|---|---|---|---|---|---|
| 776 | 3112 | 2280 | 9144 | 7224 | 29296 | 24496 | 97896 |
| 808 | 3240 | 2344 | 9528 | 7480 | 29296 | 25456 | 101840 |
| 840 | 3368 | 2408 | 9528 | 7736 | 30576 | 26416 | 105528 |
| 872 | 3496 | 2472 | 9912 | 7992 | 31704 | 27376 | 110136 |
| 904 | 3624 | 2536 | 10296 | 8248 | 32856 | 28336 | 115040 |
| 936 | 3752 | 2600 | 10296 | 8504 | 34008 | 29296 | 115040 |
| 968 | 3880 | 2664 | 10680 | 8760 | 35160 | 30576 | 124464 |
| 1000 | 4008 | 2728 | 11064 | 9144 | 36696 | 31704 | 128496 |
| 1032 | 4136 | 2792 | 11064 | 9528 | 37888 | 32856 | 133208 |
| 1064 | 4264 | 2856 | 11448 | 9912 | 39232 | 34008 | 137792 |
| 1096 | 4392 | 2984 | 11832 | 10296 | 40576 | 35160 | 142248 |
| 1128 | 4584 | 3112 | 12576 | 10680 | 42368 | 36696 | 146856 |
| 1160 | 4584 | 3240 | 12960 | 11064 | 43816 | 37888 | 151376 |
| 1192 | 4776 | 3368 | 13536 | 11448 | 45352 | 39232 | 157432 |
| 1224 | 4968 | 3496 | 14112 | 11832 | 46888 | 40576 | 161760 |
| 1256 | 4968 | 3624 | 14688 | 12216 | 48936 | 42368 | 169544 |
| 1288 | 5160 | 3752 | 15264 | 12576 | 51024 | 43816 | 175600 |
| 1320 | 5352 | 3880 | 15264 | 12960 | 51024 | 45352 | 181656 |
| 1352 | 5352 | 4008 | 15840 | 13536 | 55056 | 46888 | 187712 |
| 1384 | 5544 | 4136 | 16416 | 14112 | 57336 | 48936 | 195816 |
| 1416 | 5736 | 4264 | 16992 | 14688 | 59256 | 51024 | 203704 |
| 1480 | 5992 | 4392 | 17568 | 15264 | 61664 | 52752 | 211936 |
| 1544 | 6200 | 4584 | 18336 | 15840 | 63776 | 55056 | 220296 |
| 1608 | 6456 | 4776 | 19080 | 16416 | 66592 | 57336 | 230104 |
| 1672 | 6712 | 4968 | 19848 | 16992 | 68808 | 59256 | 236160 |
| 1736 | 6968 | 5160 | 20616 | 17568 | 71112 | 61664 | 245648 |
| 1800 | 7224 | 5352 | 21384 | 18336 | 73712 | 63776 | 254328 |
| 1864 | 7480 | 5544 | 22152 | 19080 | 76208 | 66592 | 266440 |
| 1928 | 7736 | 5736 | 22920 | 19848 | 78704 | 68808 | 275376 |
| 1992 | 7992 | 5992 | 23688 | 20616 | 81176 | 71112 | 284608 |
| 2024 | 7992 | 6200 | 24496 | 21384 | 84760 | 73712 | 293736 |
| 2088 | 8248 | 6456 | 25456 | 22152 | 87936 | 75376 | 299856 |
| 2152 | 8504 | 6712 | 26416 | 22920 | 90816 | | |
| 2216 | 8760 | 6968 | 28336 | 23688 | 93800 | | |

### 7.1.7.3 Redundancy Version determination for Format 1C

If the DCI Format 1C CRC is scrambled by P-RNTI or RA-RNTI, then

- the UE shall set the Redundancy Version to 0

Else if the DCI Format 1C CRC is scrambled by SI-RNTI, then

- the UE shall set the Redundancy Version as defined in [8].

### 7.1.8 Storing soft channel bits

Both for FDD and TDD, if the UE is configured with more than one serving cell, then for each serving cell, for at least $K_{\mathrm{MIMO}} \cdot \min\left(M_{\mathrm{DL_HARQ}}, M_{\mathrm{limit}}\right)$ transport blocks, upon decoding failure of a code block of a transport block, the UE shall store received soft channel bits corresponding to a range of at least $w_k$ $w_{k+1}, \ldots, w_{\mathrm{mod}(k+n_{SB}-1, N_{cb})}$, where:

$$n_{SB} = \min\left(N_{cb}, \left\lfloor \frac{N'_{soft}}{C \cdot N_{cells}^{DL} \cdot K_{\mathrm{MIMO}} \cdot \min\left(M_{\mathrm{DL_HARQ}}, M_{\mathrm{limit}}\right)} \right\rfloor\right),$$

$w_k$, $C$, $N_{cb}$, $K_{\mathrm{MIMO}}$, ,and $M_{\mathrm{limit}}$ are defined in subclause 5.1.4.1.2 of [4].

$M_{\mathrm{DL_HARQ}}$ is the maximum number of DL HARQ processes.

$N_{cells}^{DL}$ is the number of configured serving cells.

If the UE signals *ue-Category-v1170*, $N'_{soft}$ is the total number of soft channel bits [12] according to the UE category indicated by *ue-Category-v1170* [11]. Else if the UE signals *ue-Category-v1020* and not *ue-Category-v1170*, $N'_{soft}$ is the total number of soft channel bits [12] according to the UE category indicated by *ue-Category-v1020* [11]. Otherwise, $N'_{soft}$ is the total number of soft channel bits [12] according to the UE category indicated by *ue-Category* (without suffix) [11].

In determining *k*, the UE should give priority to storing soft channel bits corresponding to lower values of *k*. $w_k$ shall correspond to a received soft channel bit. The range $w_k$ $w_{k+1}, \ldots, w_{\mathrm{mod}(k+n_{SB}-1, N_{cb})}$ may include subsets not containing received soft channel bits.

### 7.1.9 PDSCH resource mapping parameters

A UE configured in transmission mode 10 for a given serving cell can be configured with up to 4 parameter sets by higher layer signaling to decode PDSCH according to a detected PDCCH/EPDCCH with DCI format 2D intended for the UE and the given serving cell. The UE shall use the parameter set according to the value of the 'PDSCH RE Mapping and Quasi-Co-Location indicator' field (mapping defined in Table 7.1.9-1) in the detected PDCCH/EPDCCH with DCI format 2D for determining the PDSCH RE mapping (defined in subclause 6.4 of [3]), and for determining PDSCH antenna port quasi co-location (defined in subclause 7.1.10) if the UE is configured with Type B quasi co-location type (defined in subclause 7.1.10). For PDSCH without a corresponding PDCCH/EPDCCH, the UE shall use the parameter set indicated in the PDCCH/EPDCCH with DCI format 2D corresponding to the associated SPS activation for determining the PDSCH RE mapping (defined in subclause 6.4 of [3]) and PDSCH antenna port quasi co-location (defined in subclause 7.1.10).

**Table 7.1.9-1: PDSCH RE Mapping and Quasi-Co-Location Indicator field in DCI format 2D**

| Value of 'PDSCH RE Mapping and Quasi-Co-Location Indicator' field | Description |
|---|---|
| '00' | Parameter set 1 configured by higher layers |
| '01' | Parameter set 2 configured by higher layers |
| '10' | Parameter set 3 configured by higher layers |
| '11' | Parameter set 4 configured by higher layers |

The following parameters for determining PDSCH RE mapping and PDSCH antenna port quasi co-location are configured via higher layer signaling for each parameter set:

- *crs-PortsCount-r11*.
- *crs-FreqShift-r11*.
- *mbsfn-SubframeConfigList-r11*.
- *csi-RS-ConfigZPId-r11*.
- *pdsch-Start-r11*.
- *qcl-CSI-RS-ConfigNZPId-r11*.

To decode PDSCH according to a detected PDCCH/EPDCCH with DCI format 1A with CRC scrambled with C-RNTI intended for the UE and the given serving cell and for PDSCH transmission on antenna port 7, a UE configured in

transmission mode 10 for a given serving cell shall use the parameter set 1 in table 7.1.9-1 for determining the PDSCH RE mapping (defined in subclause 6.4 of [3]), and for determining PDSCH antenna port quasi co-location (defined in subclause 7.1.10) if the UE is configured with Type B quasi co-location type (defined in subclause 7.1.10).

To decode PDSCH corresponding to detected PDCCH/EPDCCH with DCI format 1A with CRC scrambled with SPS C-RNTI and PDSCH without a corresponding PDCCH/EPDCCH associated with SPS activation indicated in PDCCH/EPDCCH with DCI format 1A, a UE configured in transmission mode 10 for a given serving cell shall use the parameter set 1 in table 7.1.9-1 for determining the PDSCH RE mapping (defined in subclause 6.4 of [3]), and for determining PDSCH antenna port quasi co-location (defined in subclause 7.1.10) if the UE is configured with Type B quasi co-location type (defined in subclause 7.1.10).

To decode PDSCH according to a detected PDCCH/EPDCCH with DCI format 1A intended for the UE on a given serving cell and for PDSCH transmission on antenna port 0 – 3, a UE configured in transmission mode 10 for the given serving cell shall determine the PDSCH RE mapping (as described in subclause 6.4 of [3]) using the lowest indexed zero-power CSI-RS resource.

### 7.1.10 Antenna ports quasi co-location for PDSCH

A UE configured in transmission mode 8-10 for a serving cell may assume the antenna ports 7 – 14 of the serving cell are quasi co-located (as defined in [3]) for a given subframe with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

A UE configured in transmission mode 1-9 for a serving cell may assume the antenna ports 0 – 3, 5, 7 – 22 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

A UE configured in transmission mode 10 for a serving cell is configured with one of two quasi co-location types for the serving cell by higher layer parameter *qcl-Operation* to decode PDSCH according to transmission scheme associated with antenna ports 7-14:

- Type A: The UE may assume the antenna ports 0 – 3, 7 – 22 of a serving cell are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, and average delay.
- Type B: The UE may assume the antenna ports 15 – 22 corresponding to the CSI-RS resource configuration identified by the higher layer parameter *qcl-CSI-RS-ConfigNZPId-r11* (defined in subclause 7.1.9) and the antenna ports 7 – 14 associated with the PDSCH are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

## 7.2 UE procedure for reporting Channel State Information (CSI)

The time and frequency resources that can be used by the UE to report CSI which consists of Channel Quality Indicator (CQI), precoding matrix indicator (PMI), precoding type indicator (PTI), and/or rank indication (RI) are controlled by the eNB. For spatial multiplexing, as given in [3], the UE shall determine a RI corresponding to the number of useful transmission layers. For transmit diversity as given in [3], RI is equal to one.

A UE in transmission mode 8 or 9 is configured with or without PMI/RI reporting by the higher layer parameter *pmi-RI-Report*.

A UE in transmission mode 10 can be configured with one or more CSI processes per serving cell by higher layers. Each CSI process is associated with a CSI-RS resource (defined in subclause 7.2.5) and a CSI-interference measurement (CSI-IM) resource (defined in subclause 7.2.6). A CSI reported by the UE corresponds to a CSI process configured by higher layers. Each CSI process can be configured with or without PMI/RI reporting by higher layer signalling.

A UE is configured with resource-restricted CSI measurements if the subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers.

CSI reporting is periodic or aperiodic.

If the UE is configured with more than one serving cell, it transmits CSI for activated serving cell(s) only.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUCCH as defined hereafter in subframes with no PUSCH allocation.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUSCH of the serving cell with smallest *ServCellIndex* as defined hereafter in subframes with a PUSCH allocation, where the UE shall use the same PUCCH-based periodic CSI reporting format on PUSCH.

A UE shall transmit aperiodic CSI reporting on PUSCH if the conditions specified hereafter are met. For aperiodic CQI/PMI reporting, RI reporting is transmitted only if the configured CSI feedback type supports RI reporting.

The CSI transmissions on PUCCH and PUSCH for various scheduling modes are summarized in the following table:

**Table 7.2-1: Physical Channels for Aperiodic or Periodic CSI reporting**

| Scheduling Mode | Periodic CSI reporting channels | Aperiodic CSI reporting channel |
|---|---|---|
| **Frequency non-selective** | PUCCH | |
| **Frequency selective** | PUCCH | PUSCH |

In case both periodic and aperiodic CSI reporting would occur in the same subframe, the UE shall only transmit the aperiodic CSI report in that subframe.

When reporting RI the UE reports a single instance of the number of useful transmission layers. For each RI reporting interval when the UE is configured in transmission modes 4 or when the UE is configured in transmission mode 8, 9 or 10 with PMI/RI reporting, a UE shall determine a RI from the supported set of RI values as defined in subclause 5.2.2.6 of [4] and report the number in each RI report. For each RI reporting interval when the UE is configured in transmission mode 3, a UE shall determine RI as defined in subclause 5.2.2.6 of [4] in each reporting interval and report the detected number in each RI report to support selection between transmit diversity and large delay CDD.

When reporting PMI the UE reports either a single or a multiple PMI report. The number of RBs represented by a single UE PMI report can be $N_{\mathrm{RB}}^{\mathrm{DL}}$ or a smaller subset of RBs. The number of RBs represented by a single PMI report is semi-statically configured by higher layer signalling. A UE is restricted to report PMI, RI and PTI within a precoder codebook subset specified by a bitmap parameter *codebookSubsetRestriction* configured by higher layer signalling. For a UE configured in transmission mode 10, the bitmap parameter *codebookSubsetRestriction* is configured for each CSI process and each subframe sets (if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers) by higher layer signaling. For a specific precoder codebook and associated transmission mode, the bitmap can specify all possible precoder codebook subsets from which the UE can assume the eNB may be using when the UE is configured in the relevant transmission mode. Codebook subset restriction is supported for transmission modes 3, 4, 5, 6 and for transmission modes 8, 9 and 10 with PMI/RI reporting. The resulting number of bits for each transmission mode is

given in Table 7.2-1b. The bitmap forms the bit sequence $a_{A_c-1},...,a_3,a_2,a_1,a_0$ where $a_0$ is the LSB and $a_{A_c-1}$ is the MSB and where a bit value of zero indicates that the PMI and RI reporting is not allowed to correspond to precoder(s) associated with the bit. The association of bits to precoders for the relevant transmission modes are given as follows:

1. Transmission mode 3
    a. 2 antenna ports: bit $a_{\upsilon-1}, \upsilon = 2$ is associated with the precoder in Table 6.3.4.2.3-1 of [3] corresponding to $\upsilon$ layers and codebook index 0 while bit $a_0$ is associated with the precoder for 2 antenna ports in subclause 6.3.4.3 of [3].
    b. 4 antenna ports: bit $a_{\upsilon-1}, \upsilon = 2,3,4$ is associated with the precoders in Table 6.3.4.2.3-2 of [3] corresponding to $\upsilon$ layers and codebook indices 12, 13, 14, and 15 while bit $a_0$ is associated with the precoder for 4 antenna ports in subclause 6.3.4.3 of [3].
2. Transmission mode 4
    a. 2 antenna ports: see Table 7.2-1c
    b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for $\upsilon$ layers and with codebook index $i_c$ in Table 6.3.4.2.3-2 of [3].
3. Transmission modes 5 and 6
    a. 2 antenna ports: bit $a_{i_c}$ is associated with the precoder for $\upsilon = 1$ layer with codebook index $i_c$ in Table 6.3.4.2.3-1 of [3].
    b. 4 antenna ports: bit $a_{i_c}$ is associated with the precoder for $\upsilon = 1$ layer with codebook index $i_c$ in Table 6.3.4.2.3-2 of [3].
4. Transmission mode 8
    a. 2 antenna ports: see Table 7.2-1c
    b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for $\upsilon$ layers and with codebook index $i_c$ in Table 6.3.4.2.3-2 of [3], $\upsilon = 1,2$.
5. Transmission modes 9 and 10
    a. 2 antenna ports: see Table 7.2-1c
    b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for $\upsilon$ layers and with codebook index $i_c$ in Table 6.3.4.2.3-2 of [3].
    c. 8 antenna ports: bit $a_{f1(\upsilon-1)+i_1}$ is associated with the precoder for $\upsilon$ layers ($\upsilon \in \{1,2,3,4,5,6,7,8\}$) and codebook index $i_1$ where $f1(\cdot) = \{0,16,32,36,40,44,48,52\}$ and bit $a_{53+g1(\upsilon-1)+i_2}$ is associated with the precoder for $\upsilon$ layers ($\upsilon \in \{1,2,3,4\}$) and codebook index $i_2$ where $g1(\cdot) = \{0,16,32,48\}$. Codebook indices $i_1$ and $i_2$ are given in Table 7.2.4-1, 7.2.4-2, 7.2.4-3, 7.2.4-4, 7.2.4-5, 7.2.4-6, 7.2.4-7, or 7.2.4-8, for $\upsilon$=1,2,3,4,5,6,7, or 8 respectively.

**Table 7.2-1b: Number of bits in codebook subset restriction bitmap for applicable transmission modes**

| | Number of bits $A_c$ | | |
|---|---|---|---|
| | 2 antenna ports | 4 antenna ports | 8 antenna ports |
| **Transmission mode 3** | 2 | 4 | |
| **Transmission mode 4** | 6 | 64 | |
| **Transmission mode 5** | 4 | 16 | |
| **Transmission mode 6** | 4 | 16 | |
| **Transmission mode 8** | 6 | 32 | |
| **Transmission modes 9 and 10** | 6 | 64 | 109 |

**Table 7.2-1c: Association of bits in *codebookSubSetRestriction* bitmap to precoders in the 2 antenna port codebook of Table 6.3.4.2.3-1 in [3]**

| Codebook index $i_c$ | Number of layers $\upsilon$ | |
|---|---|---|
| | 1 | 2 |
| 0 | $a_0$ | - |
| 1 | $a_1$ | $a_4$ |
| 2 | $a_2$ | $a_5$ |
| 3 | $a_3$ | - |

The set of subbands ($S$) a UE shall evaluate for CQI reporting spans the entire downlink system bandwidth. A subband is a set of $k$ contiguous PRBs where $k$ is a function of system bandwidth. Note the last subband in set $S$ may have fewer than $k$ contiguous PRBs depending on $N_{\mathrm{RB}}^{\mathrm{DL}}$ . The number of subbands for system bandwidth given by $N_{\mathrm{RB}}^{\mathrm{DL}}$ is defined by $N = \left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k \right\rceil$ . The subbands shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

- For transmission modes 1, 2, 3 and 5, as well as transmission modes 8, 9 and 10 without PMI/RI reporting, transmission mode 4 with RI=1, and transmission modes 8, 9 and 10 with PMI/RI reporting and RI=1, a single 4-bit wideband CQI is reported according to Table 7.2.3-1.
- For transmission modes 3 and 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, CQI is calculated assuming transmission of one codeword for RI=1 and two codewords for RI > 1.
- For RI > 1 with transmission mode 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, PUSCH based triggered reporting includes reporting a wideband CQI which comprises:
  - A 4-bit wideband CQI for codeword 0 according to Table 7.2.3-1
  - A 4-bit wideband CQI for codeword 1 according to Table 7.2.3-1
- For RI > 1 with transmission mode 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, PUCCH based reporting includes reporting a 4-bit wideband CQI for codeword 0 according to Table 7.2.3-1 and a wideband spatial differential CQI. The wideband spatial differential CQI value comprises:
  - A 3-bit wideband spatial differential CQI value for codeword 1 offset level
    - Codeword 1 offset level = wideband CQI index for codeword 0 – wideband CQI index for codeword 1.
  - The mapping from the 3-bit wideband spatial differential CQI value to the offset level is shown in Table 7.2-2.

**Table 7.2-2 Mapping spatial differential CQI value to offset level**

| Spatial differential CQI value | Offset level |
|---|---|
| 0 | 0 |
| 1 | 1 |
| 2 | 2 |
| 3 | ≥3 |
| 4 | ≤-4 |
| 5 | -3 |
| 6 | -2 |
| 7 | -1 |

## 7.2.1 Aperiodic CSI Reporting using PUSCH

A UE shall perform aperiodic CSI reporting using the PUSCH in subframe $n+k$ on serving cell $c$, upon decoding in subframe $n$ either:

- an uplink DCI format [4], or
- a Random Access Response Grant,

for serving cell $c$ if the respective CSI request field is set to trigger a report and is not reserved.

If the CSI request field is 1 bit and the UE is configured in transmission mode 1-9, a report is triggered for serving cell $c$, if the CSI request field is set to '1'. If the CSI request field is 1 bit and the UE is configured in transmission mode 10, a report is triggered for a set of CSI process(es) for serving cell $c$ corresponding to the higher layer configured set of CSI process(es) associated with the value of CSI request field of '01' in Table 7.2.1-1B, if the CSI request field is set to '1'.

If the CSI request field size is 2 bits and the UE is configured in transmission mode 1-9 for all serving cells, a report is triggered according to the value in Table 7.2.1-1A corresponding to aperiodic CSI reporting. If the CSI request field size is 2 bits and the UE is configured in transmission mode 10 for at least one serving cell, a report is triggered according to the value in Table 7.2.1-1B corresponding to aperiodic CSI reporting. For a given serving cell, if the UE is configured in transmission modes 1-9, the "CSI process" in Table 7.2.1-1B refers to the aperiodic CSI configured for the UE on the given serving cell. A UE is not expected to be configured by higher layers with more than 5 CSI processes in each of the 1st and 2nd set of CSI process(es) in Table 7.2.1-1B.

A UE is not expected to receive more than one aperiodic CSI report request for a given subframe.

If a UE is configured with more than one CSI process for a serving cell, the UE on reception of an aperiodic CSI report request triggering a CSI report according to Table 7.2.1-1B is not expected to update CSI corresponding to the CSI reference resource (defined in subclause 7.2.3) for all CSI processes except the $\max(N_x - N_u, 0)$ lowest-indexed CSI processes for the serving cell associated with the request when the UE has $N_u$ unreported CSI processes associated with other aperiodic CSI requests for the serving cell, where a CSI process associated with a CSI request shall only be counted as unreported in a subframe before the subframe where the PUSCH carrying the corresponding CSI is transmitted, and $N_{CSI-P}$ is the maximum number of CSI processes supported by the UE for the serving cell and:

- for FDD $N_x = N_{CSI-P}$;
- for TDD
  - if the UE is configured with four CSI processes for the serving cell , $N_x = N_{CSI-P}$
  - if the UE is configured with two or three CSI processes for the serving cell, $N_x = 3$.

If more than one value of $N_{CSI-P}$ is included in the *UE-EUTRA-Capability*, the UE assumes a value of $N_{CSI-P}$ that is consistent with its CSI process configuration. If more than one consistent value of $N_{CSI-P}$ exists, the UE may assume any one of the consistent values.

**Table 7.2.1-1A: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space**

| Value of CSI request field | Description |
|---|---|
| '00' | No aperiodic CSI report is triggered |
| '01' | Aperiodic CSI report is triggered for serving cell $c$ |
| '10' | Aperiodic CSI report is triggered for a 1st set of serving cells configured by higher layers |
| '11' | Aperiodic CSI report is triggered for a 2nd set of serving cells configured by higher layers |

**Table 7.2.1-1B: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space**

| Value of CSI request field | Description |
|---|---|
| '00' | No aperiodic CSI report is triggered |
| '01' | Aperiodic CSI report is triggered for a set of CSI process(es) configured by higher layers for serving cell $c$ |
| '10' | Aperiodic CSI report is triggered for a 1st set of CSI process(es) configured by higher layers |
| '11' | Aperiodic CSI report is triggered for a 2nd set of CSI process(es) configured by higher layers |

NOTE: PDCCH/EPDCCH with DCI formats used to grant PUSCH transmissions as given by DCI format 0 and DCI format 4 are herein referred to as uplink DCI format when common behaviour is addressed.

When the CSI request field from an uplink DCI format is set to trigger a report, for FDD *k=4*, and for TDD UL/DL configuration 1-6, *k* is given in Table 8-2. For TDD UL/DL configuration 0, if the MSB of the UL index is set to 1 and LSB of the UL index is set to 0, *k* is given in Table 8-2; or if MSB of the UL index is set to 0 and LSB of the UL index is set to 1, *k* is equal to 7; or if both MSB and LSB of the UL index is set to 1, *k* is given in Table 8-2. . For TDD, if a UE is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different, the "TDD UL/DL Configuration" given in Table 8-2 refers to the UL-reference UL/DL configuration (defined in subclause 8.0).

When the CSI request field from a Random Access Response Grant is set to trigger a report and is not reserved, *k* is equal to $k_1$ if the UL delay field in subclause 6.2 is set to zero, where $k_1$ is given in subclause 6.1.1. The UE shall postpone aperiodic CSI reporting to the next available UL subframe if the UL delay field is set to 1.

The minimum reporting interval for aperiodic reporting of CQI and PMI and RI is 1 subframe. The subband size for CQI shall be the same for transmitter-receiver configurations with and without precoding.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, when aperiodic CSI report with no transport block associated as defined in subclause 8.6.2 and positive SR is transmitted in the same subframe, the UE shall transmit SR, and, if applicable, HARQ-ACK, on PUCCH resources as described in subclause 10.1

A UE is semi-statically configured by higher layers to feed back CQI and PMI and corresponding RI on the same PUSCH using one of the following CSI reporting modes given in Table 7.2.1-1 and described below.

**Table 7.2.1-1: CQI and PMI Feedback Types for PUSCH CSI reporting Modes**

| | | PMI Feedback Type | | |
|---|---|---|---|---|
| | | No PMI | Single PMI | Multiple PMI |
| PUSCH CQI Feedback Type | Wideband (wideband CQI) | | | Mode 1-2 |
| | UE Selected (subband CQI) | Mode 2-0 | | Mode 2-2 |
| | Higher Layer-configured (subband CQI) | Mode 3-0 | Mode 3-1 | |

For each of the transmission modes defined in subclause 7.1, the following reporting modes are supported on PUSCH:

Transmission mode 1 : Modes 2-0, 3-0
Transmission mode 2 : Modes 2-0, 3-0

Transmission mode 3 : Modes 2-0, 3-0
Transmission mode 4 : Modes 1-2, 2-2, 3-1
Transmission mode 5 : Mode 3-1
Transmission mode 6 : Modes 1-2, 2-2, 3-1
Transmission mode 7 : Modes 2-0, 3-0
Transmission mode 8 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting
Transmission mode 9 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1
Transmission mode 10 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1.

The aperiodic CSI reporting mode is given by the parameter *cqi-ReportModeAperiodic* which is configured by higher-layer signalling.

For a serving cell with $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 7$, PUSCH reporting modes are not supported for that serving cell.
RI is only reported for transmission modes 3 and 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting.

For serving cell $c$, a UE configured in transmission mode 10 with PMI/RI reporting for a CSI process can be configured with a 'RI-reference CSI process' for the CSI process. If the UE is configured with a 'RI-reference CSI process' for the CSI process, the reported RI for the CSI process shall be the same as the reported RI for the configured 'RI-reference CSI process'. The RI for the 'RI-reference CSI process' is not based on any other configured CSI process other than the 'RI-reference CSI process'. The UE is not expected to receive an aperiodic CSI report request for a given subframe triggering a CSI report including CSI associated with the CSI process and not including CSI associated with the configured 'RI-reference CSI process'. If the UE is configured with a 'RI-reference CSI process' for a CSI process and if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers for only one of the CSI processes then the UE is not expected to receive configuration for the CSI process configured with the subframe subsets that have a different set of restricted RIs with precoder codebook subset restriction between the two subframe sets. The UE is not expected to receive configurations for the CSI process and the 'RI-reference CSI process' that have a different:

- Aperiodic CSI reporting mode, and/or
- number of CSI-RS antenna ports, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are not configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for each subframe set if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers for only one of the CSI processes, and the set of restricted RIs for the two subframe sets are the same.

A RI report for a serving cell on an aperiodic reporting mode is valid only for CQI/PMI report for that serving cell on that aperiodic reporting mode

- Wideband feedback
  - Mode 1-2 description:
    - For each subband a preferred precoding matrix is selected from the codebook subset assuming transmission only in the subband
    - A UE shall report one wideband CQI value per codeword which is calculated assuming the use of the corresponding selected precoding matrix in each subband and transmission on set *S* subbands.
    - The UE shall report the selected precoding matrix indicator for each set *S* subband except with 8 CSI-RS ports configured for transmission modes 9 and 10 in which case a first precoding matrix indicator $i_1$ is reported for the set *S* subbands and a second precoding matrix indicator $i_2$ is reported for each set *S* subband.

- Subband size is given by Table 7.2.1-3.
- For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.

- Higher Layer-configured subband feedback
  - Mode 3-0 description:
    - A UE shall report a wideband CQI value which is calculated assuming transmission on set *S* subbands
    - The UE shall also report one subband CQI value for each set *S* subband. The subband CQI value is calculated assuming transmission only in the subband
    - Both the wideband and subband CQI represent channel quality for the first codeword, even when RI>1.
    - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - Mode 3-1 description:
    - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
    - A UE shall report one subband CQI value per codeword for each set *S* subband which are calculated assuming the use of the single precoding matrix in all subbands and assuming transmission in the corresponding subband.
    - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
    - The UE shall report the selected single precoding matrix indicator except with 8 CSI-RS ports configured for transmission modes 9 and 10 in which case a first and second precoding matrix indicator are reported corresponding to the selected single precoding matrix.
    - For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - Subband CQI value for each codeword are encoded differentially with respect to their respective wideband CQI using 2-bits as defined by
    - Subband differential CQI offset level = subband CQI index – wideband CQI index. The mapping from the 2-bit subband differential CQI value to the offset level is shown in Table 7.2.1-2.

**Table 7.2.1-2: Mapping subband differential CQI value to offset level**

| Subband differential CQI value | Offset level |
|---|---|
| 0 | 0 |
| 1 | 1 |
| 2 | ≥2 |
| 3 | ≤-1 |

  - Supported subband size (*k*) is given in Table 7.2.1-3.

**Table 7.2.1-3: Subband Size (*k*) vs. System Bandwidth**

| System Bandwidth $N_{RB}^{DL}$ | Subband Size (*k*) |
|---|---|
| 6 - 7 | NA |
| 8 - 10 | 4 |
| 11 - 26 | 4 |
| 27 - 63 | 6 |
| 64 - 110 | 8 |

- UE-selected subband feedback
  - Mode 2-0 description:
    - The UE shall select a set of *M* preferred subbands of size *k* (where *k* and *M* are given in Table 7.2.1-5 for each system bandwidth range) within the set of subbands *S*.
    - The UE shall also report one CQI value reflecting transmission only over the *M* selected subbands determined in the previous step. The CQI represents channel quality for the first codeword, even when RI>1.
    - Additionally, the UE shall also report one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
    - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - Mode 2-2 description:
    - The UE shall perform joint selection of the set of *M* preferred subbands of size *k* within the set of subbands *S* and a preferred single precoding matrix selected from the codebook subset that is preferred to be used for transmission over the *M* selected subbands.
    - The UE shall report one CQI value per codeword reflecting transmission only over the selected *M* preferred subbands and using the same selected single precoding matrix in each of the *M* subbands.
    - Except with 8 CSI-RS ports configured for transmission modes 9 and 10, the UE shall also report the selected single precoding matrix indicator preferred for the M selected subbands. A UE shall also report the selected single precoding matrix indicator for all set *S* subbands.
    - For transmission modes 9 and 10, and with 8 CSI-RS ports configured, a UE shall report a first precoding matrix indicator for all set *S* subbands. A UE shall also report a second precoding matrix indicator for all set *S* subbands and another second precoding matrix indicator for the M selected subbands.
    - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
    - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
    - For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - For all UE-selected subband feedback modes the UE shall report the positions of the *M* selected subbands using a combinatorial index *r* defined as

- $r = \sum_{i=0}^{M-1} \left\langle {N - s_i \atop M - i} \right\rangle$
- where the set $\{s_i\}_{i=0}^{M-1}$, $(1 \le s_i \le N, \quad s_i < s_{i+1})$ contains the $M$ sorted subband indices and $\left\langle {x \atop y} \right\rangle = \begin{cases} {x \choose y} & x \ge y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label $r \in \left\{0, \cdots, {N \choose M} - 1\right\}$.

- The CQI value for the $M$ selected subbands for each codeword is encoded differentially using 2-bits relative to its respective wideband CQI as defined by
  - Differential CQI offset level = $M$ selected subbands CQI index – wideband CQI index
  - The mapping from the 2-bit differential CQI value to the offset level is shown in Table 7.2.1-4.

**Table 7.2.1-4: Mapping differential CQI value to offset level**

| Differential CQI value | Offset level |
|---|---|
| 0 | ≤1 |
| 1 | 2 |
| 2 | 3 |
| 3 | ≥4 |

- Supported subband size $k$ and $M$ values include those shown in Table 7.2.1-5. In Table 7.2.1-5 the $k$ and $M$ values are a function of system bandwidth.

- The number of bits to denote the position of the $M$ selected subbands is $L = \left\lceil \log_2 {N \choose M} \right\rceil$.

**Table 7.2.1-5: Subband Size (*k*) and Number of Subbands (*M*) in S vs. Downlink System Bandwidth**

| System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$ | Subband Size *k* (RBs) | *M* |
|---|---|---|
| 6 – 7 | NA | NA |
| 8 – 10 | 2 | 1 |
| 11 – 26 | 2 | 3 |
| 27 – 63 | 3 | 5 |
| 64 – 110 | 4 | 6 |

## 7.2.2 Periodic CSI Reporting using PUCCH

A UE is semi-statically configured by higher layers to periodically feed back different CSI components (CQI, PMI, PTI, and/or RI) on the PUCCH using the reporting modes given in Table 7.2.2-1 and described below. A UE in transmission mode 10 can be configured by higher layers for multiple periodic CSI reports corresponding to one or more CSI processes per serving cell on PUCCH.

**Table 7.2.2-1: CQI and PMI Feedback Types for PUCCH CSI reporting Modes**

| | | PMI Feedback Type | |
|---|---|---|---|
| | | No PMI | Single PMI |
| PUCCH CQI Feedback Type | Wideband (wideband CQI) | Mode 1-0 | Mode 1-1 |
| | UE Selected (subband CQI) | Mode 2-0 | Mode 2-1 |

For each of the transmission modes defined in subclause 7.1, the following periodic CSI reporting modes are supported on PUCCH:

Transmission mode 1 : Modes 1-0, 2-0
Transmission mode 2 : Modes 1-0, 2-0
Transmission mode 3 : Modes 1-0, 2-0
Transmission mode 4 : Modes 1-1, 2-1
Transmission mode 5 : Modes 1-1, 2-1
Transmission mode 6 : Modes 1-1, 2-1
Transmission mode 7 : Modes 1-0, 2-0
Transmission mode 8 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting
Transmission mode 9 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports>1; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1.
Transmission mode 10 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports>1; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1.

For a UE configured in transmission mode 1-9, one periodic CSI reporting mode for each serving cell is configured by higher-layer signalling.

For a UE configured in transmission mode 10, one or more periodic CSI reporting modes for each serving cell are configured by higher-layer signalling.

For a UE configured with transmission mode 9 or 10, and with 8 CSI-RS ports, mode 1-1 is configured to be either submode 1 or submode 2 via higher-layer signaling using the parameter *PUCCH_format1-1_CSI_reporting_mode.*

For the UE-selected subband CQI, a CQI report in a certain subframe of a certain serving cell describes the channel quality in a particular part or in particular parts of the bandwidth of that serving cell described subsequently as bandwidth part (BP) or parts. The bandwidth parts shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

For each serving cell

- There are a total of $N$ subbands for a serving cell system bandwidth given by $N_{\mathrm{RB}}^{\mathrm{DL}}$ where $\left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / k \right\rfloor$ subbands are of size $k$. If $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k \right\rceil - \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / k \right\rfloor > 0$ then one of the subbands is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - k \cdot \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / k \right\rfloor$.
- A bandwidth part $j$ is frequency-consecutive and consists of $N_{\mathrm{j}}$ subbands where $J$ bandwidth parts span $S$ or $N_{\mathrm{RB}}^{\mathrm{DL}}$ as given in Table 7.2.2-2. If $J = 1$ then $N_{\mathrm{j}}$ is $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \right\rceil$. If $J>1$ then $N_{\mathrm{j}}$ is either $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \right\rceil$ or $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \right\rceil - 1$, depending on $N_{\mathrm{RB}}^{\mathrm{DL}}$, $k$ and $J$.

- Each bandwidth part $j$, where $0 \le j \le J$-1, is scanned in sequential order according to increasing frequency.
- For UE selected subband feedback a single subband out of $N_j$ subbands of a bandwidth part is selected along with a corresponding $L$-bit label indexed in the order of increasing frequency, where $L = \left\lceil \log_2 \left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \right\rceil \right\rceil$ .

The CQI and PMI payload sizes of each PUCCH CSI reporting mode are given in Table 7.2.2-3.

The following CQI/PMI and RI reporting types with distinct periods and offsets are supported for the PUCCH CSI reporting modes given in Table 7.2.2-3:

- Type 1 report supports CQI feedback for the UE selected sub-bands
- Type 1a report supports subband CQI and second PMI feedback
- Type 2, Type 2b, and Type 2c report supports wideband CQI and PMI feedback
- Type 2a report supports wideband PMI feedback
- Type 3 report supports RI feedback
- Type 4 report supports wideband CQI
- Type 5 report supports RI and wideband PMI feedback
- Type 6 report supports RI and PTI feedback

For a UE configured in transmission mode 1-9 and for each serving cell, or for a UE configured in transmission mode 10 and for each CSI process in each serving cell, the periodicity $N_{pd}$ (in subframes) and offset $N_{OFFSET,CQI}$ (in subframes) for CQI/PMI reporting are determined based on the parameter *cqi-pmi-ConfigIndex* ($I_{CQI/PMI}$) given in Table 7.2.2-1A for FDD and Table 7.2.2-1C for TDD. The periodicity $M_{RI}$ and relative offset $N_{OFFSET,RI}$ for RI reporting are determined based on the parameter *ri-ConfigIndex* ($I_{RI}$) given in Table 7.2.2-1B. Both *cqi-pmi-ConfigIndex* and *ri-ConfigIndex* are configured by higher layer signalling. The relative reporting offset for RI $N_{OFFSET,RI}$ takes values from the set $\{0,-1,...,-(N_{pd}-1)\}$. If a UE is configured to report for more than one CSI subframe set then parameter *cqi-pmi-ConfigIndex* and *ri-ConfigIndex* respectively correspond to the CQI/PMI and RI periodicity and relative reporting offset for subframe set 1 and *cqi-pmi-ConfigIndex2* and *ri-ConfigIndex*2 respectively correspond to the CQI/PMI and RI periodicity and relative reporting offset for subframe set 2. For a UE configured with transmission mode 10, the parameters *cqi-pmi-ConfigIndex* , *ri-ConfigIndex*, *cqi-pmi-ConfigIndex2* and *ri-ConfigIndex*2 can be configured for each CSI process.

In the case where wideband CQI/PMI reporting is configured:

- The reporting instances for wideband CQI/PMI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (N_{pd}) = 0$ .
- In case RI reporting is configured, the reporting interval of the RI reporting is an integer multiple $M_{RI}$ of period $N_{pd}$ (in subframes).
    - The reporting instances for RI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}) \bmod (N_{pd} \cdot M_{RI}) = 0$ .

In the case where both wideband CQI/PMI and subband CQI reporting are configured:

- The reporting instances for wideband CQI/PMI and subband CQI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod N_{pd} = 0$ .
    - When PTI is not transmitted (due to not being configured) or the most recently transmitted PTI is equal to 1 for a UE configured in transmission mode 9 or for a UE configured in transmission mode 10 without a 'RI-reference CSI process' for a CSI process, or the transmitted PTI is equal to 1 reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for the CSI process, or the transmitted PTI is equal to 1 for a 'RI-reference CSI process' reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with the 'RI-reference CSI process' for the CSI process, and the most recent type 6 report for the CSI process is dropped:
        - The wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission modes 9 and 10) report has period $H \cdot N_{pd}$ , and is reported on the

subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (H \cdot N_{pd}) = 0$. The integer $H$ is defined as $H = J \cdot K + 1$, where $J$ is the number of bandwidth parts.

- Between every two consecutive wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission modes 9 and 10) reports, the remaining $J \cdot K$ reporting instances are used in sequence for subband CQI reports on $K$ full cycles of bandwidth parts except when the gap between two consecutive wideband CQI/PMI reports contains less than $J \cdot K$ reporting instances due to a system frame number transition to 0, in which case the UE shall not transmit the remainder of the subband CQI reports which have not been transmitted before the second of the two wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission modes 9 and 10) reports. Each full cycle of bandwidth parts shall be in increasing order starting from bandwidth part 0 to bandwidth part $J-1$. The parameter $K$ is configured by higher-layer signalling.

- When the most recently transmitted PTI is 0 for a UE configured in transmission mode 9 or for a UE configured in transmission mode 10 without a 'RI-reference CSI process' for a CSI process, or the transmitted PTI is 0 reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for the CSI process, or the transmitted PTI is 0 for a 'RI-reference CSI process' reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with the 'RI-reference CSI process' for the CSI process, and the most recent type 6 report for the CSI process is dropped:

  - The wideband first precoding matrix indicator report has period $H' \cdot N_{pd}$, and is reported on the subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (H' \cdot N_{pd}) = 0$, where $H'$ is signalled by higher layers.

  - Between every two consecutive wideband first precoding matrix indicator reports, the remaining reporting instances are used for a wideband second precoding matrix indicator with wideband CQI as described below

- In case RI reporting is configured, the reporting interval of RI is $M_{RI}$ times the wideband CQI/PMI period $H \cdot N_{pd}$, and RI is reported on the same PUCCH cyclic shift resource as both the wideband CQI/PMI and subband CQI reports.

  - The reporting instances for RI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}) \bmod (H \cdot N_{pd} \cdot M_{RI}) = 0$

In case of collision of a CSI report with PUCCH reporting type 3, 5, or 6 of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2a, 2b, 2c, or 4 of the same serving cell the latter CSI report with PUCCH reporting type (1, 1a, 2, 2a, 2b, 2c, or 4) has lower priority and is dropped.

For a serving cell and UE configured in transmission mode 10, in case of collision between CSI reports of same serving cell with PUCCH reporting type of the same priority, and the CSI reports corresponding to different CSI processes, the CSI reports corresponding to all CSI processes except the CSI process with the lowest *CSIProcessIndex* are dropped.

If the UE is configured with more than one serving cell, the UE transmits a CSI report of only one serving cell in any given subframe. For a given subframe, in case of collision of a CSI report with PUCCH reporting type 3, 5, 6, or 2a of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2b, 2c, or 4 of another serving cell, the latter CSI with PUCCH reporting type (1, 1a, 2, 2b, 2c, or 4) has lower priority and is dropped. For a given subframe, in case of collision of CSI report with PUCCH reporting type 2, 2b, 2c, or 4 of one serving cell with CSI report with PUCCH reporting type 1 or 1a of another serving cell, the latter CSI report with PUCCH reporting type 1, or 1a has lower priority and is dropped.
For a given subframe and serving cells with UE configured in transmission mode 1-9, in case of collision between CSI reports of these different serving cells with PUCCH reporting type of the same priority, the CSI reports for all these serving cells except the serving cell with lowest *ServCellIndex* are dropped.

For a given subframe and serving cells with UE configured in transmission mode 10, in case of collision between CSI reports of different serving cells with PUCCH reporting type of the same priority and the CSI reports corresponding to CSI processes with same *csi-ProcessId-r11*, the CSI reports of all serving cells except the serving cell with lowest *ServCellIndex* are dropped.

For a given subframe and serving cells with UE configured in transmission mode 10, in case of collision between CSI reports of different serving cells with PUCCH reporting type of the same priority and the CSI reports corresponding to CSI processes with different *csi-ProcessId-r11*, the CSI reports of all serving cells except the serving cell with CSI reports corresponding to CSI process with the lowest *csi-ProcessId-r11* are dropped.

For a given subframe, in case of collision between CSI report of a given serving cell with UE configured in transmission mode 1-9, and CSI report(s) corresponding to CSI process(es) of a different serving cell with the UE configured in transmission mode 10, and the CSI reports of the serving cells with PUCCH reporting type of the same priority, the CSI report(s) corresponding to CSI process(es) with *csi-ProcessId-r11* > 1 of the different serving cell are dropped.

For a given subframe, in case of collision between CSI report of a given serving cell with UE configured in transmission mode 1-9, and CSI report corresponding to CSI process with *csi-ProcessId-r11* = 1 of a different serving cell with the UE configured in transmission mode 10, and the CSI reports of the serving cells with PUCCH reporting type of the same priority, the CSI report of the serving cell with highest *ServCellIndex* is dropped.

See subclause 10.1 for UE behaviour regarding collision between CSI and HARQ-ACK and the corresponding PUCCH format assignment.

The CSI report of a given PUCCH reporting type shall be transmitted on the PUCCH resource $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$ as defined in [3], where $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$ is UE specific and configured by higher layers for each serving cell.

If the UE is not configured for simultaneous PUSCH and PUCCH transmission or, if the UE is configured for simultaneous PUSCH and PUCCH transmission and not transmitting PUSCH, in case of collision between CSI and positive SR in a same subframe, CSI is dropped.

**Table 7.2.2-1A: Mapping of $I_{CQI/PMI}$ to $N_{pd}$ and $N_{OFFSET,CQI}$ for FDD**

| $I_{CQI/PMI}$ | Value of $N_{pd}$ | Value of $N_{OFFSET,CQI}$ |
|---|---|---|
| $0 \le I_{CQI/PMI} \le 1$ | 2 | $I_{CQI/PMI}$ |
| $2 \le I_{CQI/PMI} \le 6$ | 5 | $I_{CQI/PMI} - 2$ |
| $7 \le I_{CQI/PMI} \le 16$ | 10 | $I_{CQI/PMI} - 7$ |
| $17 \le I_{CQI/PMI} \le 36$ | 20 | $I_{CQI/PMI} - 17$ |
| $37 \le I_{CQI/PMI} \le 76$ | 40 | $I_{CQI/PMI} - 37$ |
| $77 \le I_{CQI/PMI} \le 156$ | 80 | $I_{CQI/PMI} - 77$ |
| $157 \le I_{CQI/PMI} \le 316$ | 160 | $I_{CQI/PMI} - 157$ |
| $I_{CQI/PMI} = 317$ | Reserved | |
| $318 \le I_{CQI/PMI} \le 349$ | 32 | $I_{CQI/PMI} - 318$ |
| $350 \le I_{CQI/PMI} \le 413$ | 64 | $I_{CQI/PMI} - 350$ |
| $414 \le I_{CQI/PMI} \le 541$ | 128 | $I_{CQI/PMI} - 414$ |
| $542 \le I_{CQI/PMI} \le 1023$ | Reserved | |

**Table 7.2.2-1B: Mapping of $I_{RI}$ to $M_{RI}$ and $N_{OFFSET,RI}$.**

| $I_{RI}$ | Value of $M_{RI}$ | Value of $N_{OFFSET,RI}$ |
|---|---|---|
| $0 \le I_{RI} \le 160$ | 1 | $-I_{RI}$ |
| $161 \le I_{RI} \le 321$ | 2 | $-(I_{RI} - 161)$ |
| $322 \le I_{RI} \le 482$ | 4 | $-(I_{RI} - 322)$ |
| $483 \le I_{RI} \le 643$ | 8 | $-(I_{RI} - 483)$ |
| $644 \le I_{RI} \le 804$ | 16 | $-(I_{RI} - 644)$ |
| $805 \le I_{RI} \le 965$ | 32 | $-(I_{RI} - 805)$ |
| $966 \le I_{RI} \le 1023$ | Reserved | |

**Table 7.2.2-1C: Mapping of $I_{CQI/PMI}$ to $N_{pd}$ and $N_{OFFSET,CQI}$ for TDD**

| $I_{CQI/PMI}$ | Value of $N_{pd}$ | Value of $N_{OFFSET,CQI}$ |
|---|---|---|
| $I_{CQI/PMI} = 0$ | 1 | $I_{CQI/PMI}$ |
| $1 \le I_{CQI/PMI} \le 5$ | 5 | $I_{CQI/PMI} - 1$ |
| $6 \le I_{CQI/PMI} \le 15$ | 10 | $I_{CQI/PMI} - 6$ |
| $16 \le I_{CQI/PMI} \le 35$ | 20 | $I_{CQI/PMI} - 16$ |
| $36 \le I_{CQI/PMI} \le 75$ | 40 | $I_{CQI/PMI} - 36$ |
| $76 \le I_{CQI/PMI} \le 155$ | 80 | $I_{CQI/PMI} - 76$ |
| $156 \le I_{CQI/PMI} \le 315$ | 160 | $I_{CQI/PMI} - 156$ |
| $316 \le I_{CQI/PMI} \le 1023$ | Reserved | |

For TDD periodic CQI/PMI reporting, the following periodicity values apply for a serving cell *c* depending on the TDD UL/DL configuration of the primary cell [3]:

- The reporting period of $N_{pd} = 1$ is applicable for the serving cell *c* only if TDD UL/DL configuration of the primary cell belongs to {0, 1, 3, 4, 6}, and where all UL subframes of the primary cell in a radio frame are used for CQI/PMI reporting.
- The reporting period of $N_{pd} = 5$ is applicable for the serving cell *c* only if TDD UL/DL configuration of the primary cell belongs to {0, 1, 2, 6}.
- The reporting periods of $N_{pd} = \{10,20,40,80,160\}$ are applicable for the serving cell c for any TDD UL/DL configuration of the primary cell.

For a serving cell with $N_{\mathrm{RB}}^{\mathrm{DL}} \le 7$, Mode 2-0 and Mode 2-1 are not supported for that serving cell.

The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1D for first and second precoding matrix indicator $i_1$ and $i_2$. Joint encoding of rank and first precoding matrix indicator $i_1$ for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1F for PUCCH Reporting Type 1a.

**Table 7.2.2-1D: PUCCH mode 1-1 submode 2 codebook subsampling**

| RI | Relationship between the first PMI value and codebook index $i_1$ | | Relationship between the second PMI value and codebook index $i_2$ | | total |
|---|---|---|---|---|---|
| | Value of the first PMI $I_{PMI1}$ | Codebook index $i_1$ | Value of the second PMI $I_{PMI2}$ | Codebook index $i_2$ | #bits |
| 1 | 0-7 | $2I_{PMI1}$ | 0-1 | $2I_{PMI2}$ | 4 |
| 2 | 0-7 | $2I_{PMI1}$ | 0-1 | $I_{PMI2}$ | 4 |
| 3 | 0-1 | $2I_{PMI1}$ | 0-7 | $4\lfloor I_{PMI2}/4 \rfloor + I_{PMI2}$ | 4 |
| 4 | 0-1 | $2I_{PMI1}$ | 0-7 | $I_{PMI2}$ | 4 |
| 5 | 0-3 | $I_{PMI1}$ | 0 | 0 | 2 |
| 6 | 0-3 | $I_{PMI1}$ | 0 | 0 | 2 |
| 7 | 0-3 | $I_{PMI1}$ | 0 | 0 | 2 |
| 8 | 0 | 0 | 0 | 0 | 0 |

**Table 7.2.2-1E: Joint encoding of RI and $i_1$ for PUCCH mode 1-1 submode 1**

| Value of joint encoding of RI and the first PMI $I_{RI/PMI1}$ | RI | Codebook index $i_1$ |
|---|---|---|
| 0-7 | 1 | $2I_{RI/PMI1}$ |
| 8-15 | 2 | $2(I_{RI/PMI1}-8)$ |
| 16-17 | 3 | $2(I_{RI/PMI1}-16)$ |
| 18-19 | 4 | $2(I_{RI/PMI1}-18)$ |
| 20-21 | 5 | $2(I_{RI/PMI1}-20)$ |
| 22-23 | 6 | $2(I_{RI/PMI1}-22)$ |
| 24-25 | 7 | $2(I_{RI/PMI1}-24)$ |
| 26 | 8 | 0 |
| 27-31 | reserved | NA |

**Table 7.2.2-1F: PUCCH mode 2-1 codebook subsampling.**

| RI | Relationship between the second PMI value and codebook index $i_2$ | |
|---|---|---|
| | Value of the second PMI $I_{PMI2}$ | Codebook index $i_2$ |
| 1 | 0-15 | $I_{PMI2}$ |
| 2 | 0-3 | $2I_{PMI2}$ |
| 3 | 0-3 | $8\cdot\lfloor I_{PMI2}/2 \rfloor + (I_{PMI2} \bmod 2) + 2$ |
| 4 | 0-3 | $2I_{PMI2}$ |
| 5 | 0 | 0 |
| 6 | 0 | 0 |
| 7 | 0 | 0 |
| 8 | 0 | 0 |

An RI or PTI or any precoding matrix indicator reported for a serving cell in a periodic reporting mode is valid only for CSI reports for that serving cell on that periodic CSI reporting mode.

For serving cell $c$, a UE configured in transmission mode 10 with PMI/RI reporting for a CSI process can be configured with a 'RI-reference CSI process'. The RI for the 'RI-reference CSI process' is not based on any other configured CSI process other than the 'RI-reference CSI process'. If the UE is configured with a 'RI-reference CSI

process' for a CSI process and if subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers for only one of the CSI processes then the UE is not expected to receive configuration for the CSI process configured with the subframe subsets that have a different set of restricted RIs with precoder codebook subset restriction between the two subframe sets.The UE is not expected to receive configurations for the CSI process and the 'RI-reference CSI process' that have a different:

- periodic CSI reporting mode (including sub-mode if configured), and/or
- number of CSI-RS antenna ports, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are not configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for each subframe set if subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers for only one of the CSI processes, and the set of restricted RIs for the two subframe sets are the same.

For the calculation of CQI/PMI conditioned on the last reported RI, in the absence of a last reported RI the UE shall conduct the CQI/PMI calculation conditioned on the lowest possible RI as given by the bitmap parameter *codebookSubsetRestriction* . If reporting for more than one CSI subframe set is configured, CQI/PMI is conditioned on the last reported RI linked to the same subframe set as the CSI report.

- Wideband feedback
  - Mode 1-0 description:
    - In the subframe where RI is reported (only for transmission mode 3):
      - A UE shall determine a RI assuming transmission on set *S* subbands.
      - The UE shall report a type 3 report consisting of one RI.
    - In the subframe where CQI is reported:
      - A UE shall report a type 4 report consisting of one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
      - For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1.
  - Mode 1-1 description:
    - In the subframe where RI is reported (only for transmission modes 4, 8, 9 and 10):
      - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.
      - The UE shall report a type 3 report consisting of one RI.
    - In the subframe where RI and a first PMI are reported (only for transmission modes 9 and 10, and configured with submode 1 and 8 CSI-RS ports)
      - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.

- The UE shall report a type 5 report consisting of jointly coded RI and a first PMI corresponding to a set of precoding matrices selected from the codebook subset assuming transmission on set *S* subbands.

- If the UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process and in case of collision of type 5 report for the CSI process with type 5 report for the 'RI-reference CSI process', the wideband first PMI for the CSI process shall be the same as the wideband first PMI in the most recent type 5 report for the configured 'RI-reference CSI process'; otherwise, the wideband first PMI value is calculated conditioned on the reported periodic RI.

▪ In the subframe where CQI/PMI is reported for all transmission modes except with 8 CSI-RS ports configured for transmission modes 9 and 10:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2 report consisting of
    - A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
    - The selected single PMI (wideband PMI).
    - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - For transmission modes 4, 8, 9 and 10,
    - If a UE is configured in transmission mode 10 with a ‘'RI-reference CSI process’' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ‘'RI-reference CSI process’' is reported in the most recent RI reporting instance for the CSI process, the PMI and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ‘'RI-reference CSI process’' in the most recent RI reporting instance for the CSI process; otherwise the PMI and CQI are calculated conditioned on the last reported periodic RI.
  - For other transmission modes the PMI and CQI are calculated conditioned on transmission rank 1.
▪ In the subframe where wideband CQI/second PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured to submode 1 only:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2b report consisting of
    - A single wideband CQI value which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands.
    - The wideband second PMI corresponding to the selected single precoding matrix.
    - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 5 report for the CSI process is dropped, and a type 5 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process,
    - The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI and the wideband first PMI

for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.

- The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.

- Otherwise,
  - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI.
  - The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.

- In the subframe where wideband CQI/first PMI/second PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured to submode 2 only:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2c report consisting of
    - A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
    - The wideband first PMI and the wideband second PMI corresponding to the selected single precoding matrix as defined in subclause 7.2.4.
    - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the wideband first PMI, the wideband second PMI and the wideband CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise the wideband first PMI, the wideband second PMI and the wideband CQI are calculated conditioned on the last reported periodic RI.

- UE Selected subband feedback
  - Mode 2-0 description:
    - In the subframe where RI is reported (only for transmission mode 3):
      - A UE shall determine a RI assuming transmission on set *S* subbands.
      - The UE shall report a type 3 report consisting of one RI.
    - In the subframe where wideband CQI is reported:
      - The UE shall report a type 4 report on each respective successive reporting opportunity consisting of one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
      - For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1.
    - In the subframe where CQI for the selected subbands is reported:

- The UE shall select the preferred subband within the set of $N_j$ subbands in each of the $J$ bandwidth parts where $J$ is given in Table 7.2.2-2.
- The UE shall report a type 1 report consisting of one CQI value reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband $L$-bit label. A type 1 report for each bandwidth part will in turn be reported in respective successive reporting opportunities. The CQI represents channel quality for the first codeword, even when RI>1.
- For transmission mode 3 the preferred subband selection and CQI values are calculated conditioned on the last reported periodic RI. For other transmission modes they are calculated conditioned on transmission rank 1.

o Mode 2-1 description:

- In the subframe where RI is reported (only for transmission modes 4 and 8 and with 2 or 4 CSI-RS ports configured for transmission modes 9 and 10):
  - Ifa UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set $S$ subbands.
  - The UE shall report a type 3 report consisting of one RI.
- In the subframe where RI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured then:
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set $S$ subbands.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the PTI for the CSI process shall be the same as the PTI in the most recent type 6 report for the configured 'RI-reference CSI process'; otherwise, the UE shall determine a precoder type indication (PTI).
  - The UE shall report a type 6 report consisting of one RI and the PTI.
- In the subframe where wideband CQI/PMI is reported for all transmission modes except with 8 CSI-RS ports configured for transmission modes 9 and 10:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set $S$ subbands.
  - A UE shall report a type 2 report on each respective successive reporting opportunity consisting of:
    - A wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set $S$ subbands.
    - The selected single PMI (wideband PMI).
    - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - For transmission modes 4, 8, 9 and 10,
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the PMI and CQI values for the CSI process are

calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise the PMI and CQI values are calculated conditioned on the last reported periodic RI.

- For other transmission modes the PMI and CQI values are calculated conditioned on transmission rank 1.

- In the subframe where the wideband first PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured:
  - A set of precoding matrices corresponding to the wideband first PMI is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2a report on each respective successive reporting opportunity consisting of the wideband first PMI corresponding to the selected set of precoding matrices.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=0 is reported in the most recent RI reporting instance for the CSI process, the wideband first PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise with the last reported PTI=0, the wideband first PMI value is calculated conditioned on the last reported periodic RI.
- In the subframe where wideband CQI/second PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2b report on each respective successive reporting opportunity consisting of:
    - A wideband CQI value which is calculated assuming the use of the selected single precoding matrix in all subbands and transmission on set *S* subbands.
    - The wideband second PMI corresponding to the selected single precoding matrix.
    - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=1 is reported in the most recent RI reporting instance for the CSI process,
    - The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process,
    - The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
  - Otherwise, with the last reported PTI=1,

- The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI.
- The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.

- If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.

- In the subframe where CQI for the selected subband is reported for all transmission modes except with 8 CSI-RS ports configured for transmission modes 9 and 10:
  - The UE shall select the preferred subband within the set of $N_j$ subbands in each of the $J$ bandwidth parts where $J$ is given in Table 7.2.2-2.
  - The UE shall report a type 1 report per bandwidth part on each respective successive reporting opportunity consisting of:
    - CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband $L$-bit label.
    - When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
      - Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
      - Assuming the use of the most recently reported single precoding matrix in all subbands and transmission on the selected subband within the applicable bandwidth part.
    - The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
  - For transmission modes 4, 8, 9 and 10,
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the subband selection and CQI values for the CSI process are calculated conditioned on the last reported periodic wideband PMI for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise the subband selection and CQI values are calculated conditioned on the last reported periodic wideband PMI and RI.
  - For other transmission modes the subband selection and CQI values are calculated conditioned on the last reported PMI and transmission rank 1.

- In the subframe where wideband CQI/second PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set $S$ subbands.
  - The UE shall report a type 2b report on each respective successive reporting opportunity consisting of:
    - A wideband CQI value which is calculated assuming the use of the selected single precoding matrix in all subbands and transmission on set $S$ subbands.

- The wideband second PMI corresponding to the selected single precoding matrix.
- When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.

- If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=0 is reported in the most recent RI reporting instance for the CSI process,
  - The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process.
  - The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
- Otherwise, with the last reported PTI=0,
  - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI. The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.
- If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.

- In the subframe where subband CQI/second PMI for the selected subband is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured:
  - The UE shall select the preferred subband within the set of $N_j$ subbands in each of the $J$ bandwidth parts where $J$ is given in Table 7.2.2-2.
  - The UE shall report a type 1a report per bandwidth part on each respective successive reporting opportunity consisting of:
    - CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband $L$-bit label.
    - When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
      - Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
      - Assuming the use of the precoding matrix corresponding to the selected second PMI and the most recently reported first PMI and transmission on the selected subband within the applicable bandwidth part.
    - The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
    - A second PMI of the preferred precoding matrix selected from the codebook subset assuming transmission only over the selected subband within the applicable bandwidth part determined in the previous step.

- If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=1 is reported in the most recent RI reporting instance for the CSI process,
    - The subband second PMI values for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process.
    - The subband selection and CQI values are calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
- Otherwise, with the last reported PTI=1
    - The subband second PMI values are calculated conditioned on the last reported periodic RI and the wideband first PMI.
    - The subband selection and CQI values are calculated conditioned on the selected precoding matrix and the last reported periodic RI.
- If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.

**Table 7.2.2-2: Subband Size (*k*) and Bandwidth Parts *(J)* vs. Downlink System Bandwidth**

| System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$ | Subband Size *k* (RBs) | Bandwidth Parts (*J*) |
|---|---|---|
| 6 – 7 | NA | NA |
| 8 – 10 | 4 | 1 |
| 11 – 26 | 4 | 2 |
| 27 – 63 | 6 | 3 |
| 64 – 110 | 8 | 4 |

If parameter *ttiBundling* provided by higher layers is set to *TRUE* and if an UL-SCH in subframe bundling operation collides with a periodic CSI reporting instance, then the UE shall drop the periodic CSI report of a given PUCCH reporting type in that subframe and shall not multiplex the periodic CSI report payload in the PUSCH transmission in that subframe. A UE is not expected to be configured with simultaneous PUCCH and PUSCH transmission when UL-SCH subframe bundling is configured.

**Table 7.2.2-3: PUCCH Reporting Type Payload size per PUCCH Reporting Mode and Mode State**

| PUCCH Reporting Type | Reported | Mode State | PUCCH Reporting Modes | | | |
|---|---|---|---|---|---|---|
| | | | Mode 1-1 (bits/BP) | Mode 2-1 (bits/BP) | Mode 1-0 (bits/BP) | Mode 2-0 (bits/BP) |
| 1 | Sub-band CQI | RI = 1 | NA | 4+L | NA | 4+L |
| | | RI > 1 | NA | 7+L | NA | 4+L |
| 1a | Sub-band CQI / second PMI | 8 antenna ports RI = 1 | NA | 8+L | NA | NA |
| | | 8 antenna ports 1 < RI < 5 | NA | 9+L | NA | NA |
| | | 8 antenna ports RI > 4 | NA | 7+L | NA | NA |
| 2 | Wideband CQI/PMI | 2 antenna ports RI = 1 | 6 | 6 | NA | NA |
| | | 4 antenna ports RI = 1 | 8 | 8 | NA | NA |
| | | 2 antenna ports RI > 1 | 8 | 8 | NA | NA |
| | | 4 antenna ports RI > 1 | 11 | 11 | NA | NA |
| 2a | Wideband first PMI | 8 antenna ports RI < 3 | NA | 4 | NA | NA |
| | | 8 antenna ports 2 < RI < 8 | NA | 2 | NA | NA |
| | | 8 antenna ports RI = 8 | NA | 0 | NA | NA |
| 2b | Wideband CQI / second PMI | 8 antenna ports RI = 1 | 8 | 8 | NA | NA |
| | | 8 antenna ports 1 < RI < 4 | 11 | 11 | NA | NA |
| | | 8 antenna ports RI = 4 | 10 | 10 | NA | NA |
| | | 8 antenna ports RI > 4 | 7 | 7 | NA | NA |
| 2c | Wideband CQI / first PMI / second PMI | 8 antenna ports RI = 1 | 8 | NA | NA | NA |
| | | 8 antenna ports 1 < RI ≤ 4 | 11 | NA | NA | NA |
| | | 8 antenna ports 4 < RI ≤ 7 | 9 | NA | NA | NA |
| | | 8 antenna ports RI = 8 | 7 | NA | NA | NA |
| 3 | RI | 2/4 antenna ports, 2-layer spatial multiplexing | 1 | 1 | 1 | 1 |
| | | 8 antenna ports, 2-layer spatial multiplexing | 1 | NA | NA | NA |
| | | 4 antenna ports, 4-layer spatial multiplexing | 2 | 2 | 2 | 2 |
| | | 8 antenna ports, 4-layer spatial multiplexing | 2 | NA | NA | NA |
| | | 8-layer spatial multiplexing | 3 | NA | NA | NA |
| 4 | Wideband CQI | RI = 1 or RI>1 | NA | NA | 4 | 4 |
| 5 | RI/ first PMI | 8 antenna ports, 2-layer spatial multiplexing | 4 | NA | NA | NA |
| | | 8 antenna ports, 4 and 8-layer spatial multiplexing | 5 | | | |
| 6 | RI/PTI | 8 antenna ports, 2-layer spatial multiplexing | NA | 2 | NA | NA |
| | | 8 antenna ports, 4-layer spatial multiplexing | NA | 3 | NA | NA |
| | | 8 antenna ports, 8-layer spatial multiplexing | NA | 4 | NA | NA |

### 7.2.3 Channel Quality Indicator (CQI) definition

The CQI indices and their interpretations are given in Table 7.2.3-1.

Based on an unrestricted observation interval in time and frequency, the UE shall derive for each CQI value reported in uplink subframe *n* the highest CQI index between 1 and 15 in Table 7.2.3-1 which satisfies the following condition, or CQI index 0 if CQI index 1 does not satisfy the condition:

- A single PDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding 0.1.

If CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers, each CSI reference resource belongs to either $C_{\mathrm{CSI},0}$ or $C_{\mathrm{CSI},1}$ but not to both. When CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers a UE is not expected to receive a trigger for which the CSI reference resource is in subframe that does not belong to either subframe set. For a UE in transmission mode 10 and periodic CSI reporting, the CSI subframe set for the CSI reference resource is configured by higher layers for each CSI process.

For a UE in transmission mode 9 when parameter *pmi-RI-Report* is configured by higher layers, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe *n* based on only the Channel-State Information (CSI) reference signals (CSI-RS) defined in [3] for which the UE is configured to assume non-zero power for the CSI-RS. For a UE in transmission mode 9 when the parameter *pmi-RI-Report* is not configured by higher layers or in transmission modes 1-8 the UE shall derive the channel measurements for computing CQI based on CRS.

For a UE in transmission mode 10, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe *n* and corresponding to a CSI process, based on only the non-zero power CSI-RS (defined in [3]) within a configured CSI-RS resource associated with the CSI process.

For a UE in transmission mode 10 , the UE shall derive the interference measurements for computing the CQI value reported in uplink subframe *n* and corresponding to a CSI process, based on only the zero power CSI-RS (defined in [3]) within the configured CSI-IM resource associated with the CSI process. If the UE in transmission mode 10 is configured by higher layers for CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ for the CSI process, the configured CSI-IM resource within the subframe subset belonging to the CSI reference resource is used to derive the interference measurement.

A combination of modulation scheme and transport block size corresponds to a CQI index if:

- the combination could be signalled for transmission on the PDSCH in the CSI reference resource according to the relevant Transport Block Size table, and
- the modulation scheme is indicated by the CQI index, and
- the combination of transport block size and modulation scheme when applied to the reference resource results in the effective channel code rate which is the closest possible to the code rate indicated by the CQI index. If more than one combination of transport block size and modulation scheme results in an effective channel code rate equally close to the code rate indicated by the CQI index, only the combination with the smallest of such transport block sizes is relevant.

The CSI reference resource for a serving cell is defined as follows:

- In the frequency domain, the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the derived CQI value relates.
- In the time domain,
  - for a UE configured in transmission mode 1-9 or transmission mode 10 with a single configured CSI process for the serving cell, the CSI reference resource is defined by a single downlink subframe $n-n_{CQI_ref}$,
    - where for periodic CSI reporting $n_{CQI_ref}$ is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink subframe;

- where for aperiodic CSI reporting $n_{CQI_ref}$ is such that the reference resource is in the same valid downlink subframe as the corresponding CSI request in an uplink DCI format.
- where for aperiodic CSI reporting $n_{CQI_ref}$ is equal to 4 and downlink subframe $n-n_{CQI_ref}$ corresponds to a valid downlink subframe, where downlink subframe $n-n_{CQI_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant.

- for a UE configured in transmission mode 10 with multiple configured CSI processes for the serving cell, the CSI reference resource for a given CSI process is defined by a single downlink subframe $n-n_{CQI_ref}$,
  - where for FDD and periodic or aperiodic CSI reporting $n_{CQI_ref}$ is the smallest value greater than or equal to 5, such that it corresponds to a valid downlink subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for FDD and aperiodic CSI reporting $n_{CQI_ref}$ is equal to 5 and downlink subframe $n-n_{CQI_ref}$ corresponds to a valid downlink subframe, where downlink subframe $n-n_{CQI_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant.
  - where for TDD, and 2 or 3 configured CSI processes, and periodic or aperiodic CSI reporting, $n_{CQI_ref}$ is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for TDD, and 2 or 3 configured CSI processes, and aperiodic CSI reporting, $n_{CQI_ref}$ is equal to 4 and downlink subframe $n-n_{CQI_ref}$ corresponds to a valid downlink subframe, where downlink subframe $n-n_{CQI_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant;
  - where for TDD, and 4 configured CSI processes, and periodic or aperiodic CSI reporting, $n_{CQI_ref}$ is the smallest value greater than or equal to 5, such that it corresponds to a valid downlink subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for TDD, and 4 configured CSI processes, and aperiodic CSI reporting, $n_{CQI_ref}$ is equal to 5 and downlink subframe $n-n_{CQI_ref}$ corresponds to a valid downlink subframe, where downlink subframe $n-n_{CQI_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant.

A downlink subframe in a serving cell shall be considered to be valid if:

- it is configured as a downlink subframe for that UE, and
- in case multiple cells with different uplink-downlink configurations are aggregated and the UE is not capable of simultaneous reception and transmission in the aggregated cells, the subframe in the primary cell is a downlink subframe or a special subframe with the length of DwPTS more than $7680 \cdot T_s$, and
- except for transmission mode 9 or 10, it is not an MBSFN subframe, and
- it does not contain a DwPTS field in case the length of DwPTS is $7680 \cdot T_s$ and less, and
- it does not fall within a configured measurement gap for that UE, and
- for periodic CSI reporting, it is an element of the CSI subframe set linked to the periodic CSI report when that UE is configured with CSI subframe sets, and
- for a UE configured in transmission mode 10 with multiple configured CSI processes, and aperiodic CSI reporting for a CSI process, it is an element of the CSI subframe set linked to the downlink subframe with the corresponding CSI request in an uplink DCI format, when that UE is configured with CSI subframe sets for the CSI process.

If there is no valid downlink subframe for the CSI reference resource in a serving cell, CSI reporting is omitted for the serving cell in uplink subframe $n$.

- In the layer domain, the CSI reference resource is defined by any RI and PMI on which the CQI is conditioned.

In the CSI reference resource, the UE shall assume the following for the purpose of deriving the CQI index, and if also configured, PMI and RI:

- The first 3 OFDM symbols are occupied by control signalling
- No resource elements used by primary or secondary synchronization signals or PBCH or EPDCCH
- CP length of the non-MBSFN subframes
- Redundancy Version 0
- If CSI-RS is used for channel measurements, the ratio of PDSCH EPRE to CSI-RS EPRE is as given in subclause 7.2.5
- For transmission mode 9 CSI reporting:
  - CRS REs are as in non-MBSFN subframes;
  - If the UE is configured for PMI/RI reporting, the UE-specific reference signal overhead is consistent with the most recent reported rank if more than one CSI-RS port is configured, and is consistent with rank 1 transmission if only one CSI-RS port is configured; and PDSCH signals on antenna ports $\{7 \ldots 6+\upsilon\}$ for $\upsilon$ layers would result in signals equivalent to corresponding symbols transmitted on antenna ports $\{15 \ldots 14+P\}$, as given by $\begin{bmatrix} y^{(15)}(i) \\ \vdots \\ y^{(14+P)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$, where $x(i) = \left[x^{(0)}(i) \quad \ldots \quad x^{(\upsilon-1)}(i)\right]^T$ is a vector of symbols from the layer mapping in subclause 6.3.3.2 of [3], $P \in \{1,2,4,8\}$ is the number of CSI-RS ports configured, and if only one CSI-RS port is configured, $W(i)$ is 1, otherwise $W(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$. The corresponding PDSCH signals transmitted on antenna ports $\{15 \ldots 14+P\}$ would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in subclause 7.2.5.

- For transmission mode 10 CSI reporting, if a CSI process is configured without PMI/RI reporting:
  - If the number of antenna ports of the associated CSI-RS resource is one, a PDSCH transmission is on single-antenna port, port 7. The channel on antenna port {7} is inferred from the channel on antenna port {15} of the associated CSI-RS resource.
    - CRS REs are as in non-MBSFN subframes. The CRS overhead is assumed to be the same as the CRS overhead corresponding to the number of CRS antenna ports of the serving cell;
    - The UE-specific reference signal overhead is 12 REs per PRB pair.
  - Otherwise,
    - If the number of antenna ports of the associated CSI-RS resource is 2, the PDSCH transmission scheme assumes the transmit diversity scheme defined in subclause 7.1.2 on antenna ports {0,1} except that the channels on antenna ports {0,1} are inferred from the channels on antenna port {15, 16} of the associated CSI resource respectively.
    - If the number of antenna ports of the associated CSI-RS resource is 4, the PDSCH transmission scheme assumes the transmit diversity scheme defined in subclause 7.1.2 on antenna ports {0,1,2,3} except that the channels on antenna ports {0,1,2,3} are inferred from the channels on antenna ports {15, 16, 17, 18} of the associated CSI-RS resource respectively.
    - The UE is not expected to be configured with more than 4 antenna ports for the CSI-RS resource associated with the CSI process configured without PMI/RI reporting.
    - The overhead of CRS REs is assuming the same number of antenna ports as that of the associated CSI-RS resource.
    - UE-specific reference signal overhead is zero.
- For transmission mode 10 CSI reporting, if a CSI process is configured with PMI/RI reporting:
  - CRS REs are as in non-MBSFN subframes. The CRS overhead is assumed to be the same as the CRS overhead corresponding to the number of CRS antenna ports of the serving cell;
  - The UE-specific reference signal overhead is consistent with the most recent reported rank for the CSI process if more than one CSI-RS port is configured, and is consistent with rank 1 transmission if only one CSI-RS port is configured; and PDSCH signals on antenna ports $\{7 \ldots 6+\upsilon\}$ for $\upsilon$ layers would result in signals equivalent to corresponding symbols transmitted on antenna ports

$\{15\ldots14+P\}$, as given by $\begin{bmatrix} y^{(15)}(i) \\ \vdots \\ y^{(14+P)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$, where

$x(i) = \left[x^{(0)}(i) \quad \ldots \quad x^{(\upsilon-1)}(i)\right]^T$ is a vector of symbols from the layer mapping in subclause 6.3.3.2 of [3], $P \in \{1,2,4,8\}$ is the number of antenna ports of the associated CSI-RS resource, and if $P$=1, $W(i)$ is 1, otherwise $W(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$. The corresponding PDSCH signals transmitted on antenna ports $\{15\ldots14+P\}$ would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in subclause 7.2.5

- Assume no REs allocated for CSI-RS and zero-power CSI-RS
- Assume no REs allocated for PRS
- The PDSCH transmission scheme given by Table 7.2.3-0 depending on the transmission mode currently configured for the UE (which may be the default mode).
- If CRS is used for channel measurements, the ratio of PDSCH EPRE to cell-specific RS EPRE is as given in subclause 5.2 with the exception of $\rho_A$ which shall be assumed to be
  - $\rho_A = P_A + \Delta_{offset} + 10\log_{10}(2)$ [dB] for any modulation scheme, if the UE is configured with transmission mode 2 with 4 cell-specific antenna ports, or transmission mode 3 with 4 cell-specific antenna ports and the associated RI is equal to one;
  - $\rho_A = P_A + \Delta_{offset}$ [dB] for any modulation scheme and any number of layers, otherwise.

  The shift $\Delta_{offset}$ is given by the parameter *nomPDSCH-RS-EPRE-Offset* which is configured by higher-layer signalling.

**Table 7.2.3-0: PDSCH transmission scheme assumed for CSI reference resource**

| Transmission mode | Transmission scheme of PDSCH |
|---|---|
| 1 | Single-antenna port, port 0 |
| 2 | Transmit diversity |
| 3 | Transmit diversity if the associated rank indicator is 1, otherwise large delay CDD |
| 4 | Closed-loop spatial multiplexing |
| 5 | Multi-user MIMO |
| 6 | Closed-loop spatial multiplexing with a single transmission layer |
| 7 | If the number of PBCH antenna ports is one, Single-antenna port, port 0; otherwise Transmit diversity |
| 8 | If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity<br><br>If the UE is configured with PMI/RI reporting: closed-loop spatial multiplexing |
| 9 | If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity<br><br>If the UE is configured with PMI/RI reporting: if the number of CSI-RS ports is one, single-antenna port, port 7; otherwise up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) |
| 10 | If a CSI process of the UE is configured without PMI/RI reporting: if the number of CSI-RS ports is one, single-antenna port, port7; otherwise transmit diversity<br><br>If a CSI process of the UE is configured with PMI/RI reporting: if the number of CSI-RS ports is one, single-antenna port, port 7; otherwise up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B) |

**Table 7.2.3-1: 4-bit CQI Table**

| CQI index | modulation | code rate x 1024 | efficiency |
|---|---|---|---|
| 0 | out of range | | |
| 1 | QPSK | 78 | 0.1523 |
| 2 | QPSK | 120 | 0.2344 |
| 3 | QPSK | 193 | 0.3770 |
| 4 | QPSK | 308 | 0.6016 |
| 5 | QPSK | 449 | 0.8770 |
| 6 | QPSK | 602 | 1.1758 |
| 7 | 16QAM | 378 | 1.4766 |
| 8 | 16QAM | 490 | 1.9141 |
| 9 | 16QAM | 616 | 2.4063 |
| 10 | 64QAM | 466 | 2.7305 |
| 11 | 64QAM | 567 | 3.3223 |
| 12 | 64QAM | 666 | 3.9023 |
| 13 | 64QAM | 772 | 4.5234 |
| 14 | 64QAM | 873 | 5.1152 |
| 15 | 64QAM | 948 | 5.5547 |

## 7.2.4 Precoding Matrix Indicator (PMI) definition

For transmission modes 4, 5 and 6, precoding feedback is used for channel dependent codebook based precoding and relies on UEs reporting precoding matrix indicator (PMI). For transmission mode 8, the UE shall report PMI if configured with PMI/RI reporting. For transmission modes 9 and 10, the UE shall report PMI if configured with PMI/RI reporting and the number of CSI-RS ports is larger than 1. A UE shall report PMI based on the feedback modes described in 7.2.1 and 7.2.2. For other transmission modes, PMI reporting is not supported.

For 2 and 4 antenna ports, each PMI value corresponds to a codebook index given in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [3] as follows:

- For 2 antenna ports $\{0,1\}$ or $\{15,16\}$ and an associated RI value of 1, a PMI value of $n \in \{0,1,2,3\}$ corresponds to the codebook index $n$ given in Table 6.3.4.2.3-1 of [3] with $\upsilon = 1$.
- For 2 antenna ports $\{0,1\}$ or $\{15,16\}$ and an associated RI value of 2, a PMI value of $n \in \{0,1\}$ corresponds to the codebook index $n+1$ given in Table 6.3.4.2.3-1 of [3] with $\upsilon = 2$.
- For 4 antenna ports $\{0,1,2,3\}$ or $\{15,16,17,18\}$, a PMI value of $n \in \{0,1,\cdots,15\}$ corresponds to the codebook index $n$ given in Table 6.3.4.2.3-2 of [3] with $\upsilon$ equal to the associated RI value.

For 8 antenna ports, each PMI value corresponds to a pair of codebook indices given in Table 7.2.4-1, 7.2.4-2, 7.2.4-3, 7.2.4-4, 7.2.4-5, 7.2.4-6, 7.2.4-7, or 7.2.4-8, where the quantities $\varphi_n$ and $v_m$ are given by

$$\varphi_n = e^{j\pi n/2}$$
$$v_m = \begin{bmatrix} 1 & e^{j2\pi n/32} & e^{j4\pi n/32} & e^{j6\pi n/32} \end{bmatrix}^{\mathrm{T}}$$

- as follows:For 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, a first PMI value of $i_1 \in \{0,1,\cdots,f(\upsilon)-1\}$ and a second PMI value of $i_2 \in \{0,1,\cdots,g(\upsilon)-1\}$ corresponds to the codebook indices $i_1$ and $i_2$ given in Table 7.2.4-$j$ with $\upsilon$ equal to the associated RI value and where $j = \upsilon$, $f(\upsilon) = \{16,16,4,4,4,4,4,1\}$ and $g(\upsilon) = \{16,16,16,8,1,1,1,1\}$.
- In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1D for first and second precoding matrix indicator $i_1$ and $i_2$. Joint encoding of rank and first precoding matrix indicator $i_1$ for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1F for PUCCH Reporting Type 1a.

**Table 7.2.4-1: Codebook for 1-layer CSI reporting using antenna ports 15 to 22**

| $i_1$ | $i_2$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| 0 – 15 | $W^{(1)}_{2i_1,0}$ | $W^{(1)}_{2i_1,1}$ | $W^{(1)}_{2i_1,2}$ | $W^{(1)}_{2i_1,3}$ | $W^{(1)}_{2i_1+1,0}$ | $W^{(1)}_{2i_1+1,1}$ | $W^{(1)}_{2i_1+1,2}$ | $W^{(1)}_{2i_1+1,3}$ |
| $i_1$ | $i_2$ | | | | | | | |
| | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| 0 - 15 | $W^{(1)}_{2i_1+2,0}$ | $W^{(1)}_{2i_1+2,1}$ | $W^{(1)}_{2i_1+2,2}$ | $W^{(1)}_{2i_1+2,3}$ | $W^{(1)}_{2i_1+3,0}$ | $W^{(1)}_{2i_1+3,1}$ | $W^{(1)}_{2i_1+3,2}$ | $W^{(1)}_{2i_1+3,3}$ |
| where $W^{(1)}_{m,n} = \frac{1}{\sqrt{8}} \begin{bmatrix} v_m \\ \varphi_n v_m \end{bmatrix}$ | | | | | | | | |

**Table 7.2.4-2: Codebook for 2-layer CSI reporting using antenna ports 15 to 22**

| $i_1$ | $i_2$ | | | |
|---|---|---|---|---|
| | **0** | **1** | **2** | **3** |
| 0 – 15 | $W^{(2)}_{2i_1,2i_1,0}$ | $W^{(2)}_{2i_1,2i_1,1}$ | $W^{(2)}_{2i_1+1,2i_1+1,0}$ | $W^{(2)}_{2i_1+1,2i_1+1,1}$ |
| $i_1$ | $i_2$ | | | |
| | **4** | **5** | **6** | **7** |
| 0 – 15 | $W^{(2)}_{2i_1+2,2i_1+2,0}$ | $W^{(2)}_{2i_1+2,2i_1+2,1}$ | $W^{(2)}_{2i_1+3,2i_1+3,0}$ | $W^{(2)}_{2i_1+3,2i_1+3,1}$ |
| $i_1$ | $i_2$ | | | |
| | **8** | **9** | **10** | **11** |
| 0 – 15 | $W^{(2)}_{2i_1,2i_1+1,0}$ | $W^{(2)}_{2i_1,2i_1+1,1}$ | $W^{(2)}_{2i_1+1,2i_1+2,0}$ | $W^{(2)}_{2i_1+1,2i_1+2,1}$ |
| $i_1$ | $i_2$ | | | |
| | **12** | **13** | **14** | **15** |
| 0 – 15 | $W^{(2)}_{2i_1,2i_1+3,0}$ | $W^{(2)}_{2i_1,2i_1+3,1}$ | $W^{(2)}_{2i_1+1,2i_1+3,0}$ | $W^{(2)}_{2i_1+1,2i_1+3,1}$ |
| where $W^{(2)}_{m,m',n} = \frac{1}{4}\begin{bmatrix} v_m & v_{m'} \\ \varphi_n v_m & -\varphi_n v_{m'} \end{bmatrix}$ | | | | |

**Table 7.2.4-3: Codebook for 3-layer CSI reporting using antenna ports 15 to 22**

| $i_1$ | $i_2$ | | | |
|---|---|---|---|---|
| | **0** | **1** | **2** | **3** |
| 0 - 3 | $W^{(3)}_{8i_1,8i_1,8i_1+8}$ | $W^{(3)}_{8i_1+8,8i_1,8i_1+8}$ | $\widetilde{W}^{(3)}_{8i_1,8i_1+8,8i_1+8}$ | $\widetilde{W}^{(3)}_{8i_1+8,8i_1,8i_1}$ |
| $i_1$ | $i_2$ | | | |
| | **4** | **5** | **6** | **7** |
| 0 - 3 | $W^{(3)}_{8i_1+2,8i_1+2,8i_1+10}$ | $W^{(3)}_{8i_1+10,8i_1+2,8i_1+10}$ | $\widetilde{W}^{(3)}_{8i_1+2,8i_1+10,8i_1+10}$ | $\widetilde{W}^{(3)}_{8i_1+10,8i_1+2,8i_1+2}$ |
| $i_1$ | $i_2$ | | | |
| | **8** | **9** | **10** | **11** |
| 0 - 3 | $W^{(3)}_{8i_1+4,8i_1+4,8i_1+12}$ | $W^{(3)}_{8i_1+12,8i_1+4,8i_1+12}$ | $\widetilde{W}^{(3)}_{8i_1+4,8i_1+12,8i_1+12}$ | $\widetilde{W}^{(3)}_{8i_1+12,8i_1+4,8i_1+4}$ |
| $i_1$ | $i_2$ | | | |
| | **12** | **13** | **14** | **15** |
| 0 - 3 | $W^{(3)}_{8i_1+6,8i_1+6,8i_1+14}$ | $W^{(3)}_{8i_1+14,8i_1+6,8i_1+14}$ | $\widetilde{W}^{(3)}_{8i_1+6,8i_1+14,8i_1+14}$ | $\widetilde{W}^{(3)}_{8i_1+14,8i_1+6,8i_1+6}$ |
| where $W^{(3)}_{m,m',m''} = \frac{1}{\sqrt{24}}\begin{bmatrix} v_m & v_{m'} & v_{m''} \\ v_m & -v_{m'} & -v_{m''} \end{bmatrix}$, $\widetilde{W}^{(3)}_{m,m',m''} = \frac{1}{\sqrt{24}}\begin{bmatrix} v_m & v_{m'} & v_{m''} \\ v_m & v_{m'} & -v_{m''} \end{bmatrix}$ | | | | |

**Table 7.2.4-4: Codebook for 4-layer CSI reporting using antenna ports 15 to 22**

| $i_1$ | $i_2$ | | | |
|---|---|---|---|---|
| | **0** | **1** | **2** | **3** |
| 0 - 3 | $W^{(4)}_{8i_1,8i_1+8,0}$ | $W^{(4)}_{8i_1,8i_1+8,1}$ | $W^{(4)}_{8i_1+2,8i_1+10,0}$ | $W^{(4)}_{8i_1+2,8i_1+10,1}$ |
| $i_1$ | $i_2$ | | | |
| | **4** | **5** | **6** | **7** |
| 0 - 3 | $W^{(4)}_{8i_1+4,8i_1+12,0}$ | $W^{(4)}_{8i_1+4,8i_1+12,1}$ | $W^{(4)}_{8i_1+6,8i_1+14,0}$ | $W^{(4)}_{8i_1+6,8i_1+14,1}$ |
| where $W^{(4)}_{m,m',n} = \frac{1}{\sqrt{32}}\begin{bmatrix} v_m & v_{m'} & v_m & v_{m'} \\ \varphi_n v_m & \varphi_n v_{m'} & -\varphi_n v_m & -\varphi_n v_{m'} \end{bmatrix}$ | | | | |

**Table 7.2.4-5: Codebook for 5-layer CSI reporting using antenna ports 15 to 22.**

| $i_1$ | $i_2$ |
|---|---|
| | **0** |
| 0 - 3 | $W_{i_1}^{(5)} = \frac{1}{\sqrt{40}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} \end{bmatrix}$ |

**Table 7.2.4-6: Codebook for 6-layer CSI reporting using antenna ports 15 to 22.**

| $i_1$ | $i_2$ |
|---|---|
| | **0** |
| 0 - 3 | $W_{i_1}^{(6)} = \frac{1}{\sqrt{48}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} \end{bmatrix}$ |

**Table 7.2.4-7: Codebook for 7-layer CSI reporting using antenna ports 15 to 22.**

| $i_1$ | $i_2$ |
|---|---|
| | **0** |
| 0 - 3 | $W_{i_1}^{(7)} = \frac{1}{\sqrt{56}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} & v_{2i_1+24} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} & v_{2i_1+24} \end{bmatrix}$ |

**Table 7.2.4-8: Codebook for 8-layer CSI reporting using antenna ports 15 to 22.**

| $i_1$ | $i_2$ |
|---|---|
| | **0** |
| 0 | $W_{i_1}^{(8)} = \frac{1}{8}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} & v_{2i_1+24} & v_{2i_1+24} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} & v_{2i_1+24} & -v_{2i_1+24} \end{bmatrix}$ |

## 7.2.5 Channel-State Information – Reference Signal (CSI-RS) definition

For a serving cell and UE configured in transmission mode 9, the UE can be configured with one CSI-RS resource configuration. For a serving cell and UE configured in transmission mode 10, the UE can be configured with one or more CSI-RS resource configuration(s). The following parameters for which the UE shall assume non-zero transmission power for CSI-RS are configured via higher layer signaling for each CSI-RS resource configuration:

- CSI-RS resource configuration identity, if the UE is configured in transmission mode 10,
- Number of CSI-RS ports. The allowable values and port mapping are given in subclause 6.10.5 of [3].
- CSI RS Configuration (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3])
- CSI RS subframe configuration $I_{\text{CSI-RS}}$. The allowable values are given in subclause 6.10.5.3 of [3].
- UE assumption on reference PDSCH transmitted power for CSI feedback $P_C$, if the UE is configured in transmission mode 9.
- UE assumption on reference PDSCH transmitted power for CSI feedback $P_C$ for each CSI process, if the UE is configured in transmission mode 10. If CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for a CSI process, $P_C$ is configured for each CSI subframe set of the CSI process.
- Pseudo-random sequence generator parameter, $n_{\text{ID}}$. The allowable values are given in [11].
- Higher layer parameter *qcl-CRS-Info-r11* for Quasi co-location type B UE assumption of CRS antenna ports and CSI-RS antenna ports with the following parameters, if the UE is configured in transmission mode 10:
  - *qcl-ScramblingIdentity-r11*.
  - *crs-PortsCount-r11*.
  - *mbsfn-SubframeConfigList-r11*.

$P_C$ is the assumed ratio of PDSCH EPRE to CSI-RS EPRE when UE derives CSI feedback and takes values in the range of [-8, 15] dB with 1 dB step size, where the PDSCH EPRE corresponds to the symbols for which the ratio of the PDSCH EPRE to the cell-specific RS EPRE is denoted by $\rho_A$, as specified in Table 5.2-2 and Table 5.2-3.

A UE should not expect the configuration of CSI-RS and PMCH in the same subframe of a serving cell.

For frame structure type 2 and 4 CRS ports, the UE is not expected to receive a CSI RS Configuration index (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3]) belonging to the set [20-31] for the normal CP case or the set [16-27] for the extended CP case.

A UE may assume the CSI-RS antenna ports of a CSI-RS resource configuration are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

A UE configured in transmission mode 10 and with quasi co-location type B, may assume the antenna ports 0 – 3 associated with *qcl-CRS-Info-r11* corresponding to a CSI-RS resource configuration and antenna ports 15 – 22 corresponding to the CSI-RS resource configuration are quasi co-located (as defined in [3]) with respect to Doppler shift, and Doppler spread.

### 7.2.6 Channel-State Information – Interference Measurement (CSI-IM) Resource definition

For a serving cell and UE configured in transmission mode 10, the UE can be configured with one or more CSI-IM resource configuration(s). The following parameters are configured via higher layer signaling for each CSI-IM resource configuration:

- Zero-power CSI RS Configuration (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3])
- Zero-power CSI RS subframe configuration $I_{\text{CSI-RS}}$. The allowable values are given in subclause 6.10.5.3 of [3].

A UE is not expected to receive CSI-IM resource configuration(s) that are not all completely overlapping with one zero-power CSI-RS resource configuration which can be configured for the UE. A UE is not expected to receive a CSI-IM resource configuration that is not completely overlapping with one of the zero-power CSI-RS resource configurations defined in subclause 7.2.7.

A UE should not expect the configuration of CSI-IM resource and PMCH in the same subframe of a serving cell.

### 7.2.7 Zero Power CSI-RS Resource definition

For a serving cell and UE configured in transmission mode 1-9, the UE can be configured with one zero-power CSI-RS resource configuration. For a serving cell and UE configured in transmission mode 10, the UE can be configured with one or more zero-power CSI-RS resource configuration(s).
The following parameters are configured via higher layer signaling for each zero-power CSI-RS resource configuration:

- Zero-power CSI RS Configuration list (16-bit bitmap *ZeroPowerCSI-RS* in [3])
- Zero-power CSI RS subframe configuration $I_{\text{CSI-RS}}$. The allowable values are given in subclause 6.10.5.3 of [3].

A UE should not expect the configuration of zero-power CSI-RS and PMCH in the same subframe of a serving cell.

For frame structure type 1, the UE is not expected to receive the 16-bit bitmap *ZeroPowerCSI-RS* with any one of the 6 LSB bits set to 1 for the normal CP case, or with any one of the 8 LSB bits set to 1 for the extended CP case.

For frame structure type 2 and 4 CRS ports, the UE is not expected to receive the 16-bit bitmap *ZeroPowerCSI-RS* with any one of the 6 LSB bits set to 1 for the normal CP case, or with any one of the 8 LSB bits set to 1 for the extended CP case.

# 7.3 UE procedure for reporting HARQ-ACK

The UE procedure for HARQ-ACK reporting for frame structure type 1 is given in subclause 7.3.1.

The UE procedure for HARQ-ACK reporting for frame structure type 2 is given in subclause 7.3.2.

## 7.3.1 FDD HARQ-ACK reporting procedure

For FDD with PUCCH format 1a/1b transmission, when both HARQ-ACK and SR are transmitted in the same sub-frame, a UE shall transmit the HARQ-ACK on its assigned HARQ-ACK PUCCH format 1a/1b resource for a negative SR transmission and transmit the HARQ-ACK on its assigned SR PUCCH resource for a positive SR transmission.

For FDD with PUCCH format 1b with channel selection, when both HARQ-ACK and SR are transmitted in the same sub-frame a UE shall transmit the HARQ-ACK on its assigned HARQ-ACK PUCCH resource with channel selection as defined in subclause 10.1.2.2.1 for a negative SR transmission and transmit one HARQ-ACK bit per serving cell on its assigned SR PUCCH resource for a positive SR transmission according to the following:

- if only one transport block or a PDCCH/EPDCCH indicating downlink SPS release is detected on a serving cell, the HARQ-ACK bit for the serving cell is the HARQ-ACK bit corresponding to the transport block or the PDCCH/EPDCCH indicating downlink SPS release;
- if two transport blocks are received on a serving cell, the HARQ-ACK bit for the serving cell is generated by spatially bundling the HARQ-ACK bits corresponding to the transport blocks;
- if neither PDSCH transmission for which HARQ-ACK response shall be provided nor PDCCH/EPDCCH indicating downlink SPS release is detected for a serving cell, the HARQ-ACK bit for the serving cell is set to NACK;

and the HARQ-ACK bits for the primary cell and the secondary cell are mapped to $b(0)$ and $b(1)$, respectively, where $b(0)$ and $b(1)$ are specified in subclause 5.4.1 in [3].

For FDD, when a PUCCH format 3 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in subclause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to a PDSCH transmission on the primary cell only or a PDCCH/EPDCCH indicating downlink SPS release on the primary cell only, in which case the SR shall be transmitted as for FDD with PUCCH format 1a/1b.

For FDD and for a PUSCH transmission, a UE shall not transmit HARQ-ACK on PUSCH in subframe *n* if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe *n-4*.

When only a positive SR is transmitted, a UE shall use PUCCH Format 1 for the SR resource as defined in subclause 5.4.1 in [3].

## 7.3.2 TDD HARQ-ACK reporting procedure

For TDD, if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, UE procedure for reporting HARQ-ACK is given in subclause 7.3.2.1.

For TDD, if a UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, UE procedure for reporting HARQ-ACK is given in subclause 7.3.2.2.

When only a positive SR is transmitted, a UE shall use PUCCH Format 1 for the SR resource as defined in subclause 5.4.1 in [3].

### 7.3.2.1 TDD HARQ-ACK reporting procedure for same UL/DL configuration

For TDD, the UE shall upon detection of a PDSCH transmission or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$ and $K$ is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*.

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK, for special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in a serving cell, shown in table 4.2-1 [3], the special subframe of the serving cell is excluded from the HARQ-ACK codebook size determination. In this case, if the serving cell is the primary cell, there is no PDCCH/EPDCCH indicating downlink SPS release in the special subframe.

For TDD UL/DL configurations 1-6 and one configured serving cell, if the UE is not configured with PUCCH format 3, the value of the Downlink Assignment Index (DAI) in DCI format 0/4, $V_{DAI}^{UL}$, detected by the UE according to Table 7.3-X in subframe $n-k'$, where $k'$ is defined in Table 7.3-Y, represents the total number of subframes with PDSCH transmissions and with PDCCH/EPDCCH indicating downlink SPS release to the corresponding UE within all the subframe(s) $n-k$, where $k \in K$. The value $V_{DAI}^{UL}$ includes all PDSCH transmission with and without corresponding PDCCH/EPDCCH within all the subframe(s) $n-k$. In case neither PDSCH transmission, nor PDCCH/EPDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of the DAI in DCI format 0/4, $V_{DAI}^{UL}$, if transmitted, is set to 4.

For TDD UL/DL configuration 1-6 and a UE configured with more than one serving cell, or for TDD UL/DL configuration 1-6 and a UE configured with one serving cell and PUCCH format 3, a value $W_{DAI}^{UL}$ is determined by the Downlink Assignment Index (DAI) in DCI format 0/4 according to Table 7.3-Z in subframe $n-k'$, where $k'$ is defined in Table 7.3-Y. In case neither PDSCH transmission, nor PDCCH/EPDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of $W_{DAI}^{UL}$ is set to 4 by the DAI in DCI format 0/4 if transmitted.

For TDD UL/DL configurations 1-6, the value of the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release up to the present subframe within subframe(s) $n-k$ of each configured serving cell, where $k \in K$, and shall be updated from subframe to subframe. Denote $V_{DAI,c}^{DL}$ as the value of the DAI in PDCCH/EPDCCH with DCI format 1/1A/1B/1D/2/2A/2B/2C/2D detected by the UE according to Table 7.3-X in subframe $n-k_m$ in serving cell $c$, where $k_m$ is the smallest value in the set $K$ (defined in Table 10.1.3.1-1) such that the UE detects a DCI format 1/1A/1B/1D/2/2A/2B/2C/2D. When configured with one serving cell, the subscript of $c$ in $V_{DAI,c}^{DL}$ can be omitted.

For all TDD UL/DL configurations, denote $U_{DAI,c}$ as the total number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release detected by the UE within the subframe(s) $n-k$ in serving cell $c$, where $k \in K$. When configured with one serving cell, the subscript of $c$ in $U_{DAI,c}$ can be omitted. Denote $N_{SPS}$, which can be zero or one, as the number of PDSCH transmissions without a corresponding PDCCH/EPDCCH within the subframe(s) $n-k$, where $k \in K$.

For TDD HARQ-ACK bundling or HARQ-ACK multiplexing and a subframe $n$ with $M=1$, the UE shall generate one or two HARQ-ACK bits by performing a logical AND operation per codeword across $M$ DL subframes associated with a single UL subframe, of all the corresponding $U_{DAI}+N_{SPS}$ individual PDSCH transmission HARQ-ACKs and individual ACK in response to received PDCCH/EPDCCH indicating downlink SPS release, where $M$ is the number of elements in the set $K$ defined in Table 10.1.3.1-1. The UE shall detect if at least one downlink assignment has been missed, and for the case that the UE is transmitting on PUSCH the UE shall also determine the parameter $N_{\text{bundled}}$.

- For TDD UL/DL configuration 0, $N_{\text{bundled}}$ shall be 1 if the UE detects the PDSCH transmission with or without corresponding PDCCH/EPDCCH, or detects PDCCH indicating downlink SPS release within the subframe $n-k$, where $k \in K$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release within the subframe(s) $n-k$, where $k \in K$.
- For the case that the UE is not transmitting on PUSCH in subframe *n* and TDD UL/DL configurations 1-6, if $U_{DAI}>0$ and $V_{DAI}^{DL} \neq (U_{DAI}-1) \bmod 4+1$, the UE detects that at least one downlink assignment has been missed.

- For the case that the UE is transmitting on PUSCH and the PUSCH transmission is adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE and TDD UL/DL configurations 1-6, if $V_{DAI}^{UL} \neq (U_{DAI} + N_{SPS} - 1) \bmod 4 + 1$ the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords where $N_{\text{bundled}}$ is determined by the UE as $N_{\text{bundled}} = V_{DAI}^{UL} + 2$. If the UE does not detect any downlink assignment missing, $N_{\text{bundled}}$ is determined by the UE as $N_{\text{bundled}} = V_{DAI}^{UL}$. UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$ and $V_{DAI}^{UL} = 4$.

- For the case that the UE is transmitting on PUSCH, and the PUSCH transmission is not based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE and TDD UL/DL configurations 1-6, if $U_{DAI} > 0$ and $V_{DAI}^{DL} \neq (U_{DAI} - 1) \bmod 4 + 1$, the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords. The UE determines $N_{\text{bundled}} = (U_{DAI} + N_{SPS})$ as the number of assigned subframes. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$.

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK, the HARQ-ACK feedback bits $o_{c,0}^{ACK}\ o_{c,1}^{ACK},...,o_{c,O_c^{ACK}-1}^{ACK}$ for the *c*-th serving cell configured by RRC are constructed as follows, where $c \geq 0$, $O_c^{ACK} = B_c^{DL}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied and $O_c^{ACK} = 2B_c^{DL}$ otherwise, where $B_c^{DL}$ is the number of downlink subframes for which the UE needs to feedback HARQ-ACK bits for the *c*-th serving cell.

- For the case that the UE is transmitting on PUCCH, $B_c^{DL} = M$ where $M$ is the number of elements in the set $K$ defined in Table 10.1.3.1-1 associated with subframe *n* and the set $K$ does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL} = M - 1$.

- For TDD UL/DL configuration 0 or for a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL} = M$ where $M$ is the number of elements in the set $K$ defined in Table 10.1.3.1-1 associated with subframe *n* and the set $K$ does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL} = M - 1$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$, where $k \in K$.

- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL} = W_{DAI}^{UL}$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

- For TDD UL/DL configurations 5 and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL} = W_{DAI}^{UL} + 4\left\lceil \left(U - W_{DAI}^{UL}\right)/4 \right\rceil$, where $U$ denotes the maximum value of $U_c$ among all the configured serving cells, $U_c$ is the total number of received PDSCHs and PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ on the *c*-th serving cell, $k \in K$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK,

- for TDD UL/DL configurations 1-6, the HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,DAI(k)-1}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$

otherwise, where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$, $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. For the case with $N_{SPS}>0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to $o_{c,O_c^{ACK}-1}^{ACK}$ The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK;

- for TDD UL/DL configuration 0, the HARQ-ACK for a PDSCH transmission or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,0}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or associated with $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ otherwise, where $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK.

For TDD when format 1b with channel selection is configured for transmission of HARQ-ACK and for 2 configured serving cells, the HARQ-ACK feedback bits $o_0^{ACK}$ $o_1^{ACK}$,...,$o_{O^{ACK}-1}^{ACK}$ on PUSCH are constructed as follows.

- For TDD UL/DL configuration 0, $o_j^{ACK}$ = HARQ-ACK($j$), $0 \le j \le A-1$ as defined in subclause 10.1.3.2.1. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.
- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with $W_{DAI}^{UL}$=1 or 2, $o_j^{ACK}$ is determined as if PUCCH format 3 is configured for transmission of HARQ-ACK, except that spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed for all serving cells configured with a downlink transmission mode that supports up to two transport blocks in case $W_{DAI}^{UL}$=2.
- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with $W_{DAI}^{UL}$=3 or 4, $o_j^{ACK}=o(j)$, $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the value of $M$ is replaced by $W_{DAI}^{UL}$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL}=4$.
- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 and a subframe $n$ with $M$=1 or 2, $o_j^{ACK}$ = HARQ-ACK($j$), $0 \le j \le A-1$ as defined in subclause 10.1.3.2.1. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.
- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 and a subframe $n$ with $M$=3 or 4, $o_j^{ACK}=o(j)$, $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

For TDD HARQ-ACK bundling, when the UE is configured by transmission mode 3, 4, 8, 9 or 10 defined in subclause 7.1 and HARQ-ACK bits are transmitted on PUSCH, the UE shall always generate 2 HARQ-ACK bits assuming both codeword 0 and 1 are enabled. For the case that the UE detects only the PDSCH transmission associated with codeword 0 within the bundled subframes, the UE shall generate NACK for codeword 1.

**Table 7.3-X: Value of Downlink Assignment Index**

| DAI MSB, LSB | $V_{DAI}^{UL}$ or $V_{DAI}^{DL}$ | Number of subframes with PDSCH transmission and with PDCCH/EPDCCH indicating DL SPS release |
|---|---|---|
| 0,0 | 1 | 1 or 5 or 9 |
| 0,1 | 2 | 2 or 6 |
| 1,0 | 3 | 3 or 7 |
| 1,1 | 4 | 0 or 4 or 8 |

**Table 7.3-Y: Uplink association index *k*' for TDD**

| TDD UL/DL Configuration | subframe number *n* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | | | 6 | 4 | | | | 6 | 4 | |
| 2 | | | 4 | | | | | 4 | | |
| 3 | | | 4 | 4 | 4 | | | | | |
| 4 | | | 4 | 4 | | | | | | |
| 5 | | | 4 | | | | | | | |
| 6 | | | 7 | 7 | 5 | | | 7 | 7 | |

**Table 7.3-Z: Value of $W_{DAI}^{UL}$ determined by the DAI field in DCI format 0/4**

| DAI MSB, LSB | $W_{DAI}^{UL}$ |
|---|---|
| 0,0 | 1 |
| 0,1 | 2 |
| 1,0 | 3 |
| 1,1 | 4 |

For TDD HARQ-ACK multiplexing and a subframe $n$ with $M > 1$, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. In case the UE is transmitting on PUSCH, the UE shall determine the number of HARQ-ACK feedback bits $O^{ACK}$ and the HARQ-ACK feedback bits $o_n^{ACK}$ , $n = 0, \ldots, O^{ACK} - 1$ to be transmitted in subframe *n*.

- If the PUSCH transmission is adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE, then $O^{ACK} = V_{DAI}^{UL}$ unless $V_{DAI}^{UL} = 4$ and $U_{DAI} + N_{SPS} = 0$ in which case the UE shall not transmit HARQ-ACK. The spatially bundled HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{DAI(k)-1}^{ACK}$ where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to $o_{O^{ACK}-1}^{ACK}$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK.
- If the PUSCH transmission is not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE, $O^{ACK} = M$ , and $o_i^{ACK}$ is associated with the spatially bundled HARQ-ACK for DL subframe $n-k_i$ , where $k_i \in K$ . The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$ .

For TDD when a PUCCH format 3 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in subclause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to one of the following cases

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1', or

- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, or

- a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in the subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1',

in which case the UE shall transmit the HARQ-ACK and scheduling request according to the procedure for PUCCH format 1b with channel selection in TDD.

For TDD when the UE is configured with HARQ-ACK bundling, HARQ-ACK multiplexing or PUCCH format 1b with channel selection, and when both HARQ-ACK and SR are transmitted in the same sub-frame, a UE shall transmit the bundled HARQ-ACK or the multiple HARQ-ACK responses (according to subclause 10.1) on its assigned HARQ-ACK PUCCH resources for a negative SR transmission. For a positive SR, the UE shall transmit $b(0),b(1)$ on its assigned SR PUCCH resource using PUCCH format 1b according to subclause 5.4.1 in [3]. The value of $b(0),b(1)$ are generated according to Table 7.3-1 from the $N_{SPS}+\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH/EPDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells $N_{cells}^{DL}$. For TDD UL/DL configurations 1-6, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq \left(U_{DAI,c}-1\right) \bmod 4+1$ for a serving cell c, the UE detects that at least one downlink assignment has been missed.

**Table 7.3-1: Mapping between multiple HARQ-ACK responses and $b(0),b(1)$**

| Number of ACK among multiple ( $N_{SPS}+\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ ) HARQ-ACK responses | $b(0),b(1)$ |
|---|---|
| 0 or None (UE detect at least one DL assignment is missed) | 0, 0 |
| 1 | 1, 1 |
| 2 | 1, 0 |
| 3 | 0, 1 |
| 4 | 1, 1 |
| 5 | 1, 0 |
| 6 | 0, 1 |
| 7 | 1, 1 |
| 8 | 1, 0 |
| 9 | 0, 1 |

For TDD if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE,* and if the UE is configured with HARQ-ACK bundling, HARQ-ACK multiplexing or PUCCH format 1b with channel selection, and if the UE receives PDSCH and/or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell within subframe(s) $n-k$, where $k \in K$, a UE shall transmit the CSI and $b(0),b(1)$ using PUCCH format 2b for normal CP

or PUCCH format 2 for extended CP, according to subclause 5.2.3.4 in [4] with $a_0'', a_1''$ replaced by $b(0), b(1)$. The value of $b(0), b(1)$ are generated according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH/EPDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells $N_{cells}^{DL}$. For TDD UL/DL configurations 1-6, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq (U_{DAI,c} - 1) \bmod 4 + 1$ for a serving cell c, the UE detects that at least one downlink assignment has been missed.

For TDD if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE,* and if the UE is configured with PUCCH format 1b with channel selection and receives at least one PDSCH on the secondary cell within subframe(s) $n-k$, where $k \in K$, the UE shall drop the CSI and transmit HARQ-ACK according to subclause 10.1.3.

For TDD and a UE is configured with PUCCH format 3,

if the parameter *simultaneousAckNackAndCQI* is set *TRUE* and if the UE receives,

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1', or
- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$,

then the UE shall transmit the CSI and HARQ-ACK using PUCCH format 2/2a/2b according to subclause 5.2.3.4 in [4];
else if

- the parameter *simultaneousAckNackAndCQI-Format3-r11* is set *TRUE* and if PUCCH format 3 resource is determined according to subclause 10.1.3.1 or subclause 10.1.3.2.2 and
  - if the total number of bits in the subframe corresponding to HARQ-ACKs, SR (if any), and the CSI is not larger than 22, or
  - if the total number of bits in the subframe corresponding to spatially bundled HARQ-ACKs, SR (if any), and the CSI is not larger than 22

then the UE shall transmit the HARQ-ACKs, SR (if any) and the CSI using the determined PUCCH format 3 resource according to [4];

else,

the UE shall drop the CSI and transmit the HARQ-ACK according to subclause 10.1.3.

### 7.3.2.2 TDD HARQ-ACK reporting procedure for different UL/DL configurations

For a configured serving cell, the DL-reference UL/DL configuration as defined in subclause 10.2 is referred to as the "DL-reference UL/DL configuration" in the rest of this subclause.

For a configured serving cell, if the DL-reference UL/DL configuration is 0, then the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D is not used.

The UE shall upon detection of a PDSCH transmission or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$ for serving cell *c*, where $k \in K_c$ intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*, wherein set

$K_c$ contains values of $k \in K$ such that subframe *n*-*k* corresponds to a DL subframe or a special subframe for serving cell *c*, $K$ defined in Table 10.1.3.1-1 (where "UL/DL configuration" in Table 10.1.3.1-1 refers to the DL-reference UL/DL configuration) is associated with subframe *n*. $M_c$ is the number of elements in set $K_c$ associated with subframe *n* for serving cell *c*,

For the remainder of this subclause $K = K_c$.

When PUCCH format 3 is configured for transmission of HARQ-ACK, for special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in a serving cell, shown in table 4.2-1 [3], the special subframe of the serving cell is excluded from the HARQ-ACK codebook size determination. In this case, if the serving cell is the primary cell, there is no PDCCH/EPDCCH indicating downlink SPS release in the special subframe.

If the UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1,2,3,4,5,6} for a serving cell, a value $W_{DAI}^{UL}$ is determined by the Downlink Assignment Index (DAI) in DCI format 0/4 corresponding to a PUSCH on the serving cell according to Table 7.3-Z in subframe $n-k'$, where $k'$ is defined in Table 7.3-Y and the "TDD UL/DL Configuration" in Table 7.3-Y refers to the UL-reference UL/DL configuration (defined in subclause 8.0) for the serving cell. In case neither PDSCH transmission, nor PDCCH/EPDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of $W_{DAI}^{UL}$ is set to 4 by the DAI in DCI format 0/4 if transmitted.

If the DL-reference UL/DL configuration belongs to {1,2,3,4,5,6}, the value of the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release up to the present subframe within subframe(s) $n-k$ of each configured serving cell, where $k \in K$, and shall be updated from subframe to subframe. Denote $V_{DAI,c}^{DL}$ as the value of the DAI in PDCCH/EPDCCH with DCI format 1/1A/1B/1D/2/2A/2B/2C/2D detected by the UE according to Table 7.3-X in subframe $n-k_m$ in serving cell $c$, where $k_m$ is the smallest value in the set $K$ such that the UE detects a DCI format 1/1A/1B/1D/2/2A/2B/2C/2D.

For all TDD UL/DL configurations, denote $U_{DAI,c}$ as the total number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release detected by the UE within the subframe(s) $n-k$ in serving cell $c$, where $k \in K$. Denote $N_{SPS}$, which can be zero or one, as the number of PDSCH transmissions without a corresponding PDCCH/EPDCCH within the subframe(s) $n-k$, where $k \in K$.

If PUCCH format 3 is configured for transmission of HARQ-ACK, the HARQ-ACK feedback bits $o_{c,0}^{ACK}\ o_{c,1}^{ACK},...,o_{c,O_c^{ACK}-1}^{ACK}$ for the *c*-th serving cell configured by RRC are constructed as follows, where $c \geq 0$,

$O_c^{ACK} = B_c^{DL}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied and $O_c^{ACK} = 2B_c^{DL}$ otherwise, where $B_c^{DL}$ is the number of downlink subframes for which the UE needs to feedback HARQ-ACK bits for the *c*-th serving cell.

- For the case that the UE is transmitting in subframe *n* on PUCCH or a PUSCH transmission not adjusted based on a detected DCI format 0/4 or a PUSCH transmission adjusted based on an associated detected DCI format 0/4 with UL-reference UL/DL configuration 0 (defined in Sec 8.0), then $B_c^{DL} = M_c$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$, where $k \in K$.

- If DL-reference UL/DL configuration of each of the configured serving cells belongs to {0, 1, 2, 3, 4, 6} and for a PUSCH transmission in a subframe *n* adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 using UL-reference UL/DL configuration belonging to {1,2,3,4,5,6} (defined in Sec 8.0), the UE shall assume $B_c^{DL} = \min\left(W_{DAI}^{UL}, M_c\right)$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

- If DL-reference UL/DL configuration of at least one configured serving cell belongs to {5} and for a PUSCH transmission adjusted based on an associated detected PDCCH/EPDCCH with DCI format 0/4 using UL-

reference UL/DL configuration belonging to {1,2,3,4,5,6} (defined in Sec 8.0), the UE shall assume $B_c^{DL} = \min\left(W_{DAI}^{UL} + 4\left\lfloor \left(U - W_{DAI}^{UL}\right)/4 \right\rfloor, M_c\right)$, where $U$ denotes the maximum value of $U_c$ among all the configured serving cells, $U_c$ is the total number of received PDSCHs and PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ for the *c*-th serving cell, $k \in K$ . The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

When PUCCH format 3 is configured for transmission of HARQ-ACK,

- if DL-reference UL/DL configuration belongs to {1,2,3,4,5,6}, the HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,DAI(k)-1}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ otherwise, where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$ , $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. For the case with $N_{SPS} > 0$ , the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to $o_{c,O_c^{ACK}-1}^{ACK}$ The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK;
- if DL-reference UL/DL configuration is 0, the HARQ-ACK for a PDSCH transmission or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,0}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ otherwise, where $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK.

If DL-reference UL/DL configuration of each of the serving cells belongs to {0,1,2,3,4,6} and if PUCCH format 1b with channel selection is configured for transmission of HARQ-ACK and for two configured serving cells, the HARQ-ACK feedback bits $o_0^{ACK}$ $o_1^{ACK}$ ,..., $o_{O^{ACK}-1}^{ACK}$ on PUSCH are constructed as follows

- if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6}, for a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with $W_{DAI}^{UL}$=1 or 2, $o_j^{ACK}$ is determined as if PUCCH format 3 is configured for transmission of HARQ-ACK, except that spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed for all serving cells configured with a downlink transmission mode that supports up to two transport blocks in case $W_{DAI}^{UL}$=2, where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission.
- if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6}, for a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with $W_{DAI}^{UL}$=3 or 4, $o_j^{ACK} = o(j)$ , $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the value of $M$ is replaced by $W_{DAI}^{UL}$ where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.
- if UL-reference UL/DL configuration (defined in Sec 8.0) is 0, or if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6}, for a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, for a subframe $n$ with $M$ =1 or 2 ( $M$ defined in Sec 10.1.3.2.1),

$o_j^{ACK}$ = HARQ-ACK($j$), $0 \le j \le A-1$ as defined in subclause 10.1.3.2.1, where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

- if UL-reference UL/DL configuration (defined in Sec 8.0) is 0, or if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6} and, for a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, for a subframe $n$ with $M$ =3 or 4 ($M$ defined in Sec 10.1.3.2.1), $o_j^{ACK} = o(j)$, $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

When a PUCCH format 3 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in subclause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to one of the following cases

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6}, the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH/EPDCCH is equal to '1', or
- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, or
- a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in the subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1',

in which case the UE shall transmit the HARQ-ACK and scheduling request according to the procedure for PUCCH format 1b with channel selection in TDD.

If the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE,* and if the UE is configured with PUCCH format 1b with channel selection, and if the UE receives PDSCH and/or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell within subframe(s) $n-k$, where $k \in K$, a UE shall transmit the CSI and $b(0),b(1)$ using PUCCH format 2b for normal CP or PUCCH format 2 for extended CP, according to subclause 5.2.3.4 in [4] with $a_0'', a_1''$ replaced by $b(0),b(1)$. The value of $b(0),b(1)$ are generated according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH/EPDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells $N_{cells}^{DL}$. If DL-reference UL/DL configuration belongs to {1,2,3,4,5,6} and, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq \left(U_{DAI,c}-1\right) \bmod 4 + 1$ for a serving cell c, the UE detects that at least one downlink assignment has been missed.

If the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE,* and if the UE is configured with PUCCH format 1b with channel selection and receives at least one PDSCH on the secondary cell within subframe(s) $n-k$, where $k \in K$, the UE shall drop the CSI and transmit HARQ-ACK according to subclause 10.1.3.

When both HARQ-ACK and CSI are configured to be transmitted in the same sub-frame and if a UE is configured with PUCCH format 3,

if the parameter *simultaneousAckNackAndCQI* is set *TRUE* and if the UE receives

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH/EPDCCH is equal to '1', or
- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$,

then the UE shall transmit the CSI and HARQ-ACK using PUCCH format 2/2a/2b according to subclause 5.2.3.4 in [4];

else if

- the parameter *simultaneousAckNackAndCQI-Format3-r11* is set *TRUE* and if PUCCH format 3 resource is determined according to subclause 10.1.3.1 or subclause 10.1.3.2.2 and
    - if the total number of bits in the subframe corresponding to HARQ-ACKs, SR (if any), and the CSI is not larger than 22, or
    - if the total number of bits in the subframe corresponding to spatially bundled HARQ-ACKs, SR (if any), and the CSI is not larger than 22

then the UE shall transmit the HARQ-ACKs, SR (if any) and the CSI using the determined PUCCH format 3 resource according to [4];

else,

the UE shall drop the CSI and transmit the HARQ-ACK according to subclause 10.1.3.

# 8 Physical uplink shared channel related procedures

For FDD and transmission mode 1, there shall be 8 uplink HARQ processes per serving cell for non-subframe bundling operation, i.e. normal HARQ operation, and 4 uplink HARQ processes for subframe bundling operation. For FDD and transmission mode 2, there shall be 16 uplink HARQ processes per serving cell for non-subframe bundling operation and there are two HARQ processes associated with a given subframe as described in [8]. The subframe bundling operation is configured by the parameter *ttiBundling* provided by higher layers.

In case higher layers configure the use of subframe bundling for FDD and TDD, the subframe bundling operation is only applied to UL-SCH, such that four consecutive uplink subframes are used.

## 8.0 UE procedure for transmitting the physical uplink shared channel

For FDD and normal HARQ operation, the UE shall upon detection on a given serving cell of a PDCCH/EPDCCH with DCI format 0/4 and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+4* according to the PDCCH/EPDCCH and PHICH information.

For normal HARQ operation, if the UE detects a PHICH transmission and if the most recent PUSCH transmission for the same transport block was using spatial multiplexing according to subclause 8.0.2 and the UE does not detect a PDCCH/EPDCCH with DCI format 4 in subframe *n* intended for the UE, the UE shall adjust the corresponding PUSCH retransmission in the associated subframe according to the PHICH information, and using the number of transmission layers and precoding matrix according to the most recent PDCCH/EPDCCH, if the number of negatively acknowledged transport blocks is equal to the number of transport blocks indicated in the most recent PDCCH/EPDCCH associated with the corresponding PUSCH.

For normal HARQ operation, if the UE detects a PHICH transmission and if the most recent PUSCH transmission for the same transport block was using spatial multiplexing according to subclause 8.0.2 and the UE does not detect a PDCCH/EPDCCH with DCI format 4 in subframe *n* intended for the UE, and if the number of negatively acknowledged transport blocks is not equal to the number of transport blocks indicated in the most recent PDCCH/EPDCCH associated with the corresponding PUSCH then the UE shall adjust the corresponding PUSCH retransmission in the associated subframe according to the PHICH information, using the precoding matrix with codebook index 0 and the number of transmission layers equal to number of layers corresponding to the negatively acknowledged transport block from the most recent PDCCH/EPDCCH. In this case, the UL DMRS resources are calculated according to the cyclic shift field for DMRS [3] in the most recent PDCCH/EPDCCH with DCI format 4 associated with the corresponding PUSCH transmission and number of layers corresponding to the negatively acknowledged transport block.

If a UE is configured with the carrier indicator field for a given serving cell, the UE shall use the carrier indicator field value from the detected PDCCH/EPDCCH with uplink DCI format to determine the serving cell for the corresponding PUSCH transmission.

For FDD and normal HARQ operation, if a PDCCH/EPDCCH with CSI request field set to trigger an aperiodic CSI report, as described in subclause 7.2.1, is detected by a UE on subframe *n,* then on subframe *n+4* UCI is mapped on the corresponding PUSCH transmission, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

For TDD, if a UE is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different, if the serving cell is a primary cell or if the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, the serving cell UL/DL configuration is the UL-reference UL/DL configuration.

For TDD, if a UE is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different and if the serving cell is a secondary cell and if the UE is configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, then for the serving cell, the UL reference UL/DL configuration is given in Table 8-0A corresponding to the pair formed by (other serving cell UL/DL configuration, serving cell UL/DL configuration).

**Table 8-0A: UL-reference UL/DL Configuration for serving cell based on the pair formed by (other serving cell UL/DL configuration, serving cell UL/DL configuration)**

| Set # | (other serving cell UL/DL configuration, serving cell UL/DL configuration) | UL-reference UL/DL configuration |
|---|---|---|
| Set 1 | (1,1),(1,2),(1,4),(1,5) | 1 |
| | (2,2),(2,5) | 2 |
| | (3,3),(3,4),(3,5) | 3 |
| | (4,4),(4,5) | 4 |
| | (5,5) | 5 |
| Set 2 | (1,0),(2,0),(3,0),(4,0),(5,0) | 0 |
| | (2,1),(4,1),(5,1) | 1 |
| | (5,2) | 2 |
| | (4,3),(5,3) | 3 |
| | (5,4) | 4 |
| | (1,6),(2,6),(3,6),(4,6),(5,6) | 6 |
| Set 3 | (3,1) | 1 |
| | (3,2),(4,2) | 2 |
| | (1,3),(2,3) | 3 |
| | (2,4) | 4 |
| Set 4 | (0,0),(6,0) | 0 |
| | (0,1),(0,2),(0,4),(0,5),(6,1),(6,2),(6,5) | 1 |
| | (0,3),(6,3) | 3 |
| | (6,4) | 4 |
| | (0,6),(6,6) | 6 |

For TDD and normal HARQ operation, if a PDCCH/EPDCCH with CSI request field set to trigger an aperiodic CSI report, as described in subclause 7.2.1, is detected by a UE on subframe *n*, then on subframe *n+k* UCI is mapped on the corresponding PUSCH transmission where *k* is given by Table 8-2, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

For FDD and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission in subframe *n-5* intended for the UE, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+4* according to the PDCCH/EPDCCH and PHICH information.

For FDD and TDD, the NDI as signalled on PDCCH/EPDCCH, the RV as determined in subclause 8.6.1, and the TBS as determined in subclause 8.6.2, shall be delivered to higher layers.

For TDD and transmission mode 1, the number of HARQ processes per serving cell shall be determined by the DL/UL configuration (Table 4.2-2 of [3]), as indicated in Table 8-1. For TDD and transmission mode 2, the number of HARQ processes per serving cell for non-subframe bundling operation shall be twice the number determined by the DL/UL configuration (Table 4.2-2 of [3]) as indicated in Table 8-1 and there are two HARQ processes associated with a given subframe as described in [8].

**Table 8-1: Number of synchronous UL HARQ processes for TDD**

| TDD UL/DL configuration | Number of HARQ processes for normal HARQ operation | Number of HARQ processes for subframe bundling operation |
|---|---|---|
| 0 | 7 | 3 |
| 1 | 4 | 2 |
| 2 | 2 | N/A |
| 3 | 3 | N/A |
| 4 | 2 | N/A |
| 5 | 1 | N/A |
| 6 | 6 | 3 |

For TDD, if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same,

- For TDD UL/DL configurations 1-6 and normal HARQ operation, the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE,

adjust the corresponding PUSCH transmission in subframe $n+k$, with $k$ given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information.

- For TDD UL/DL configuration 0 and normal HARQ operation the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe $n$ intended for the UE, adjust the corresponding PUSCH transmission in subframe $n+k$ if the MSB of the UL index in the PDCCH/EPDCCH with uplink DCI format is set to 1 or PHICH is received in subframe $n$=0 or 5 in the resource corresponding to $I_{PHICH} = 0$, as defined in subclause 9.1.2, with $k$ given in Table 8-2. If, for TDD UL/DL configuration 0 and normal HARQ operation, the LSB of the UL index in the DCI format 0/4 is set to 1 in subframe $n$ or a PHICH is received in subframe $n$=0 or 5 in the resource corresponding to $I_{PHICH} = 1$, as defined in subclause 9.1.2, or PHICH is received in subframe $n$=1 or 6, the UE shall adjust the corresponding PUSCH transmission in subframe $n+7$. If, for TDD UL/DL configuration 0, both the MSB and LSB of the UL index in the PDCCH/EPDCCH with uplink DCI format are set in subframe $n$, the UE shall adjust the corresponding PUSCH transmission in both subframes $n+k$ and $n+7$, with $k$ given in Table 8-2.

For TDD, if a UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same,

- For a serving cell with an UL-reference UL/DL configurations belonging to {1,2,3,4,5,6} and normal HARQ operation, the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe $n$ intended for the UE, adjust the corresponding PUSCH transmission in subframe $n+k$ for the serving cell, with $k$ given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information, where the "TDD UL/DL Configuration" given in Table 8-2 refers to the UL-reference UL/DL configuration.

- For a serving cell with UL-reference UL/DL configuration 0 and normal HARQ operation the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe $n$ intended for the UE, adjust the corresponding PUSCH transmission in subframe $n+k$ for the serving cell if the MSB of the UL index in the PDCCH/EPDCCH with uplink DCI format is set to 1 or PHICH is received in subframe $n$=0 or 5 in the resource corresponding to $I_{PHICH} = 0$, as defined in subclause 9.1.2, with $k$ given in Table 8-2. If, for a serving cell with UL-reference UL/DL configuration 0 and normal HARQ operation, the LSB of the UL index in the DCI format 0/4 is set to 1 in subframe $n$ or a PHICH is received in subframe $n$=0 or 5 in the resource corresponding to $I_{PHICH} = 1$, as defined in subclause 9.1.2, or PHICH is received in subframe $n$=1 or 6, the UE shall adjust the corresponding PUSCH transmission in subframe $n+7$ for the serving cell. If, for a serving cell with UL-reference UL/DL configuration 0, both the MSB and LSB of the UL index in the PDCCH/EPDCCH with uplink DCI format are set in subframe $n$, the UE shall adjust the corresponding PUSCH transmission in both subframes $n+k$ and $n+7$ for the serving cell, with $k$ given in Table 8-2, where the TDD UL/DL Configuration" given in Table 8-2 refers to the UL-reference UL/DL configuration.

For TDD UL/DL configurations 1 and 6 and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe $n$ intended for the UE, and/or a PHICH transmission intended for the UE in subframe $n-l$ with $l$ given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe $n+k$, with $k$ given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information.

For TDD UL/DL configuration 0 and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe $n$ intended for the UE, and/or a PHICH transmission intended for the UE in subframe $n-l$ with $l$ given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe $n+k$, if the MSB of the UL index in the DCI format 0 is set to 1 or if $I_{PHICH} = 0$, as defined in subclause 9.1.2, with $k$ given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information. If, for TDD UL/DL configuration 0 and subframe bundling operation, the LSB of the UL index in the PDCCH/EPDCCH with DCI format 0 is set to 1 in subframe $n$ or if $I_{PHICH} = 1$, as defined in subclause 9.1.2, the UE shall adjust the corresponding first PUSCH transmission in the bundle in subframe $n+7$, according to the PDCCH/EPDCCH and PHICH information.

**Table 8-2 *k* for TDD configurations 0-6**

| TDD UL/DL Configuration | subframe number *n* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 4 | 6 | | | | 4 | 6 | | | |
| 1 | | 6 | | | 4 | | 6 | | | 4 |
| 2 | | | | 4 | | | | | 4 | |
| 3 | 4 | | | | | | | | 4 | 4 |
| 4 | | | | | | | | | 4 | 4 |
| 5 | | | | | | | | | 4 | |
| 6 | 7 | 7 | | | | 7 | 7 | | | 5 |

**Table 8-2a *l* for TDD configurations 0, 1 and 6**

| TDD UL/DL Configuration | subframe number *n* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 9 | 6 | | | | 9 | 6 | | | |
| 1 | | 2 | | | 3 | | 2 | | | 3 |
| 6 | 5 | 5 | | | | 6 | 6 | | | 8 |

A UE is semi-statically configured via higher layer signalling to transmit PUSCH transmissions signalled via PDCCH/EPDCCH according to one of two uplink transmission modes, denoted mode 1 - 2.

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-3 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and the PUSCH retransmission for the same transport block is by C-RNTI.

If a UE is configured by higher layers to decode EPDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the EPDCCH according to the combination defined in Table 8-3A and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these EPDCCHs and the PUSCH retransmission for the same transport block is by C-RNTI.

Transmission mode 1 is the default uplink transmission mode for a UE until the UE is assigned an uplink transmission mode by higher layer signalling.

When a UE configured in transmission mode 2 receives a DCI Format 0 uplink scheduling grant, it shall assume that the PUSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

**Table 8-3: PDCCH and PUSCH configured by C-RNTI**

| Transmission mode | DCI format | Search Space | Transmission scheme of PUSCH corresponding to PDCCH |
|---|---|---|---|
| Mode 1 | DCI format 0 | Common and UE specific by C-RNTI | Single-antenna port, port 10 (see subclause 8.0.1) |
| Mode 2 | DCI format 0 | Common and UE specific by C-RNTI | Single-antenna port, port 10 (see subclause 8.0.1) |
| | DCI format 4 | UE specific by C-RNTI | Closed-loop spatial multiplexing (see subclause 8.0.2) |

**Table 8-3A: EPDCCH and PUSCH configured by C-RNTI**

| Transmission mode | DCI format | Search Space | Transmission scheme of PUSCH corresponding to EPDCCH |
|---|---|---|---|
| Mode 1 | DCI format 0 | UE specific by C-RNTI | Single-antenna port, port 10 (see subclause 8.0.1) |
| Mode 2 | DCI format 0 | UE specific by C-RNTI | Single-antenna port, port 10 (see subclause 8.0.1) |
| | DCI format 4 | UE specific by C-RNTI | Closed-loop spatial multiplexing (see subclause 8.0.2) |

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI and is also configured to receive random access procedures initiated by "PDCCH orders", the UE shall decode the PDCCH according to the combination defined in Table 8-4.

If a UE is configured by higher layers to decode EPDCCHs with the CRC scrambled by the C-RNTI and is also configured to receive random access procedures initiated by "PDCCH orders", the UE shall decode the EPDCCH according to the combination defined in Table 8-4A.

**Table 8-4: PDCCH configured as "PDCCH order" to initiate random access procedure**

| DCI format | Search Space |
|---|---|
| DCI format 1A | Common and<br>UE specific by C-RNTI |

**Table 8-4A: EPDCCH configured as "PDCCH order" to initiate random access procedure**

| DCI format | Search Space |
|---|---|
| DCI format 1A | UE specific by C-RNTI |

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-5 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and PUSCH retransmission for the same transport block is by SPS C-RNTI. The scrambling initialization of initial transmission of this PUSCH without a corresponding PDCCH and the PUSCH retransmission for the same transport block is by SPS C-RNTI.

If a UE is configured by higher layers to decode EPDCCHs with the CRC scrambled by the SPS C-RNTI, the UE shall decode the EPDCCH according to the combination defined in Table 8-5A and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these EPDCCHs and PUSCH retransmission for the same transport block is by SPS C-RNTI. The scrambling initialization of initial transmission of this PUSCH without a corresponding EPDCCH and the PUSCH retransmission for the same transport block is by SPS C-RNTI.

**Table 8-5: PDCCH and PUSCH configured by SPS C-RNTI**

| Transmission mode | DCI format | Search Space | Transmission scheme of PUSCH corresponding to PDCCH |
|---|---|---|---|
| Mode 1 | DCI format 0 | Common and<br>UE specific by C-RNTI | Single-antenna port, port 10 (see subclause 8.0.1) |
| Mode 2 | DCI format 0 | Common and<br>UE specific by C-RNTI | Single-antenna port, port 10 (see subclause 8.0.1) |

**Table 8-5A: EPDCCH and PUSCH configured by SPS C-RNTI**

| Transmission mode | DCI format | Search Space | Transmission scheme of PUSCH corresponding to PDCCH |
|---|---|---|---|
| Mode 1 | DCI format 0 | UE specific by C-RNTI | Single-antenna port, port 10 (see subclause 8.0.1) |
| Mode 2 | DCI format 0 | UE specific by C-RNTI | Single-antenna port, port 10 (see subclause 8.0.1) |

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the Temporary C-RNTI regardless of whether UE is configured or not configured to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-6 and transmit the corresponding PUSCH. The scrambling initialization of PUSCH corresponding to these PDCCH is by Temporary C-RNTI.

If a Temporary C-RNTI is set by higher layers, the scrambling of PUSCH corresponding to the Random Access Response Grant in subclause 6.2 and the PUSCH retransmission for the same transport block is by Temporary C-RNTI. Else, the scrambling of PUSCH corresponding to the Random Access Response Grant in subclause 6.2 and the PUSCH retransmission for the same transport block is by C-RNTI.

**Table 8-6: PDCCH configured by Temporary C-RNTI**

| DCI format | Search Space |
|---|---|
| DCI format 0 | Common |

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUCCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8-7. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

**Table 8-7: PDCCH configured by TPC-PUCCH-RNTI**

| DCI format | Search Space |
|---|---|
| DCI format 3/3A | Common |

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUSCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8.8. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

**Table 8-8: PDCCH configured by TPC-PUSCH-RNTI**

| DCI format | Search Space |
|---|---|
| DCI format 3/3A | Common |

## 8.0.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 10) of the PUSCH, the UE transmission on the PUSCH is performed according to subclause 5.3.2A.1 of [3].

## 8.0.2 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PUSCH, the UE transmission on the PUSCH is performed according to the applicable number of transmission layers as defined in subclause 5.3.2A.2 of [3].

# 8.1 Resource allocation for PDCCH/EPDCCH with uplink DCI format

Two resource allocation schemes Type 0 and Type 1 are supported for PDCCH/EPDCCH with uplink DCI format.

If the resource allocation type bit is not present in the uplink DCI format, only resource allocation type 0 is supported.

If the resource allocation type bit is present in the uplink DCI format, the selected resource allocation type for a decoded PDCCH/EPDCCH is indicated by a resource allocation type bit where type 0 is indicated by 0 value and type 1 is indicated otherwise. The UE shall interpret the resource allocation field depending on the resource allocation type bit in the PDCCH/EPDCCH with uplink DCI format detected.

## 8.1.1 Uplink resource allocation type 0

The resource allocation information for uplink resource allocation type 0 indicates to a scheduled UE a set of contiguously allocated virtual resource block indices denoted by $n_{\mathrm{VRB}}$. A resource allocation field in the scheduling grant consists of a resource indication value (*RIV*) corresponding to a starting resource block ( $RB_{\mathrm{START}}$ ) and a length in terms of contiguously allocated resource blocks ( $L_{\mathrm{CRBs}} \geq 1$). The resource indication value is defined by

if $(L_{\mathrm{CRBs}} - 1) \leq \lfloor N_{\mathrm{RB}}^{\mathrm{UL}} / 2 \rfloor$ then

$$RIV = N_{\mathrm{RB}}^{\mathrm{UL}} (L_{\mathrm{CRBs}} - 1) + RB_{\mathrm{START}}$$

else

$$RIV = N_{\mathrm{RB}}^{\mathrm{UL}} (N_{\mathrm{RB}}^{\mathrm{UL}} - L_{\mathrm{CRBs}} + 1) + (N_{\mathrm{RB}}^{\mathrm{UL}} - 1 - RB_{\mathrm{START}})$$

## 8.1.2 Uplink resource allocation type 1

The resource allocation information for uplink resource allocation type 1 indicates to a scheduled UE two sets of resource blocks with each set including one or more consecutive resource block groups of size *P* as given in table 7.1.6.1-1 assuming $N_{\mathrm{RB}}^{\mathrm{UL}}$ as the system bandwidth. A combinatorial index *r* consists of $\left\lceil \log_2 \left( \binom{\lceil N_{RB}^{UL} / P + 1 \rceil}{4} \right) \right\rceil$ bits.

The bits from the resource allocation field in the scheduling grant represent *r* unless the number of bits in the resource allocation field in the scheduling grant is

- smaller than required to fully represent *r*, in which case the bits in the resource allocation field in the scheduling grant occupy the LSBs of *r* and the value of the remaining bits of *r* shall be assumed to be 0; or
- larger than required to fully represent *r*, in which case *r* occupies the LSBs of the resource allocation field in the scheduling grant.

The combinatorial index *r* corresponds to a starting and ending RBG index of resource block set 1, $s_0$ and $s_1 - 1$, and resource block set 2, $s_2$ and $s_3 - 1$ respectively, where *r* is given by equation $r = \sum_{i=0}^{M-1} \left\langle \begin{matrix} N - s_i \\ M - i \end{matrix} \right\rangle$ defined in subclause 7.2.1 with *M*=4 and $N = \left\lceil N_{\mathrm{RB}}^{\mathrm{UL}} / P \right\rceil + 1$. subclause 7.2.1 also defines ordering properties and range of values that $s_i$ (RBG indices) map to. Only a single RBG is allocated for a set at the starting RBG index if the corresponding ending RBG index equals the starting RBG index.

## 8.2 UE sounding procedure

A UE shall transmit Sounding Reference Symbol (SRS) on per serving cell SRS resources based on two trigger types:

- trigger type 0: higher layer signalling
- trigger type 1: DCI formats 0/4/1A for FDD and TDD and DCI formats 2B/2C/2D for TDD.

In case both trigger type 0 and trigger type 1 SRS transmissions would occur in the same subframe in the same serving cell, the UE shall only transmit the trigger type 1 SRS transmission.

A UE may be configured with SRS parameters for trigger type 0 and trigger type 1 on each serving cell. The following SRS parameters are serving cell specific and semi-statically configurable by higher layers for trigger type 0 and for trigger type 1.

- Transmission comb $\bar{k}_{TC}$, as defined in subclause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- Starting physical resource block assignment $n_{RRC}$, as defined in subclause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- *duration*: single or indefinite (until disabled), as defined in [11] for trigger type 0
- *srs-ConfigIndex* $I_{SRS}$ for SRS periodicity $T_{SRS}$ and SRS subframe offset $T_{offset}$, as defined in Table 8.2-1 and Table 8.2-2 for trigger type 0 and SRS periodicity $T_{SRS,1}$ and SRS subframe offset $T_{offset,1}$, as defined in Table 8.2-4 and Table 8.2-5 trigger type 1
- SRS bandwidth $B_{SRS}$, as defined in subclause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- Frequency hopping bandwidth, $b_{hop}$, as defined in subclause 5.5.3.2 of [3] for trigger type 0
- Cyclic shift $n_{SRS}^{cs}$, as defined in subclause 5.5.3.1 of [3] for trigger type 0 and each configuration of trigger type 1
- Number of antenna ports $N_p$ for trigger type 0 and each configuration of trigger type 1

For trigger type 1 and DCI format 4 three sets of SRS parameters, *srs-ConfigApDCI-Format4*, are configured by higher layer signalling. The 2-bit SRS request field [4] in DCI format 4 indicates the SRS parameter set given in Table 8.1-1. For trigger type 1 and DCI format 0, a single set of SRS parameters, *srs-ConfigApDCI-Format0*, is configured by higher layer signalling. For trigger type 1 and DCI formats 1A/2B/2C/2D, a single common set of SRS parameters, *srs-ConfigApDCI-Format1a2b2c*, is configured by higher layer signalling. The SRS request field is 1 bit [4] for DCI formats 0/1A/2B/2C/2D, with a type 1 SRS triggered if the value of the SRS request field is set to '1'.
A 1-bit SRS request field shall be included in DCI formats 0/1A for frame structure type 1 and 0/1A/2B/2C/2D for frame structure type 2 if the UE is configured with SRS parameters for DCI formats 0/1A/2B/2C/2D by higher-layer signalling.

**Table 8.1-1: SRS request value for trigger type 1 in DCI format 4**

| Value of SRS request field | Description |
|---|---|
| '00' | No type 1 SRS trigger |
| '01' | The 1st SRS parameter set configured by higher layers |
| '10' | The 2nd SRS parameter set configured by higher layers |
| '11' | The 3rd SRS parameter set configured by higher layers |

The serving cell specific SRS transmission bandwidths $C_{SRS}$ are configured by higher layers. The allowable values are given in subclause 5.5.3.2 of [3].

The serving cell specific SRS transmission sub-frames are configured by higher layers. The allowable values are given in subclause 5.5.3.3 of [3].

When antenna selection is enabled for a given serving cell for a UE that supports transmit antenna selection, the index $a(n_{SRS})$, of the UE antenna that transmits the SRS at time $n_{SRS}$ is given by

$a(n_{SRS}) = n_{SRS} \bmod 2$, for both partial and full sounding bandwidth, and when frequency hopping is disabled (i.e., $b_{hop} \geq B_{SRS}$),

$$a(n_{SRS}) = \begin{cases} (n_{SRS} + \lfloor n_{SRS}/2 \rfloor + \beta \cdot \lfloor n_{SRS}/K \rfloor) \bmod 2 & \text{when } K \text{ is even} \\ n_{SRS} \bmod 2 & \text{when } K \text{ is odd} \end{cases} \quad , \beta = \begin{cases} 1 & \text{where } K \bmod 4 = 0 \\ 0 & \text{otherwise} \end{cases}$$

when frequency hopping is enabled (i.e., $b_{hop} < B_{SRS}$),

where values $B_{SRS}$, $b_{hop}$, $N_b$, and $n_{SRS}$ are given in subclause 5.5.3.2 of [3], and $K = \prod_{b'=b_{hop}}^{B_{SRS}} N_{b'}$ (where $N_{b_{hop}} = 1$ regardless of the $N_b$ value), except when a single SRS transmission is configured for the UE. If a UE is configured with more than one serving cell, the UE is not expected to transmit SRS on different antenna ports simultaneously.

A UE may be configured to transmit SRS on $N_p$ antenna ports of a serving cell where $N_p$ may be configured by higher layer signalling. For PUSCH transmission mode 1 $N_p \in \{0,1,2,4\}$ and for PUSCH transmission mode 2 $N_p \in \{0,1,2\}$ with two antenna ports configured for PUSCH and $N_p \in \{0,1,4\}$ with 4 antenna ports configured for PUSCH. A UE configured for SRS transmission on multiple antenna ports of a serving cell shall transmit SRS for all the configured transmit antenna ports within one SC-FDMA symbol of the same subframe of the serving cell.
The SRS transmission bandwidth and starting physical resource block assignment are the same for all the configured antenna ports of a given serving cell.

A UE not configured with multiple TAGs shall not transmit SRS whenever SRS and PUSCH transmissions happen to overlap in the same symbol.

For TDD, when one SC-FDMA symbol exists in UpPTS of a given serving cell, it can be used for SRS transmission. When two SC-FDMA symbols exist in UpPTS of a given serving cell, both can be used for SRS transmission and for trigger type 0 SRS both can be assigned to the same UE.

A UE not configured with multiple TAGs shall not transmit type 0 triggered SRS whenever type 0 triggered SRS and PUCCH format 2/2a/2b transmissions happen to coincide in the same subframe. A UE not configured with multiple TAGs shall not transmit type 1 triggered SRS whenever type 1 triggered SRS and PUCCH format 2a/2b or format 2 with HARQ-ACK transmissions happen to coincide in the same subframe. A UE not configured with multiple TAGs shall not transmit PUCCH format 2 without HARQ-ACK whenever type 1 triggered SRS and PUCCH format 2 without HARQ-ACK transmissions happen to coincide in the same subframe.

A UE not configured with multiple TAGs shall not transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACK and/or positive SR happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *FALSE*. A UE not configured with multiple TAGs shall transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACK and/or positive SR using shortened format as defined in subclauses 5.4.1 and 5.4.2A of [3] happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *TRUE*.

A UE not configured with multiple TAGs shall not transmit SRS whenever SRS transmission on any serving cells and PUCCH transmission carrying HARQ-ACK and/or positive SR using normal PUCCH format as defined in subclauses 5.4.1 and 5.4.2A of [3] happen to coincide in the same subframe.

In UpPTS, whenever SRS transmission instance overlaps with the PRACH region for preamble format 4 or exceeds the range of uplink system bandwidth configured in the serving cell, the UE shall not transmit SRS.

The parameter *ackNackSRS-SimultaneousTransmission* provided by higher layers determines if a UE is configured to support the transmission of HARQ-ACK on PUCCH and SRS in one subframe. If it is configured to support the

transmission of HARQ-ACK on PUCCH and SRS in one subframe, then in the cell specific SRS subframes of the primary cell UE shall transmit HARQ-ACK and SR using the shortened PUCCH format as defined in subclauses 5.4.1 and 5.4.2A of [3], where the HARQ-ACK or the SR symbol corresponding to the SRS location is punctured.
This shortened PUCCH format shall be used in a cell specific SRS subframe of the primary cell even if the UE does not transmit SRS in that subframe. The cell specific SRS subframes are defined in subclause 5.5.3.3 of [3]. Otherwise, the UE shall use the normal PUCCH format 1/1a/1b as defined in subclause 5.4.1 of [3] or normal PUCCH format 3 as defined in subclause 5.4.2A of [3] for the transmission of HARQ-ACK and SR.

Trigger type 0 SRS configuration of a UE in a serving cell for SRS periodicity, $T_{\text{SRS}}$, and SRS subframe offset, $T_{offset}$, is defined in Table 8.2-1 and Table 8.2-2, for FDD and TDD, respectively. The periodicity $T_{\text{SRS}}$ of the SRS transmission is serving cell specific and is selected from the set {2, 5, 10, 20, 40, 80, 160, 320} ms or subframes.
For the SRS periodicity $T_{\text{SRS}}$ of 2 ms in TDD, two SRS resources are configured in a half frame containing UL subframe(s) of a given serving cell.

Type 0 triggered SRS transmission instances in a given serving cell for TDD with $T_{\text{SRS}} > 2$ and for FDD are the subframes satisfying $(10 \cdot n_f + k_{\text{SRS}} - T_{offset}) \bmod T_{\text{SRS}} = 0$, where for FDD $k_{\text{SRS}} = \{0,1,...,9\}$ is the subframe index within the frame, for TDD $k_{\text{SRS}}$ is defined in Table 8.2-3. The SRS transmission instances for TDD with $T_{\text{SRS}} = 2$ are the subframes satisfying $(k_{\text{SRS}} - T_{offset}) \bmod 5 = 0$.

Trigger type 1 SRS configuration of a UE in a serving cell for SRS periodicity, $T_{\text{SRS},1}$, and SRS subframe offset, $T_{offset,1}$, is defined in Table 8.2-4 and Table 8.2-5, for FDD and TDD, respectively. The periodicity $T_{\text{SRS},1}$ of the SRS transmission is serving cell specific and is selected from the set {2, 5, 10} ms or subframes.
For the SRS periodicity $T_{\text{SRS},1}$ of 2 ms in TDD, two SRS resources are configured in a half frame containing UL subframe(s) of a given serving cell.

A UE configured for type 1 triggered SRS transmission in serving cell *c* and not configured with a carrier indicator field shall transmit SRS on serving cell *c* upon detection of a positive SRS request in PDCCH/EPDCCH scheduling PUSCH/PDSCH on serving cell *c*.

A UE configured for type 1 triggered SRS transmission in serving cell *c* and configured with a carrier indicator field shall transmit SRS on serving cell *c* upon detection of a positive SRS request in PDCCH/EPDCCH scheduling PUSCH/PDSCH with the value of carrier indicator field corresponding to serving cell *c*.

A UE configured for type 1 triggered SRS transmission on serving cell *c* upon detection of a positive SRS request in subframe *n* of serving cell *c* shall commence SRS transmission in the first subframe satisfying $n + k, k \geq 4$ and

$(10 \cdot n_f + k_{\text{SRS}} - T_{offset,1}) \bmod T_{\text{SRS},1} = 0$ for TDD with $T_{\text{SRS},1} > 2$ and for FDD,

$(k_{\text{SRS}} - T_{offset,1}) \bmod 5 = 0$ for TDD with $T_{\text{SRS},1} = 2$

where for FDD $k_{\text{SRS}} = \{0,1,...,9\}$ is the subframe index within the frame $n_f$, for TDD $k_{\text{SRS}}$ is defined in Table 8.2-3.

A UE configured for type 1 triggered SRS transmission is not expected to receive type 1 SRS triggering events associated with different values of trigger type 1 SRS transmission parameters, as configured by higher layer signalling, for the same subframe and the same serving cell.

A UE shall not transmit SRS whenever SRS and a PUSCH transmission corresponding to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure coincide in the same subframe.

**Table 8.2-1: UE Specific SRS Periodicity $T_{SRS}$ and Subframe Offset Configuration $T_{offset}$ for trigger type 0, FDD**

| SRS Configuration Index $I_{SRS}$ | SRS Periodicity $T_{SRS}$ (ms) | SRS Subframe Offset $T_{offset}$ |
|---|---|---|
| 0 – 1 | 2 | $I_{SRS}$ |
| 2 – 6 | 5 | $I_{SRS}$ – 2 |
| 7 – 16 | 10 | $I_{SRS}$ – 7 |
| 17 – 36 | 20 | $I_{SRS}$ – 17 |
| 37 – 76 | 40 | $I_{SRS}$ – 37 |
| 77 – 156 | 80 | $I_{SRS}$ – 77 |
| 157 – 316 | 160 | $I_{SRS}$ – 157 |
| 317 – 636 | 320 | $I_{SRS}$ – 317 |
| 637 – 1023 | reserved | reserved |

**Table 8.2-2: UE Specific SRS Periodicity $T_{SRS}$ and Subframe Offset Configuration $T_{offset}$ for trigger type 0, TDD**

| SRS Configuration Index $I_{SRS}$ | SRS Periodicity $T_{SRS}$ (ms) | SRS Subframe Offset $T_{offset}$ |
|---|---|---|
| 0 | 2 | 0, 1 |
| 1 | 2 | 0, 2 |
| 2 | 2 | 1, 2 |
| 3 | 2 | 0, 3 |
| 4 | 2 | 1, 3 |
| 5 | 2 | 0, 4 |
| 6 | 2 | 1, 4 |
| 7 | 2 | 2, 3 |
| 8 | 2 | 2, 4 |
| 9 | 2 | 3, 4 |
| 10 – 14 | 5 | $I_{SRS}$ – 10 |
| 15 – 24 | 10 | $I_{SRS}$ – 15 |
| 25 – 44 | 20 | $I_{SRS}$ – 25 |
| 45 – 84 | 40 | $I_{SRS}$ – 45 |
| 85 – 164 | 80 | $I_{SRS}$ – 85 |
| 165 – 324 | 160 | $I_{SRS}$ – 165 |
| 325 – 644 | 320 | $I_{SRS}$ – 325 |
| 645 – 1023 | reserved | reserved |

**Table 8.2-3: $k_{SRS}$ for TDD**

| | subframe index *n* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | | 2 | 3 | 4 | 5 | 6 | | 7 | 8 | 9 |
| | | 1st symbol of UpPTS | 2nd symbol of UpPTS | | | | | 1st symbol of UpPTS | 2nd symbol of UpPTS | | | |
| $k_{SRS}$ in case UpPTS length of 2 symbols | | 0 | 1 | 2 | 3 | 4 | | 5 | 6 | 7 | 8 | 9 |
| $k_{SRS}$ in case UpPTS length of 1 symbol | | 1 | | 2 | 3 | 4 | | 6 | | 7 | 8 | 9 |

**Table 8.2-4: UE Specific SRS Periodicity $T_{\mathrm{SRS},1}$ and Subframe Offset Configuration $T_{offset,1}$ for trigger type 1, FDD**

| SRS Configuration Index $I_{SRS}$ | SRS Periodicity $T_{\mathrm{SRS},1}$ (ms) | SRS Subframe Offset $T_{offset,1}$ |
|---|---|---|
| 0 – 1 | 2 | $I_{SRS}$ |
| 2 – 6 | 5 | $I_{SRS}$ – 2 |
| 7 – 16 | 10 | $I_{SRS}$ – 7 |
| 17 – 31 | reserved | reserved |

**Table 8.2-5: UE Specific SRS Periodicity $T_{\mathrm{SRS},1}$ and Subframe Offset Configuration $T_{offset,1}$ for trigger type 1, TDD**

| SRS Configuration Index $I_{SRS}$ | SRS Periodicity $T_{\mathrm{SRS},1}$ (ms) | SRS Subframe Offset $T_{offset,1}$ |
|---|---|---|
| 0 | reserved | reserved |
| 1 | 2 | 0, 2 |
| 2 | 2 | 1, 2 |
| 3 | 2 | 0, 3 |
| 4 | 2 | 1, 3 |
| 5 | 2 | 0, 4 |
| 6 | 2 | 1, 4 |
| 7 | 2 | 2, 3 |
| 8 | 2 | 2, 4 |
| 9 | 2 | 3, 4 |
| 10 – 14 | 5 | $I_{SRS}$ – 10 |
| 15 – 24 | 10 | $I_{SRS}$ – 15 |
| 25 – 31 | reserved | reserved |

# 8.3 UE HARQ-ACK procedure

For Frame Structure type 1, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in subframe *i*-4.

For TDD, if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same,

- For Frame Structure type 2 UL/DL configuration 1-6, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-*k* as indicated by the following table 8.3-1.

- For Frame Structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 0$, as defined in subclause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-*k* as indicated by the following table 8.3-1. For Frame Structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 1$, as defined in subclause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-6.

For TDD, if a UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same,

– For serving cell with an UL-reference UL/DL configuration (defined in subclause 8.0) belonging to {1,2,3,4,5,6}, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-*k* for the serving cell as indicated by the following table 8.3-1, where "TDD UL/DL Configuration" in table 8.3-1 refers to the UL-reference UL/DL Configuration.

– For a serving cell with UL-reference UL/DL configuration 0 (defined in subclause 8.0), an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 0$, as defined in subclause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-*k* for the serving cell as indicated by the following table 8.3-1, where "TDD UL/DL Configuration" in table 8.3-1 refers to the UL-reference UL/DL configuration. For a serving cell with UL-reference UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 1$, as defined in subclause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-6 for the serving cell.

**Table 8.3-1 *k* for TDD configurations 0-6**

| TDD UL/DL Configuration | subframe number *i* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 7 | 4 | | | | 7 | 4 | | | |
| 1 | | 4 | | | 6 | | 4 | | | 6 |
| 2 | | | | 6 | | | | | 6 | |
| 3 | 6 | | | | | | | | 6 | 6 |
| 4 | | | | | | | | | 6 | 6 |
| 5 | | | | | | | | | 6 | |
| 6 | 6 | 4 | | | | 7 | 4 | | | 6 |

The physical layer in the UE shall deliver indications to the higher layers as follows:

For FDD, and for TDD with a UE configured with one serving cell, and for TDD with a UE configured with more than one serving cell and with TDD UL/DL configuration of all configured serving cells the same, for downlink subframe *i*, if a transport block was transmitted in the associated PUSCH subframe then:

- if ACK is decoded on the PHICH corresponding to that transport block in subframe *i*, or if that transport block is disabled by PDCCH/EPDCCH received in downlink subframe *i*, ACK for that transport block shall be delivered to the higher layers; else NACK for that transport block shall be delivered to the higher layers.

For TDD, if the UE is configured with more than one serving cell, and if at least two serving cells have different UL/DL configurations, for downlink subframe *i*, if a transport block was transmitted in the associated PUSCH subframe then:

- if ACK is decoded on the PHICH corresponding to that transport block in subframe *i*, or if that transport block is disabled by PDCCH/EPDCCH received in downlink subframe *i*, ACK for that transport block shall be delivered to the higher layers; or

- if a PHICH resource corresponding to that transport block is not present in subframe *i* or if UE is not expected to receive PHICH corresponding to that transport block in subframe *i*, ACK for that transport block shall be delivered to the higher layers.

- else NACK for that transport block shall be delivered to the higher layers.

# 8.4 UE PUSCH hopping procedure

The UE shall perform PUSCH frequency hopping if the single bit Frequency Hopping (FH) field in a corresponding PDCCH/EPDCCH with DCI format 0 is set to 1 and the uplink resource block assignment is type 0 otherwise no PUSCH frequency hopping is performed.

A UE performing PUSCH frequency hopping shall determine its PUSCH Resource Allocation (RA) for the first slot of a subframe (*S1*) including the lowest index PRB ( $n_{PRB}^{S1}(n)$ ) in subframe *n* from the resource allocation field in the latest PDCCH/EPDCCH with DCI format 0 for the same transport block. If there is no PDCCH/EPDCCH for the same transport block, the UE shall determine its hopping type based on

- the hopping information in the most recent semi-persistent scheduling assignment PDCCH/EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled or
- the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

The resource allocation field in DCI format 0 excludes either 1 or 2 bits used for hopping information as indicated by Table 8.4-1 below where the number of PUSCH resource blocks is defined as

$$N_{RB}^{PUSCH} = \begin{cases} N_{RB}^{UL} - \widetilde{N}_{RB}^{HO} - \left(N_{RB}^{UL} \bmod 2\right) & \text{Type 1 PUSCH hopping} \\ N_{RB}^{UL} & \text{Type 2 } \mathrm{N_{sb}} = 1 \text{ PUSCH hopping} \\ N_{RB}^{UL} - \widetilde{N}_{RB}^{HO} & \text{Type 2 } \mathrm{N_{sb}} > 1 \text{ PUSCH hopping} \end{cases}$$

For type 1 and type 2 PUSCH hopping, $\widetilde{N}_{\mathrm{RB}}^{\mathrm{HO}} = N_{\mathrm{RB}}^{\mathrm{HO}} + 1$ if $N_{\mathrm{RB}}^{\mathrm{HO}}$ is an odd number where $N_{\mathrm{RB}}^{\mathrm{HO}}$ defined in [3]. $\widetilde{N}_{\mathrm{RB}}^{\mathrm{HO}} = N_{\mathrm{RB}}^{\mathrm{HO}}$ in other cases. The size of the resource allocation field in DCI format 0 after excluding either 1 or 2 bits shall be $y = \left\lceil \log_2 (N_{\mathrm{RB}}^{\mathrm{UL}} (N_{\mathrm{RB}}^{\mathrm{UL}} + 1)/2) \right\rceil - N_{UL_hop}$, where $N_{UL_hop}$ = 1 or 2 bits. The number of contiguous RBs that can be assigned to a type-1 hopping user is limited to $\left\lfloor 2^y / N_{\mathrm{RB}}^{\mathrm{UL}} \right\rfloor$. The number of contiguous RBs that can be assigned to a type-2 hopping user is limited to $\min\left(\left\lfloor 2^y / N_{\mathrm{RB}}^{\mathrm{UL}} \right\rfloor, \left\lfloor N_{\mathrm{RB}}^{\mathrm{PUSCH}} / N_{sb} \right\rfloor\right)$, where the number of sub-bands $N_{\mathrm{sb}}$ is given by higher layers.

A UE performing PUSCH frequency hopping shall use one of two possible PUSCH frequency hopping types based on the hopping information. PUSCH hopping type 1 is described in subclause 8.4.1 and type 2 is described in subclause 8.4.2.

**Table 8.4-1: Number of Hopping Bits $N_{UL_hop}$ vs. System Bandwidth**

| System BW $N_{RB}^{UL}$ | #Hopping bits for 2nd slot RA ($N_{UL_hop}$) |
|---|---|
| 6-49 | 1 |
| 50-110 | 2 |

The parameter *Hopping-mode* provided by higher layers determines if PUSCH frequency hopping is "inter-subframe" or "intra and inter-subframe".

### 8.4.1 Type 1 PUSCH hopping

For PUSCH hopping type 1 the hopping bit or bits indicated in Table 8.4-1 determine $\tilde{n}_{PRB}(i)$ as defined in Table 8.4-2. The lowest index PRB ( $n_{PRB}^{S1}(i)$ ) of the 1st slot RA in subframe *i* is defined as $n_{PRB}^{S1}(i) = \tilde{n}_{PRB}^{S1}(i) + \tilde{N}_{\mathrm{RB}}^{\mathrm{HO}} / 2$, where $n_{PRB}^{S1}(i) = RB_{START}$, and $RB_{\mathrm{START}}$ is obtained from the uplink scheduling grant as in subclause 8.4 and subclause 8.1.

The lowest index PRB ( $n_{PRB}(i)$ ) of the 2nd slot RA in subframe *i* is defined as $n_{PRB}(i) = \tilde{n}_{PRB}(i) + \tilde{N}_{\mathrm{RB}}^{\mathrm{HO}} / 2$.

The set of physical resource blocks to be used for PUSCH transmission are $L_{\mathrm{CRBs}}$ contiguously allocated resource blocks from PRB index $n_{PRB}^{S1}(i)$ for the 1st slot, and from PRB index $n_{PRB}(i)$ for the 2nd slot, respectively, where $L_{\mathrm{CRBs}}$ is obtained from the uplink scheduling grant as in subclause 8.4 and subclause 8.1.

If the *Hopping-mode* is "inter-subframe", the 1st slot RA is applied to even CURRENT_TX_NB, and the 2nd slot RA is applied to odd CURRENT_TX_NB, where CURRENT_TX_NB is defined in [8].

### 8.4.2 Type 2 PUSCH hopping

In PUSCH hopping type 2 the set of physical resource blocks to be used for transmission in slot $n_{\mathrm{s}}$ is given by the scheduling grant together with a predefined pattern according to [3] subclause 5.3.4.
If the system frame number is not acquired by the UE yet, the UE shall not transmit PUSCH with type-2 hopping and $N_{sb} > 1$ for TDD, where $N_{sb}$ is defined in [3].

**Table 8.4-2: PDCCH/EPDCCH DCI format 0 hopping bit definition**

| System BW $N_{RB}^{UL}$ | Number of Hopping bits | Information in hopping bits | $\tilde{n}_{PRB}(i)$ |
|---|---|---|---|
| 6 – 49 | 1 | 0 | $\left(\left\lfloor N_{RB}^{PUSCH} / 2 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$, |
| | | 1 | Type 2 PUSCH Hopping |
| 50 – 110 | 2 | 00 | $\left(\left\lfloor N_{RB}^{PUSCH} / 4 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$ |
| | | 01 | $\left(-\left\lfloor N_{RB}^{PUSCH} / 4 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$ |
| | | 10 | $\left(\left\lfloor N_{RB}^{PUSCH} / 2 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$ |
| | | 11 | Type 2 PUSCH Hopping |

## 8.5 UE Reference Symbol (RS) procedure

If UL sequence-group hopping or sequence hopping is configured in a serving cell, it applies to all Reference Symbols (SRS, PUSCH and PUCCH RS). If disabling of the sequence-group hopping and sequence hopping is configured for the UE in the serving cell through the higher-layer parameter *Disable-sequence-group-hopping*, the sequence-group hopping and sequence hopping for PUSCH RS are disabled.

# 8.6 Modulation order, redundancy version and transport block size determination

To determine the modulation order, redundancy version and transport block size for the physical uplink shared channel, the UE shall first

- read the "modulation and coding scheme and redundancy version" field ( $I_{\text{MCS}}$ ), and
- check the "CSI request" bit field, and
- compute the total number of allocated PRBs ( $N_{\text{PRB}}$ ) based on the procedure defined in subclause 8.1, and
- compute the number of coded symbols for control information.

## 8.6.1 Modulation order and redundancy version determination

For $0 \le I_{\text{MCS}} \le 28$ , the modulation order ( $Q_m$ ) is determined as follows:

- If the UE is capable of supporting 64QAM in PUSCH and has not been configured by higher layers to transmit only QPSK and 16QAM, the modulation order is given by $Q_m'$ in Table 8.6.1-1.
- If the UE is not capable of supporting 64QAM in PUSCH or has been configured by higher layers to transmit only QPSK and 16QAM, $Q_m'$ is first read from Table 8.6.1-1. The modulation order is set to $Q_m = \min(4, Q_m')$ .
- If the parameter *ttiBundling* provided by higher layers is set to *TRUE*, then the resource allocation size is restricted to $N_{\text{PRB}} \le 3$ and the modulation order is set to $Q_m = 2$ .

For $29 \le I_{\text{MCS}} \le 31$ the modulation order ( $Q_m$ ) is determined as follows:

- if DCI format 0 is used and $I_{\text{MCS}} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{\text{MCS}} = 29$ for the enabled TB and the signalled number of transmission layers is 1, and if
  - the "CSI request" bit field is 1 bit and the bit is set to trigger an aperiodic report and, $N_{\text{PRB}} \le 4$ or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and, $N_{\text{PRB}} \le 4$ or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{\text{PRB}} \le 20$ , or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one CSI process according to Table 7.2.1-1B and $N_{\text{PRB}} \le 4$ , or,
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one CSI process according to Table 7.2.1-1B and $N_{\text{PRB}} \le 20$ ,

then the modulation order is set to $Q_m = 2$ .

- Otherwise, the modulation order shall be determined from the DCI transported in the latest PDCCH/EPDCCH with DCI format 0/4 for the same transport block using $0 \le I_{\text{MCS}} \le 28$ . If there is no PDCCH/EPDCCH with DCI format 0/4 for the same transport block using $0 \le I_{\text{MCS}} \le 28$ , the modulation order shall be determined from
  - the most recent semi-persistent scheduling assignment PDCCH/EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,

- the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

The UE shall use $I_{MCS}$ and Table 8.6.1-1 to determine the redundancy version ($rv_{idx}$) to use in the physical uplink shared channel.

**Table 8.6.1-1: Modulation, TBS index and redundancy version table for PUSCH**

| MCS Index $I_{MCS}$ | Modulation Order $Q'_m$ | TBS Index $I_{TBS}$ | Redundancy Version $rv_{idx}$ |
|---|---|---|---|
| 0 | 2 | 0 | 0 |
| 1 | 2 | 1 | 0 |
| 2 | 2 | 2 | 0 |
| 3 | 2 | 3 | 0 |
| 4 | 2 | 4 | 0 |
| 5 | 2 | 5 | 0 |
| 6 | 2 | 6 | 0 |
| 7 | 2 | 7 | 0 |
| 8 | 2 | 8 | 0 |
| 9 | 2 | 9 | 0 |
| 10 | 2 | 10 | 0 |
| 11 | 4 | 10 | 0 |
| 12 | 4 | 11 | 0 |
| 13 | 4 | 12 | 0 |
| 14 | 4 | 13 | 0 |
| 15 | 4 | 14 | 0 |
| 16 | 4 | 15 | 0 |
| 17 | 4 | 16 | 0 |
| 18 | 4 | 17 | 0 |
| 19 | 4 | 18 | 0 |
| 20 | 4 | 19 | 0 |
| 21 | 6 | 19 | 0 |
| 22 | 6 | 20 | 0 |
| 23 | 6 | 21 | 0 |
| 24 | 6 | 22 | 0 |
| 25 | 6 | 23 | 0 |
| 26 | 6 | 24 | 0 |
| 27 | 6 | 25 | 0 |
| 28 | 6 | 26 | 0 |
| 29 | reserved | | 1 |
| 30 | | | 2 |
| 31 | | | 3 |

## 8.6.2 Transport block size determination

For $0 \le I_{MCS} \le 28$, the UE shall first determine the TBS index ( $I_{TBS}$ ) using $I_{MCS}$ and Table 8.6.1-1 except if the transport block is disabled in DCI format 4 as specified below. For a transport block that is not mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in subclause 7.17.2.2.

For $29 \le I_{MCS} \le 31$,

- if DCI format 0 is used and $I_{MCS} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{MCS} = 29$ for the enabled TB and the number of transmission layers is 1, and if
  - the "CSI request" bit field is 1 bit and is set to trigger an aperiodic CSI report and $N_{PRB} \le 4$, or
  - the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and , $N_{PRB} \le 4$ or,

- the "CSI request" bit field is 2 bits and is triggering aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{PRB} \leq 20$, or,
- the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one CSI process according to Table 7.2.1-1B and $N_{PRB} \leq 4$, or,
- the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one CSI process according to Table 7.2.1-1B and, $N_{PRB} \leq 20$

then there is no transport block for the UL-SCH and only the control information feedback for the current PUSCH reporting mode is transmitted by the UE.

- Otherwise, the transport block size shall be determined from the initial PDCCH/EPDCCH for the same transport block using $0 \leq I_{MCS} \leq 28$. If there is no initial PDCCH/EPDCCH with an uplink DCI format for the same transport block using $0 \leq I_{MCS} \leq 28$, the transport block size shall be determined from
  - the most recent semi-persistent scheduling assignment PDCCH/EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
  - the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

In DCI format 4 a transport block is disabled if either the combination of $I_{MCS} = 0$ and $N_{PRB} > 1$ or the combination of $I_{MCS} = 28$ and $N_{PRB} = 1$ is signalled, otherwise the transport block is enabled.

## 8.6.3 Control information MCS offset determination

Offset values are defined for single codeword PUSCH transmission and multiple codeword PUSCH transmission. Single codeword PUSCH transmission offsets $\beta_{offset}^{HARQ-ACK}$, $\beta_{offset}^{RI}$ and $\beta_{offset}^{CQI}$ shall be configured to values according to Table 8.6.3-1,2,3 with the higher layer signalled indexes $I_{offset}^{HARQ-ACK}$, $I_{offset}^{RI}$, and $I_{offset}^{CQI}$, respectively. Multiple codeword PUSCH transmission offsets $\beta_{offset}^{HARQ-ACK}$, $\beta_{offset}^{RI}$ and $\beta_{offset}^{CQI}$ shall be configured to values according to Table 8.6.3-1,2,3 with the higher layer signalled indexes $I_{offset,MC}^{HARQ-ACK}$, $I_{offset,MC}^{RI}$ and $I_{offset,MC}^{CQI}$, respectively.

**Table 8.6.3-1: Mapping of HARQ-ACK offset values and the index signalled by higher layers**

| $I_{offset}^{HARQ-ACK}$ or $I_{offset,MC}^{HARQ-ACK}$ | $\beta_{offset}^{HARQ-ACK}$ |
|---|---|
| 0 | 2.000 |
| 1 | 2.500 |
| 2 | 3.125 |
| 3 | 4.000 |
| 4 | 5.000 |
| 5 | 6.250 |
| 6 | 8.000 |
| 7 | 10.000 |
| 8 | 12.625 |
| 9 | 15.875 |
| 10 | 20.000 |
| 11 | 31.000 |
| 12 | 50.000 |
| 13 | 80.000 |
| 14 | 126.000 |
| 15 | 1.0 |

**Table 8.6.3-2: Mapping of RI offset values and the index signalled by higher layers**

| $I_{offset}^{RI}$ or $I_{offset,MC}^{RI}$ | $\beta_{offset}^{RI}$ |
|---|---|
| 0 | 1.250 |
| 1 | 1.625 |
| 2 | 2.000 |
| 3 | 2.500 |
| 4 | 3.125 |
| 5 | 4.000 |
| 6 | 5.000 |
| 7 | 6.250 |
| 8 | 8.000 |
| 9 | 10.000 |
| 10 | 12.625 |
| 11 | 15.875 |
| 12 | 20.000 |
| 13 | reserved |
| 14 | reserved |
| 15 | reserved |

**Table 8.6.3-3: Mapping of CQI offset values and the index signalled by higher layers**

| $I_{offset}^{CQI}$ or $I_{offset,MC}^{CQI}$ | $\beta_{offset}^{CQI}$ |
|---|---|
| 0 | reserved |
| 1 | reserved |
| 2 | 1.125 |
| 3 | 1.250 |
| 4 | 1.375 |
| 5 | 1.625 |
| 6 | 1.750 |
| 7 | 2.000 |
| 8 | 2.250 |
| 9 | 2.500 |
| 10 | 2.875 |
| 11 | 3.125 |
| 12 | 3.500 |
| 13 | 4.000 |
| 14 | 5.000 |
| 15 | 6.250 |

## 8.7 UE transmit antenna selection

UE transmit antenna selection is configured by higher layers via parameter *ue-TransmitAntennaSelection*.

A UE configured with transmit antenna selection for a serving cell is not expected to

- be configured with more than one antenna port for any uplink physical channel or signal for any configured serving cell, or
- be configured with trigger type 1 SRS transmission on any configured serving cell, or
- be configured with simultaneous PUCCH and PUSCH transmission, or
- be configured with demodulation reference signal for PUSCH with OCC for any configured serving cell (see [3], subclause 5.5.2.1.1), or
- receive DCI Format 0 indicating uplink resource allocation type 1 for any serving cell.

If UE transmit antenna selection is disabled or not supported by the UE, the UE shall transmit from UE port 0.

If closed-loop UE transmit antenna selection is enabled by higher layers the UE shall perform transmit antenna selection in response to the most recent command received via DCI Format 0 in subclause 5.3.3.2 of [4].
If a UE is configured with more than one serving cell, the UE may assume the same transmit antenna port value is indicated in each PDCCH/EPDCCH with DCI format 0 in a given subframe.

If open-loop UE transmit antenna selection is enabled by higher layers, the transmit antenna to be selected by the UE is not specified.

# 9 Physical downlink control channel procedures

## 9.1 UE procedure for determining physical downlink control channel assignment

### 9.1.1 PDCCH assignment procedure

The control region of each serving cell consists of a set of CCEs, numbered from 0 to $N_{\mathrm{CCE},k}-1$ according to subclause 6.8.1 in [3], where $N_{\mathrm{CCE},k}$ is the total number of CCEs in the control region of subframe $k$.
The UE shall monitor a set of PDCCH candidates on one or more activated serving cells as configured by higher layer signalling for control information, where monitoring implies attempting to decode each of the PDCCHs in the set according to all the monitored DCI formats.

The set of PDCCH candidates to monitor are defined in terms of search spaces, where a search space $S_k^{(L)}$ at aggregation level $L \in \{1,2,4,8\}$ is defined by a set of PDCCH candidates. For each serving cell on which PDCCH is monitored, the CCEs corresponding to PDCCH candidate $m$ of the search space $S_k^{(L)}$ are given by

$$L\ \left\{(Y_k + m') \bmod \left\lfloor N_{\mathrm{CCE},k} / L \right\rfloor\right\} + i$$

where $Y_k$ is defined below, $i = 0,\cdots,L-1$. For the common search space $m' = m$. For the PDCCH UE specific search space, for the serving cell on which PDCCH is monitored, if the monitoring UE is configured with carrier indicator field then $m' = m + M^{(L)} \cdot n_{CI}$ where $n_{CI}$ is the carrier indicator field value, else if the monitoring UE is not configured with carrier indicator field then $m' = m$, where $m = 0,\cdots,M^{(L)}-1$. $M^{(L)}$ is the number of PDCCH candidates to monitor in the given search space.

Note that the carrier indicator field value is the same as *ServCellIndex* given in [11].

The UE shall monitor one common search space in every non-DRX subframe at each of the aggregation levels 4 and 8 on the primary cell.

The UE shall monitor common search space on a cell to decode the PDCCHs necessary to decode PMCH on that cell if configured to decode PMCH by higher layers.

If a UE is not configured for EPDCCH monitoring, and if the UE is not configured with a carrier indicator field, then the UE shall monitor one PDCCH UE-specific search space at each of the aggregation levels 1, 2, 4, 8 on each activated serving cell in every non-DRX subframe.

If a UE is not configured for EPDCCH monitoring, and if the UE is configured with a carrier indicator field, then the UE shall monitor one or more UE-specific search spaces at each of the aggregation levels 1, 2, 4, 8 on one or more activated serving cells as configured by higher layer signalling in every non-DRX subframe.

If a UE is configured for EPDCCH monitoring on a serving cell, and if that serving cell is activated, and if the UE is not configured with a carrier indicator field, then the UE shall monitor one PDCCH UE-specific search space at each of the aggregation levels 1, 2, 4, 8 on that serving cell in all non-DRX subframes where EPDCCH is not monitored on that serving cell.

If a UE is configured for EPDCCH monitoring on a serving cell, and if that serving cell is activated, and if the UE is configured with a carrier indicator field, then the UE shall monitor one or more PDCCH UE-specific search spaces at each of the aggregation levels 1, 2, 4, 8 on that serving cell as configured by higher layer signalling in all non-DRX subframes where EPDCCH is not monitored on that serving cell.

The common and PDCCH UE-specific search spaces on the primary cell may overlap.

A UE configured with the carrier indicator field associated with monitoring PDCCH on serving cell *c* shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by C-RNTI in the PDCCH UE specific search space of serving cell *c*.

A UE configured with the carrier indicator field associated with monitoring PDCCH on the primary cell shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by SPS C-RNTI in the PDCCH UE specific search space of the primary cell.

The UE shall monitor the common search space for PDCCH without carrier indicator field.

For the serving cell on which PDCCH is monitored, if the UE is not configured with a carrier indicator field, it shall monitor the PDCCH UE specific search space for PDCCH without carrier indicator field, if the UE is configured with a carrier indicator field it shall monitor the PDCCH UE specific search space for PDCCH with carrier indicator field.

A UE is not expected to monitor the PDCCH of a secondary cell if it is configured to monitor PDCCH with carrier indicator field corresponding to that secondary cell in another serving cell. For the serving cell on which PDCCH is monitored, the UE shall monitor PDCCH candidates at least for the same serving cell.

A UE configured to monitor PDCCH candidates with CRC scrambled by C-RNTI or SPS C-RNTI with a common payload size and with the same first CCE index $n_{\mathrm{CCE}}$ (as described in subclause 10.1) but with different sets of DCI information fields as defined in [4] in the

- common search space
- PDCCH UE specific search space

on the primary cell shall assume that for the PDCCH candidates with CRC scrambled by C-RNTI or SPS C-RNTI,

- if the UE is configured with the carrier indicator field associated with monitoring the PDCCH on the primary cell, only the PDCCH in the common search space is transmitted by the primary cell;
- otherwise, only the PDCCH in the UE specific search space is transmitted by the primary cell.

A UE configured to monitor PDCCH candidates in a given serving cell with a given DCI format size with CIF, and CRC scrambled by C- RNTI, where the PDCCH candidates may have one or more possible values of CIF for the given DCI format size, shall assume that a PDCCH candidate with the given DCI format size may be transmitted in the given serving cell in any PDCCH UE specific search space corresponding to any of the possible values of CIF for the given DCI format size.

The aggregation levels defining the search spaces are listed in Table 9.1.1-1. The DCI formats that the UE shall monitor depend on the configured transmission mode per each serving cell as defined in subclause 7.1.

**Table 9.1.1-1: PDCCH candidates monitored by a UE**

| Search space $S_k^{(L)}$ | | | Number of PDCCH candidates $M^{(L)}$ |
|---|---|---|---|
| Type | Aggregation level $L$ | Size [in CCEs] | |
| UE-specific | 1 | 6 | 6 |
| | 2 | 12 | 6 |
| | 4 | 8 | 2 |
| | 8 | 16 | 2 |
| Common | 4 | 16 | 4 |
| | 8 | 16 | 2 |

For the common search spaces, $Y_k$ is set to 0 for the two aggregation levels $L = 4$ and $L = 8$.

For the UE-specific search space $S_k^{(L)}$ at aggregation level $L$, the variable $Y_k$ is defined by

$$Y_k = \left(A \cdot Y_{k-1}\right) \bmod D$$

where $Y_{-1} = n_{\mathrm{RNTI}} \neq 0$, $A = 39827$, $D = 65537$ and $k = \lfloor n_s/2 \rfloor$, $n_s$ is the slot number within a radio frame.

The RNTI value used for $n_{\mathrm{RNTI}}$ is defined in subclause 7.1 in downlink and subclause 8 in uplink.

## 9.1.2 PHICH assignment procedure

If a UE is not configured with multiple TAGs, or if a UE is configured with multiple TAGs and PUSCH transmissions scheduled from serving cell $c$ in subframe $n$ are not scheduled by a Random Access Response Grant corresponding to a random access preamble transmission for a secondary cell

- For PUSCH transmissions scheduled from serving cell $c$ in subframe $n$, the UE shall determine the corresponding PHICH resource of serving cell $c$ in subframe $n+k_{PHICH}$, where $k_{PHICH}$ is always 4 for FDD.
- For TDD, if the UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, for PUSCH transmissions scheduled from serving cell $c$ in subframe $n$, the UE shall determine the corresponding PHICH resource of serving cell $c$ in subframe $n+k_{PHICH}$, where $k_{PHICH}$ is given in table 9.1.2-1.
- For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, for PUSCH transmissions scheduled from serving cell $c$ in subframe $n$, the UE shall determine the corresponding PHICH resource of serving cell $c$ in subframe $n+k_{PHICH}$, where $k_{PHICH}$ is given in table 9.1.2-1, where the "TDD UL/DL Configuration" in the rest of this subclause refers to the UL-reference UL/DL configuration (defined in subclause 8.0) of the serving cell corresponding to the PUSCH transmission.

If a UE is configured with multiple TAGs, for PUSCH transmissions on subframe $n$ for a secondary cell $c$ scheduled by a Random Access Response grant corresponding to a random access preamble transmission for the secondary cell $c$,

- For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, the "TDD UL/DL Configuration" in the rest of this subclause refers to the UL-reference UL/DL configuration (defined in subclause 8.0) of secondary cell $c$.
- If the UE is not configured to monitor PDCCH/EPDCCH with carrier indicator field corresponding to secondary cell $c$ in another serving cell, the UE shall determine the corresponding PHICH resource on the secondary cell $c$ in subframe $n+k_{PHICH}$, where $k_{PHICH}$ is always 4 for FDD and where $k_{PHICH}$ is given in table 9.1.2-1 for TDD.
- If the UE is configured to monitor PDCCH/EPDCCH with carrier indicator field corresponding to secondary cell $c$ in another serving cell $c1$, the UE configured with multiple TAGs shall determine the corresponding PHICH resource on the serving cell $c1$ in subframe $n+k_{PHICH}$, where $k_{PHICH}$ is always 4 for FDD and where $k_{PHICH}$ is given in table 9.1.2-1 for TDD.

For subframe bundling operation, the corresponding PHICH resource is associated with the last subframe in the bundle.

**Table 9.1.2-1: $k_{PHICH}$ for TDD**

| TDD UL/DL Configuration | subframe index *n* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | | | 4 | 7 | 6 | | | 4 | 7 | 6 |
| 1 | | | 4 | 6 | | | | 4 | 6 | |
| 2 | | | 6 | | | | | 6 | | |
| 3 | | | 6 | 6 | 6 | | | | | |
| 4 | | | 6 | 6 | | | | | | |
| 5 | | | 6 | | | | | | | |
| 6 | | | 4 | 6 | 6 | | | 4 | 7 | |

The PHICH resource is identified by the index pair $(n_{PHICH}^{group}, n_{PHICH}^{seq})$ where $n_{PHICH}^{group}$ is the PHICH group number and $n_{PHICH}^{seq}$ is the orthogonal sequence index within the group as defined by:

$$n_{PHICH}^{group} = (I_{PRB_RA} + n_{DMRS}) \bmod N_{PHICH}^{group} + I_{PHICH} N_{PHICH}^{group}$$
$$n_{PHICH}^{seq} = (\lfloor I_{PRB_RA} / N_{PHICH}^{group} \rfloor + n_{DMRS}) \bmod 2N_{SF}^{PHICH}$$

where

- $n_{DMRS}$ is mapped from the cyclic shift for DMRS field (according to Table 9.1.2-2) in the most recent PDCCH with uplink DCI format [4] for the transport block(s) associated with the corresponding PUSCH transmission. $n_{DMRS}$ shall be set to zero, if there is no PDCCH with uplink DCI format for the same transport block, and
  - if the initial PUSCH for the same transport block is semi-persistently scheduled, or
  - if the initial PUSCH for the same transport block is scheduled by the random access response grant .
- $N_{SF}^{PHICH}$ is the spreading factor size used for PHICH modulation as described in subclause 6.9.1 in [3].
- $I_{PRB_RA} = \begin{cases} I_{PRB_RA}^{lowest_index} & \text{for the first TB of a PUSCH with associated PDCCH or for the case of no associated PDCCH when the number of negatively acknowledged TBs is not equal to the number of TBs indicated in the most recent PDCCH associated with the corresponding PUSCH} \\ I_{PRB_RA}^{lowest_index} + 1 & \text{for a second TB of a PUSCH with associated PDCCH} \end{cases}$

  where $I_{PRB_RA}^{lowest_index}$ is the lowest PRB index in the first slot of the corresponding PUSCH transmission
- $N_{PHICH}^{group}$ is the number of PHICH groups configured by higher layers as described in subclause 6.9 of [3],
- $I_{PHICH} = \begin{cases} 1 & \text{for TDD UL/DL configuration 0 with PUSCH transmission in subframe } n = 4 \text{ or } 9 \\ 0 & \text{otherwise} \end{cases}$

**Table 9.1.2-2: Mapping between $n_{DMRS}$ and the cyclic shift for DMRS field in PDCCH with uplink DCI format in [4]**

| Cyclic Shift for DMRS Field in PDCCH with uplink DCI format in [4] | $n_{DMRS}$ |
|---|---|
| 000 | 0 |
| 001 | 1 |
| 010 | 2 |
| 011 | 3 |
| 100 | 4 |
| 101 | 5 |
| 110 | 6 |
| 111 | 7 |

## 9.1.3 Control Format Indicator (CFI) assignment procedure

PHICH duration is signalled by higher layers according to Table 6.9.3-1 in [3]. The duration signalled puts a lower limit on the size of the control region determined from the control format indicator (CFI). When $N_{RB}^{DL} > 10$, if extended PHICH duration is indicated by higher layers then the UE shall assume that CFI is equal to PHICH duration.

In subframes indicated by higher layers to decode PMCH, when $N_{RB}^{DL} > 10$, a UE may assume that CFI is equal to the value of the higher layer parameter *non-MBSFNregionLength* [11].

## 9.1.4 EPDCCH assignment procedure

For each serving cell, higher layer signalling can configure a UE with one or two EPDCCH-PRB-sets for EPDCCH monitoring. The PRB-pairs corresponding to an EPDCCH-PRB-set are indicated by higher layers as described in subclause 9.1.4.4. Each EPDCCH-PRB-set consists of set of ECCEs numbered from 0 to $N_{\mathrm{ECCE},p,k}-1$ where $N_{\mathrm{ECCE},p,k}$ is the number of ECCEs in EPDCCH-PRB-set $p$ of subframe $k$. Each EPDCCH-PRB-set can be configured for either localized EPDCCH transmission or distributed EPDCCH transmission.

The UE shall monitor a set of EPDCCH candidates on one or more activated serving cells as configured by higher layer signalling for control information, where monitoring implies attempting to decode each of the EPDCCHs in the set according to the monitored DCI formats.

The set of EPDCCH candidates to monitor are defined in terms of EPDCCH UE-specific search spaces.

For each serving cell, the subframes in which the UE monitors EPDCCH UE-specific search spaces are configured by higher layers.

The UE shall not monitor EPDCCH

- For TDD and normal downlink CP, in special subframes for the special subframe configurations 0 and 5 shown in Table 4.2-1 of [3].
- For TDD and extended downlink CP, in special subframes for the special subframe configurations 0, 4 and 7 shown in Table 4.2-1 of [3].
- In subframes indicated by higher layers to decode PMCH.
- For TDD and if the UE is configured with different UL/DL configurations for the primary and a secondary cell, in a downlink subframe on the secondary cell when the same subframe on the primary cell is a special subframe and the UE is not capable of simultaneous reception and transmission on the primary and secondary cells.

An EPDCCH UE-specific search space $ES_k^{(L)}$ at aggregation level $L \in \{1,2,4,8,16,32\}$ is defined by a set of EPDCCH candidates.

For an EPDCCH-PRB-set $p$, the ECCEs corresponding to EPDCCH candidate *m* of the search space $ES_k^{(L)}$ are given by

$$L\left\{(Y_{p,k}+\left\lfloor\frac{m\cdot N_{ECCE,p,k}}{L\cdot M_p^{(L)}}\right\rfloor+b)\bmod\left\lfloor N_{\mathrm{ECCE},p,k}/L\right\rfloor\right\}+i$$

where

$Y_{p,k}$ is defined below,

$i=0,\cdots,L-1$

$b=n_{CI}$ if the UE is configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, otherwise $b=0$

$n_{CI}$ is the carrier indicator field value,

$m=0,1,\ldots M_p^{(L)}-1$,

If the UE is not configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, $M_p^{(L)}$ is the number of EPDCCH candidates to monitor at aggregation level $L$ in EPDCCH-PRB-set $p$ for the serving cell on which EPDCCH is monitored, as given in Tables 9.1.4-1a, 9.1.4-1b, 9.1.4-2a, 9.1.4-2b, 9.1.4-3a, 9.1.4-3b, 9.1.4-4a,

9.4.4-4b, 9.1.4-5a, 9.1.4-5b below; otherwise, $M_p^{(L)}$ is the number of EPDCCH candidates to monitor at aggregation level $L$ in EPDCCH-PRB-set $p$ for the serving cell indicated by $n_{CI}$.

Note that the carrier indicator field value is the same as *ServCellIndex* given in [11].

A UE is not expected to monitor an EPDCCH candidate, if an ECCE corresponding to that EPDCCH candidate is mapped to a PRB pair that overlaps in frequency with a transmission of either PBCH or primary or secondary synchronization signals in the same subframe.

If a UE is configured with two EPDCCH-PRB-sets with the same $n_{\mathrm{ID},i}^{\mathrm{EPDCCH}}$ value (where $n_{\mathrm{ID},i}^{\mathrm{EPDCCH}}$ is defined in subclause 6.10.3A.1 in [3]), if the UE receives an EPDCCH candidate with a given DCI payload size corresponding to one of the EPDCCH-PRB-sets and mapped only to a given set of REs (as described in subclause 6.8A.5 in [3]), and if the UE is also configured to monitor an EPDCCH candidate with the same DCI payload size and corresponding to the other EPDCCH-PRB-set and which is mapped only to the same set of REs, and if the number of the first ECCE of the received EPDCCH candidate is used for determining PUCCH resource for HARQ-ACK transmission (as described in subclause 10.1.2 and subclause 10.1.3), the number of the first ECCE shall be determined based on EPDCCH-PRB-set $p = 0$.

The variable $Y_{p,k}$ is defined by

$$Y_{p,k} = \left(A_p \cdot Y_{p,k-1}\right) \bmod D$$

where $Y_{p,-1} = n_{\mathrm{RNTI}} \neq 0$, $A_0 = 39827$, $A_1 = 39829$, $D = 65537$ and $k = \lfloor n_s/2 \rfloor$, $n_s$ is the slot number within a radio frame. The RNTI value used for $n_{\mathrm{RNTI}}$ is defined in subclause 7.1 in downlink and subclause 8 in uplink. The DCI formats that the UE shall monitor depend on the configured transmission mode per each serving cell as defined in subclause 7.1.

The aggregation levels defining the search spaces and the number of monitored EPDCCH candidates is given as follows

- For a UE configured with only one EPDCCH-PRB-set for distributed transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-1a, Table 9.1.4-1b.
- For a UE configured with only one EPDCCH-PRB-set for localized transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-2a, Table 9.1.4-2b.
- For a UE configured with two EPDCCH-PRB-sets for distributed transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-3a, 9.1.4-3b.
- For a UE configured with two EPDCCH-PRB-sets for localized transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-4a, 9.4.4-4b.
- For a UE configured with one EPDCCH-PRB-set for distributed transmission, and one EPDCCH-PRB-set for localized transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-5a, 9.1.4-5b.

If the UE is not configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} = N_{\mathrm{RB}}^{\mathrm{DL}}$ of the serving cell on which EPDCCH is monitored. If the UE is configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} = N_{\mathrm{RB}}^{\mathrm{DL}}$ of the serving cell indicated by $n_{CI}$.

For Tables 9.1.4-1a, 9.1.4-1b, 9.1.4-2a, 9.1.4-2b, 9.1.4-3a, 9.1.4-3b, 9.1.4-4a, 9.4.4-4b, 9.1.4-5a, 9.1.4-5b

- Case 1 applies
  - for normal subframes and normal downlink CP when DCI formats 2/2A/2B/2C/2D are monitored and $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} \geq 25$ , or

- for special subframes with special subframe configuration 3,4,8 and normal downlink CP when DCI formats 2/2A/2B/2C/2D are monitored and $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} \geq 25$ , or
- for normal subframes and normal downlink CP when DCI formats 1A/1B/1D/1/2/2A/2B/2C/2D/0/4 are monitored, and when $n_{\mathrm{EPDCCH}} < 104$ ( $n_{\mathrm{EPDCCH}}$ defined in subclause 6.8A.1 in [3]), or
- for special subframes with special subframe configuration 3, 4, 8 and normal downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4 are monitored, and when $n_{\mathrm{EPDCCH}} < 104$ ( $n_{\mathrm{EPDCCH}}$ defined in subclause 6.8A.1 in [3]);

- Case 2 applies
  - for normal subframes and extended downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4 are monitored or,
  - for special subframes with special subframe configuration 1,2,6,7,9 and normal downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4 are monitored , or
  - for special subframes with special subframe configuration 1,2,3,5,6 and extended downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4 are monitored;
- otherwise
  - Case 3 is applied.

$N_{\mathrm{RB}}^{X_p}$ is the number of PRB-pairs constituting EPDCCH-PRB-set $p$ .

**Table 9.1.4-1a: EPDCCH candidates monitored by a UE (One Distributed EPDCCH-PRB-set - Case1, Case 2)**

| $N_{\mathrm{RB}}^{X_p}$ | Number of EPDCCH candidates $M_p^{(L)}$ for Case 1 | | | | | Number of EPDCCH candidates $M_p^{(L)}$ for Case 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L=2 | L=4 | L=8 | L=16 | L=32 | L=1 | L=2 | L=4 | L=8 | L=16 |
| 2 | 4 | 2 | 1 | 0 | 0 | 4 | 2 | 1 | 0 | 0 |
| 4 | 8 | 4 | 2 | 1 | 0 | 8 | 4 | 2 | 1 | 0 |
| 8 | 6 | 4 | 3 | 2 | 1 | 6 | 4 | 3 | 2 | 1 |

**Table 9.1.4-1b: EPDCCH candidates monitored by a UE (One Distributed EPDCCH-PRB-set – Case 3)**

| $N_{\mathrm{RB}}^{X_p}$ | Number of EPDCCH candidates $M_p^{(L)}$ for Case 3 | | | | |
|---|---|---|---|---|---|
| | L=1 | L=2 | L=4 | L=8 | L=16 |
| 2 | 8 | 4 | 2 | 1 | 0 |
| 4 | 4 | 5 | 4 | 2 | 1 |
| 8 | 4 | 4 | 4 | 2 | 2 |

**Table 9.1.4-2a: EPDCCH candidates monitored by a UE (One Localized EPDCCH-PRB-set - Case1, Case 2)**

| $N_{\mathrm{RB}}^{X_p}$ | Number of EPDCCH candidates $M_p^{(L)}$ for Case 1 | | | | Number of EPDCCH candidates $M_p^{(L)}$ for Case 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | L=2 | L=4 | L=8 | L=16 | L=1 | L=2 | L=4 | L=8 |
| 2 | 4 | 2 | 1 | 0 | 4 | 2 | 1 | 0 |
| 4 | 8 | 4 | 2 | 1 | 8 | 4 | 2 | 1 |
| 8 | 6 | 6 | 2 | 2 | 6 | 6 | 2 | 2 |

**Table 9.1.4-2b: EPDCCH candidates monitored by a UE (One Localized EPDCCH-PRB-set – Case 3)**

| $N_{RB}^{X_p}$ | Number of EPDCCH candidates $M_p^{(L)}$ for Case 3 | | | |
|---|---|---|---|---|
| | L=1 | L=2 | L=4 | L=8 |
| 2 | 8 | 4 | 2 | 1 |
| 4 | 6 | 6 | 2 | 2 |
| 8 | 6 | 6 | 2 | 2 |

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**Table 9.1.4-3a: EPDCCH candidates monitored by a UE (Two Distributed EPDCCH-PRB-sets - Case1, Case 2)**

| $N_{RB}^{Xp_1}$ | $N_{RB}^{Xp_2}$ | Number of EPDCCH candidates $[M_{p1}^{(L)}, M_{p2}^{(L)}]$ for Case 1 | | | | | Number of EPDCCH candidates $[M_{p1}^{(L)}, M_{p2}^{(L)}]$ for Case 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L=2 | L=4 | L=8 | L=16 | L=32 | L=1 | L=2 | L=4 | L=8 | L=16 |
| 2 | 2 | 4,4 | 2,2 | 1,1 | 0,0 | 0,0 | 4,4 | 2,2 | 1,1 | 0,0 | 0,0 |
| 4 | 4 | 3,3 | 3,3 | 1,1 | 1,1 | 0,0 | 3,3 | 3,3 | 1,1 | 1,1 | 0,0 |
| 8 | 8 | 3,3 | 2,2 | 1,1 | 1,1 | 1,1 | 3,3 | 2,2 | 1,1 | 1,1 | 1,1 |
| 4 | 2 | 5,3 | 3,2 | 1,1 | 1,0 | 0,0 | 5,3 | 3,2 | 1,1 | 1,0 | 0,0 |
| 8 | 2 | 4,2 | 4,2 | 1,1 | 1,0 | 1,0 | 4,2 | 4,2 | 1,1 | 1,0 | 1,0 |
| 8 | 4 | 3,3 | 2,2 | 2,1 | 1,1 | 1,0 | 3,3 | 2,2 | 2,1 | 1,1 | 1,0 |

**Table 9.1.4-3b: EPDCCH candidates monitored by a UE (Two Distributed EPDCCH-PRB-sets – Case 3)**

| $N_{RB}^{Xp_1}$ | $N_{RB}^{Xp_2}$ | Number of EPDCCH candidates $[M_{p1}^{(L)}, M_{p2}^{(L)}]$ for Case 3 | | | | |
|---|---|---|---|---|---|---|
| | | L=1 | L=2 | L=4 | L=8 | L=16 |
| 2 | 2 | 2,2 | 3,3 | 2,2 | 1,1 | 0,0 |
| 4 | 4 | 2,2 | 2,2 | 2,2 | 1,1 | 1,1 |
| 8 | 8 | 2,2 | 2,2 | 2,2 | 1,1 | 1,1 |
| 4 | 2 | 3,1 | 3,2 | 3,1 | 1,1 | 1,0 |
| 8 | 2 | 3,1 | 4,1 | 3,1 | 1,1 | 1,0 |
| 8 | 4 | 2,2 | 2,2 | 2,2 | 1,1 | 1,1 |

**Table 9.1.4-4a: EPDCCH candidates monitored by a UE (Two Localized EPDCCH-PRB-sets - Case1, Case 2)**

| $N_{RB}^{Xp_1}$ | $N_{RB}^{Xp_2}$ | Number of EPDCCH candidates $[M_{p1}^{(L)}, M_{p2}^{(L)}]$ for Case 1 | | | | Number of EPDCCH candidates $[M_{p1}^{(L)}, M_{p2}^{(L)}]$ for Case 2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | L=2 | L=4 | L=8 | L=16 | L=1 | L=2 | L=4 | L=8 |
| 2 | 2 | 4,4 | 2,2 | 1,1 | 0,0 | 4,4 | 2,2 | 1,1 | 0,0 |
| 4 | 4 | 3,3 | 3,3 | 1,1 | 1,1 | 3,3 | 3,3 | 1,1 | 1,1 |
| 8 | 8 | 3,3 | 3,3 | 1,1 | 1,1 | 3,3 | 3,3 | 1,1 | 1,1 |
| 4 | 2 | 4,3 | 4,2 | 1,1 | 1,0 | 4,3 | 4,2 | 1,1 | 1,0 |
| 8 | 2 | 5,2 | 4,2 | 1,1 | 1,0 | 5,2 | 4,2 | 1,1 | 1,0 |
| 8 | 4 | 3,3 | 3,3 | 1,1 | 1,1 | 3,3 | 3,3 | 1,1 | 1,1 |

**Table 9.1.4-4b: EPDCCH candidates monitored by a UE (Two Localized EPDCCH-PRB-sets – Case 3)**

| $N_{RB}^{Xp_1}$ | $N_{RB}^{Xp_2}$ | Number of EPDCCH candidates $[M_{p1}^{(L)}, M_{p2}^{(L)}]$ for Case 3 | | | |
|---|---|---|---|---|---|
| | | L=1 | L=2 | L=4 | L=8 |
| 2 | 2 | 3,3 | 3,3 | 1,1 | 1,1 |
| 4 | 4 | 3,3 | 3,3 | 1,1 | 1,1 |
| 8 | 8 | 3,3 | 3,3 | 1,1 | 1,1 |
| 4 | 2 | 4,2 | 4,2 | 1,1 | 1,1 |
| 8 | 2 | 4,2 | 4,2 | 1,1 | 1,1 |
| 8 | 4 | 3,3 | 3,3 | 1,1 | 1,1 |

**Table 9.1.4-5a: EPDCCH candidates monitored by a UE (NOTE)**

| $N_{RB}^{Xp_1}$ | $N_{RB}^{Xp_2}$ | Number of EPDCCH candidates $[M_{p1}^{(L)}, M_{p2}^{(L)}]$ for Case 1 | | | | | Number of EPDCCH candidates $[M_{p1}^{(L)}, M_{p2}^{(L)}]$ for Case 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L=2 | L=4 | L=8 | L=16 | L=32 | L=1 | L=2 | L=4 | L=8 | L=16 |
| 2 | 2 | 4,4 | 2,2 | 1,1 | 0,0 | 0,0 | 4,4 | 2,2 | 1,1 | 0,0 | 0,0 |
| 4 | 4 | 4,2 | 4,3 | 0,2 | 0,1 | 0,0 | 4,2 | 4,3 | 0,2 | 0,1 | 0,0 |
| 8 | 8 | 4,1 | 4,2 | 0,2 | 0,2 | 0,1 | 4,1 | 4,2 | 0,2 | 0,2 | 0,1 |
| 2 | 4 | 4,3 | 2,4 | 0,2 | 0,1 | 0,0 | 4,3 | 2,4 | 0,2 | 0,1 | 0,0 |
| 2 | 8 | 4,1 | 2,2 | 0,4 | 0,2 | 0,1 | 4,1 | 2,2 | 0,4 | 0,2 | 0,1 |
| 4 | 2 | 5,2 | 4,2 | 1,1 | 1,0 | 0,0 | 5,2 | 4,2 | 1,1 | 1,0 | 0,0 |
| 4 | 8 | 4,1 | 4,2 | 0,2 | 0,2 | 0,1 | 4,1 | 4,2 | 0,2 | 0,2 | 0,1 |
| 8 | 2 | 5,1 | 4,2 | 2,1 | 1,0 | 0,0 | 5,1 | 4,2 | 2,1 | 1,0 | 0,0 |
| 8 | 4 | 6,1 | 4,2 | 0,2 | 0,1 | 0,0 | 6,1 | 4,2 | 0,2 | 0,1 | 0,0 |

NOTE: One localized EPDCCH-PRB-set and one distributed EPDCCH-PRB-set, - Case1, Case 2;
$p_1$ is the identity of the localized EPDCCH-PRB-set,
$p_2$ is the identity of the distributed EPDCCH-PRB-set

**Table 9.1.4-5b: EPDCCH candidates monitored by a UE (NOTE)**
**(**

| $N_{RB}^{Xp_1}$ | $N_{RB}^{Xp_2}$ | Number of EPDCCH candidates $[M_{p1}^{(L)}, M_{p2}^{(L)}]$ for Case 3 | | | | |
|---|---|---|---|---|---|---|
| | | L=1 | L=2 | L=4 | L=8 | L=16 |
| 2 | 2 | 4,1 | 4,2 | 2,2 | 0,1 | 0,0 |
| 4 | 4 | 4,1 | 4,1 | 2,2 | 0,1 | 0,1 |
| 8 | 8 | 4,1 | 4,1 | 2,2 | 0,1 | 0,1 |
| 2 | 4 | 4,1 | 4,1 | 2,2 | 0,1 | 0,1 |
| 2 | 8 | 4,1 | 4,1 | 2,2 | 0,1 | 0,1 |
| 4 | 2 | 4,1 | 4,1 | 2,2 | 1,1 | 0,0 |
| 4 | 8 | 4,1 | 4,1 | 2,2 | 0,1 | 0,1 |
| 8 | 2 | 4,1 | 4,1 | 4,1 | 0,1 | 0,0 |
| 8 | 4 | 4,1 | 4,1 | 2,2 | 0,1 | 0,1 |

NOTE: One localized EPDCCH-PRB-set and one distributed EPDCCH-PRB-set - Case 3);
$p_1$ is the identity of the localized EPDCCH-PRB-set,
$p_2$ is the identity of the distributed EPDCCH-PRB-set)

If the UE is not configured with a carrier indicator field, then the UE shall monitor one EPDCCH UE-specific search space at each of the aggregation levels given by Tables 9.1.4-1a to 9.1.4-5b on each activated serving cell for which it is configured to monitor EPDCCH.

If a UE is configured for EPDCCH monitoring, and if the UE is configured with a carrier indicator field, then the UE shall monitor one or more EPDCCH UE-specific search spaces at each of the aggregation levels given by Tables 9.1.4-1a to 9.1.4-5b on one or more activated serving cells as configured by higher layer signalling.

A UE configured with the carrier indicator field associated with monitoring EPDCCH on serving cell *c* shall monitor EPDCCH configured with carrier indicator field and with CRC scrambled by C-RNTI in the EPDCCH UE specific search space of serving cell *c*.

A UE configured with the carrier indicator field associated with monitoring EPDCCH on the primary cell shall monitor EPDCCH configured with carrier indicator field and with CRC scrambled by SPS C-RNTI in the EPDCCH UE specific search space of the primary cell.

For the serving cell on which EPDCCH is monitored, if the UE is not configured with a carrier indicator field, it shall monitor the EPDCCH UE specific search space for EPDCCH without carrier indicator field, if the UE is configured with a carrier indicator field it shall monitor the EPDCCH UE specific search space for EPDCCH with carrier indicator field.

A UE is not expected to monitor the EPDCCH of a secondary cell if it is configured to monitor EPDCCH with carrier indicator field corresponding to that secondary cell in another serving cell. For the serving cell on which EPDCCH is monitored, the UE shall monitor EPDCCH candidates at least for the same serving cell.

A UE configured to monitor EPDCCH candidates in a given serving cell with a given DCI format size with CIF, and CRC scrambled by C- RNTI, where the EPDCCH candidates may have one or more possible values of CIF for the given DCI format size, shall assume that an EPDCCH candidate with the given DCI format size may be transmitted in the given serving cell in any EPDCCH UE specific search space corresponding to any of the possible values of CIF for the given DCI format size.

For the serving cell on which EPDCCH is monitored, a UE is not required to monitor the EPDCCH in a subframe which is configured by higher layers to be part of a positioning reference signal occasion if the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix.

A UE may assume the same $c_{\text{init}}$ value (described in subclause 6.10.3A.1 of [3]) is used for antenna ports 107,108 while monitoring an EPDCCH candidate associated with either antenna port 107 or antenna port 108.
A UE may assume the same $c_{\text{init}}$ value (described in subclause 6.10.3A.1 of [3]) is used for antenna ports 109,110 while monitoring an EPDCCH candidate associated with either antenna port 109 or antenna port 110.

### 9.1.4.1 EPDCCH starting position

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission modes 1-9,

- if the UE is configured with a higher layer parameter *epdcch-StartSymbol-r11*,
  - the starting OFDM symbol for EPDCCH given by index $l_{\text{EPDCCHStart}}$ in the first slot in a subframe is determined from the higher layer parameter,
- otherwise
  - the starting OFDM symbol for EPDCCH given by index $l_{\text{EPDCCHStart}}$ in the first slot in a subframe is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{EPDCCHStart}}$ is given by the CFI value+1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \le 10$

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission mode 10, for each EPDCCH-PRB-set, the starting OFDM symbol for monitoring EPDCCH in subframe $k$ is determined from the higher layer parameter *pdsch-Start-r11* (defined in subclause 9.1.4.3) as follows

- if the value of the parameter *pdsch-Start-r11* belongs to {1,2,3,4},
  - $l'_{EPDCCHStart}$ is given by the higher layer parameter *pdsch-Start-r11*
- otherwise

- $l'_{EPDCCHStart}$ is given by the CFI value in subframe $k$ of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, and
  $l'_{EPDCCHStart}$ is given by the CFI value+1 in subframe $k$ of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} \le 10$

- if subframe $k$ is indicated by the higher layer parameter *mbsfn-SubframeConfigList-r11* (defined in subclause 9.1.4.3), or if subframe $k$ is subframe 1 or 6 for frame structure type 2,
  - $l_{EPDCCHStart} = \min(2, l'_{EPDCCHStart})$,
- otherwise
  - $l_{\mathrm{EPDCCHStart}} = l'_{\mathrm{EPDCCHStart}}$.

### 9.1.4.2 Antenna ports quasi co-location for EPDCCH

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission modes 1-9, and if the UE is configured to monitor EPDCCH,

- the UE may assume the antenna ports 0 – 3, 107 – 110 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission mode 10, and if the UE is configured to monitor EPDCCH, for each EPDCCH-PRB-set,

- if the UE is configured by higher layers to decode PDSCH according to quasi co-location Type-A as described in subclause 7.1.10
  - the UE may assume the antenna ports 0 – 3, 107 – 110 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread..
- if the UE is configured by higher layers to decode PDSCH according to quasi co-location Type-B as described in subclause 7.1.10
  - the UE may assume antenna ports 15 – 22 corresponding to the higher layer parameter *qcl-CSI-RS-ConfigNZPId-r11* (defined in subclause 9.1.4.3) and antenna ports 107-110 are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

### 9.1.4.3 Resource mapping parameters for EPDCCH

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission mode 10, and if the UE is configured to monitor EPDCCH, for each EPDCCH-PRB-set, the UE shall use the parameter set indicated by the higher layer parameter *re-MappingQCL-ConfigId-r11* for determining the EPDCCH RE mapping (defined in subclause 6.8A.5 of [3]) and EPDCCH antenna port quasi co-location. The following parameters for determining EPDCCH RE mapping (as described in subclause 6.8A.5 of [3]) and EPDCCH antenna port quasi co-location are included in the parameter set:

- *crs-PortsCount-r11*.
- *crs-FreqShift-r11*.
- *mbsfn-SubframeConfigList-r11*.
- *csi-RS-ConfigZPId-r11*.
- *pdsch-Start-r11*.
- *qcl-CSI-RS-ConfigNZPId-r11*.

### 9.1.4.4 PRB-pair indication for EPDCCH

For a given serving cell, for each EPDCCH-PRB-pair set $p$, the UE is configured with a higher layer parameter *resourceBlockAssignment-r11* indicating a combinatorial index $r$ corresponding to the PRB index $\{k_i\}_{i=0}^{N_{RB}^{X_p}-1}$, ($1 \le k_i \le N_{RB}^{DL}$, $k_i < k_{i+1}$) and given by equation $r = \sum_{i=0}^{N_{RB}^{X_p}-1} \left\langle \begin{matrix} N_{RB}^{DL} - k_i \\ N_{RB}^{X_p} - i \end{matrix} \right\rangle$, where $N_{RB}^{DL}$ is the number of PRB pairs associated with the downlink bandwidth, $N_{\mathrm{RB}}^{X_p}$ is the number of PRB-pairs constituting EPDCCH-PRB-set $p$, and is

configured by the higher layer parameter *numberPRBPairs-r11,* and $\left\langle \begin{matrix} x \\ y \end{matrix} \right\rangle = \begin{cases} \begin{pmatrix} x \\ y \end{pmatrix} & x \geq y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label $r \in \left\{ 0,...,\begin{pmatrix} N_{RB}^{DL} \\ N_{RB}^{X_p} \end{pmatrix} - 1 \right\}$.

## 9.2 PDCCH/EPDCCH validation for semi-persistent scheduling

A UE shall validate a Semi-Persistent Scheduling assignment PDCCH only if all the following conditions are met:

- the CRC parity bits obtained for the PDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI
- the new data indicator field is set to '0'. In case of DCI formats 2, 2A, 2B, 2C and 2D, the new data indicator field refers to the one for the enabled transport block.

A UE shall validate a Semi-Persistent Scheduling assignment EPDCCH only if all the following conditions are met:

- the CRC parity bits obtained for the EPDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI
- the new data indicator field is set to '0'. In case of DCI formats 2, 2A, 2B, 2C and 2D, the new data indicator field refers to the one for the enabled transport block.

Validation is achieved if all the fields for the respective used DCI format are set according to Table 9.2-1 or Table 9.2-1A.

If validation is achieved, the UE shall consider the received DCI information accordingly as a valid semi-persistent activation or release.

If validation is not achieved, the received DCI format shall be considered by the UE as having been received with a non-matching CRC.

**Table 9.2-1: Special fields for Semi-Persistent Scheduling Activation PDCCH/EPDCCH Validation**

| | DCI format 0 | DCI format 1/1A | DCI format 2/2A/2B/2C/2D |
|---|---|---|---|
| **TPC command for scheduled PUSCH** | set to '00' | N/A | N/A |
| **Cyclic shift DM RS** | set to '000' | N/A | N/A |
| **Modulation and coding scheme and redundancy version** | MSB is set to '0' | N/A | N/A |
| **HARQ process number** | N/A | FDD: set to '000'<br>TDD: set to '0000' | FDD: set to '000'<br>TDD: set to '0000' |
| **Modulation and coding scheme** | N/A | MSB is set to '0' | For the enabled transport block: MSB is set to '0' |
| **Redundancy version** | N/A | set to '00' | For the enabled transport block: set to '00' |

**Table 9.2-1A: Special fields for Semi-Persistent Scheduling Release PDCCH/EPDCCH Validation**

| | DCI format 0 | DCI format 1A |
|---|---|---|
| **TPC command for scheduled PUSCH** | set to '00' | N/A |
| **Cyclic shift DM RS** | set to '000' | N/A |
| **Modulation and coding scheme and redundancy version** | set to '11111' | N/A |
| **Resource block assignment and hopping resource allocation** | Set to all '1's | N/A |
| **HARQ process number** | N/A | FDD: set to '000'<br>TDD: set to '0000' |
| **Modulation and coding scheme** | N/A | set to '11111' |
| **Redundancy version** | N/A | set to '00' |
| **Resource block assignment** | N/A | Set to all '1's |

For the case that the DCI format indicates a semi-persistent downlink scheduling activation, the TPC command for PUCCH field shall be used as an index to one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 9.2-2

**Table 9.2-2: PUCCH resource value for downlink semi-persistent scheduling**

| Value of 'TPC command for PUCCH' | $n_{\mathrm{PUCCH}}^{(1,p)}$ |
|---|---|
| '00' | The first PUCCH resource value configured by the higher layers |
| '01' | The second PUCCH resource value configured by the higher layers |
| '10' | The third PUCCH resource value configured by the higher layers |
| '11' | The fourth PUCCH resource value configured by the higher layers |

## 9.3 PDCCH/EPDCCH control information procedure

A UE shall discard the PDCCH/EPDCCH if consistent control information is not detected.

# 10 Physical uplink control channel procedures

## 10.1 UE procedure for determining physical uplink control channel assignment

If the UE is configured for a single serving cell and is not configured for simultaneous PUSCH and PUCCH transmissions, then in subframe $n$ uplink control information (UCI) shall be transmitted

- on PUCCH using format 1/1a/1b/3 or 2/2a/2b if the UE is not transmitting on PUSCH
- on PUSCH if the UE is transmitting on PUSCH in subframe $n$ unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted

If the UE is configured for a single serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe $n$ UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCI consists only of HARQ-ACK and/or SR
- on PUCCH using format 2 if the UCI consists only of periodic CSI
- on PUCCH using format 2/2a/2b/3 if the UCI consists of periodic CSI and HARQ-ACK and if the UE is not transmitting PUSCH
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK/HARQ-ACK+SR/positive SR and periodic/aperiodic CSI in which case the HARQ-ACK/HARQ-ACK+SR/positive SR is transmitted on PUCCH using format 1/1a/1b/3 and the periodic/aperiodic CSI transmitted on PUSCH unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case periodic/aperiodic CSI is not transmitted

If the UE is configured with more than one serving cell and is not configured for simultaneous PUSCH and PUCCH transmission, then in subframe $n$ UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 or 2/2a/2b if the UE is not transmitting PUSCH
- on PUSCH of the serving cell given in subclause 7.2.1 if the UCI consists of aperiodic CSI or aperiodic CSI and HARQ-ACK
- on primary cell PUSCH if the UCI consists of periodic CSI and/or HARQ-ACK and if the UE is transmitting on the primary cell PUSCH in subframe $n$ unless the primary cell PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted
- on PUSCH of the secondary cell with smallest *SCellIndex* if the UCI consists of periodic CSI and/or HARQ-ACK and if the UE is not transmitting PUSCH on primary cell but is transmitting PUSCH on at least one secondary cell

If the UE is configured with more than one serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe $n$ UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCI consists only of HARQ-ACK and/or SR
- on PUCCH using format 2 if the UCI consists only of periodic CSI
- as described in subclause 10.1.1, if the UCI consists of periodic CSI and HARQ-ACK and if the UE is not transmitting on PUSCH
- on PUCCH and primary cell PUSCH if the UCI consists of HARQ-ACK and periodic CSI and the UE is transmitting PUSCH on the primary cell, in which case the HARQ-ACK is transmitted on PUCCH using format 1a/1b/3 and the periodic CSI is transmitted on PUSCH unless the primary cell PUSCH transmission

corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case periodic CSI is not transmitted

- on PUCCH and PUSCH of the secondary cell with the smallest *SCellIndex* if the UCI consists of HARQ-ACK and periodic CSI and if the UE is not transmitting PUSCH on primary cell but is transmitting PUSCH on at least one secondary cell, in which case, the HARQ-ACK is transmitted on PUCCH using format 1a/1b/3 and the periodic CSI is transmitted on PUSCH
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK/HARQ-ACK+SR/positive SR and aperiodic CSI in which case the HARQ-ACK/HARQ-ACK+SR/positive SR is transmitted on PUCCH using format 1/1a/1b/3 and the aperiodic CSI is transmitted on PUSCH of the serving cell given in subclause 7.2.1

If the UE is configured with more than one serving cell, then reporting prioritization and collision handling of periodic CSI reports of a certain PUCCH reporting type is given in subclause 7.2.2.

A UE transmits PUCCH only on the primary cell.

A UE is configured by higher layers to transmit PUCCH on one antenna port $(p = p_0)$ or two antenna ports $(p \in [p_0, p_1])$.

For FDD with two configured serving cells and PUCCH format 1b with channel selection or for FDD with two or more configured serving cells and PUCCH format 3, $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} N_c^{\text{received}}$ where $N_{cells}^{DL}$ is the number of configured cells and $N_c^{\text{received}}$ is the number of transport blocks or the SPS release PDCCH/EPDCCH, if any, received in subframe $n-4$ in serving cell $c$.

For TDD, if a UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configurations of all serving cells are the same, then

- For TDD with two configured serving cells and PUCCH format 1b with channel selection and a subframe $n$ with $M = 1$, or for TDD UL/DL configuration 0 and PUCCH format 3, $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} \sum_{k \in K} N_{k,c}^{\text{received}}$, where $N_{k,c}^{\text{received}}$ is the number of transport blocks or the SPS release PDCCH/EPDCCH, if any, received in subframe $n-k$ in serving cell $c$, where $k \in K$, and $M$ is the number of elements in $K$.
- For TDD UL/DL configurations 1-6 and PUCCH format 3, or for TDD with two configured serving cells and PUCCH format 1b with channel selection and $M = 2$, $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} \left( \left( \left( V_{\text{DAI},c}^{\text{DL}} - U_{\text{DAI},c} \right) \bmod 4 \right) \cdot n_c^{\text{ACK}} + \sum_{k \in K} N_{k,c}^{\text{received}} \right)$ where $V_{\text{DAI, c}}^{\text{DL}}$ is the $V_{\text{DAI}}^{\text{DL}}$ in serving cell $c$, $U_{\text{DAI, c}}$ is the $U_{\text{DAI}}$ in serving cell $c$, and $n_c^{ACK}$ is the number of HARQ-ACK bits corresponding to the configured DL transmission mode on serving cell $c$. In case spatial HARQ-ACK bundling is applied, $n_c^{\text{ACK}} = 1$ and $N_{k,c}^{\text{received}}$ is the number of PDCCH/EPDCCH or PDSCH without a corresponding PDCCH/EPDCCH received in subframe $n-k$ and serving cell $c$, where $k \in K$ and $M$ is the number of elements in $K$. In case spatial HARQ-ACK bundling is not applied, $N_{k,c}^{\text{received}}$ is the number of transport blocks received or the SPS release PDCCH/EPDCCH received in subframe $n-k$ in serving cell $c$, where $k \in K$ and $M$ is the number of elements in $K$. $V_{\text{DAI, c}}^{\text{DL}} = 0$ if no transport block or SPS release PDCCH/EPDCCH is detected in subframe(s) $n-k$ in serving cell $c$, where $k \in K$.
- For TDD with two configured serving cells and PUCCH format 1b with channel selection and $M = 3$ or 4, $n_{\text{HARQ}} = 2$ if UE receives PDSCH or PDCCH/EPDCCH indicating downlink SPS release only on one serving cell within subframes $n-k$, where $k \in K$; otherwise $n_{\text{HARQ}} = 4$.

For TDD if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then

- For PUCCH format 3, or for TDD with two configured serving cells and PUCCH format 1b with channel selection and $M \le 2$ (defined in subclause 10.1.3.2.1),
  $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} \left( \left( \left( V_{\text{DAI},c}^{\text{DL}} - U_{\text{DAI},c} \right) \bmod 4 \right) \cdot n_c^{\text{ACK}} + \sum_{k \in K} N_{k,c}^{\text{received}} \right)$ where $V_{\text{DAI, c}}^{\text{DL}}$ is the $V_{\text{DAI}}^{\text{DL}}$ in serving cell $c$, $U_{\text{DAI, c}}$ is the $U_{\text{DAI}}$ in serving cell $c$, and $n_c^{ACK}$ is the number of HARQ-ACK bits corresponding to the configured DL transmission mode on serving cell $c$. In case spatial HARQ-ACK bundling is applied, $n_c^{\text{ACK}} = 1$ and $N_{k,c}^{\text{received}}$ is the number of PDCCH/EPDCCH or PDSCH without a corresponding PDCCH/EPDCCH received in subframe $n-k$ and serving cell $c$, where $k \in K$ and $K = K_c$ (defined in subclause 7.3.2.2). In case spatial HARQ-ACK bundling is not applied, $N_{k,c}^{\text{received}}$ is the number of transport blocks received or the SPS release PDCCH/EPDCCH received in subframe $n-k$ in serving cell $c$, where $k \in K$ and $K = K_c$ (defined in subclause 7.3.2.2). $V_{\text{DAI, c}}^{\text{DL}}$=0 if no transport block or SPS release PDCCH/EPDCCH is detected in subframe(s) $n-k$ in serving cell $c$, where $k \in K$ and $K = K_c$ (defined in subclause 7.3.2.2). For a serving cell $c$, set $V_{\text{DAI, c}}^{\text{DL}} = U_{\text{DAI, c}}$ if the DL-reference UL/DL configuration (defined in subclause 10.2) for serving cell $c$ is TDD UL/DL configuration 0,
- For TDD with two configured serving cells and PUCCH format 1b with channel selection and $M$ = 3 or 4 (defined in subclause 10.1.3.2.1), $n_{\text{HARQ}} = 2$ if UE receives PDSCH or PDCCH/EPDCCH indicating downlink SPS release only on one serving cell within subframes $n-k$ ,where $k \in K$ and $K = K_c$ (defined in subclause 7.3.2.2);otherwise $n_{\text{HARQ}} = 4$.

Throughout the following subclauses, subframes are numbered in monotonically increasing order; if the last subframe of a radio frame is denoted as $k$, the first subframe of the next radio frame is denoted as $k+1$.

Throughout the following subclauses, if the UE is configured with higher layer parameter *n1PUCCH-AN-r11* then $N_{\text{PUCCH}}^{(1)}$ is given by *n1PUCCH-AN-r11*, else $N_{\text{PUCCH}}^{(1)}$ is given by higher layer parameter *n1PUCCH-AN*.

## 10.1.1 PUCCH format information

Using the PUCCH formats defined in subclause 5.4.1 and 5.4.2 in [3], the following combinations of UCI on PUCCH are supported:

- Format 1a for 1-bit HARQ-ACK or in case of FDD for 1-bit HARQ-ACK with positive SR
- Format 1b for 2-bit HARQ-ACK or for 2-bit HARQ-ACK with positive SR
- Format 1b for up to 4-bit HARQ-ACK with channel selection when the UE is configured with more than one serving cell or, in the case of TDD, when the UE is configured with a single serving cell
- Format 1 for positive SR
- Format 2 for a CSI report when not multiplexed with HARQ-ACK
- Format 2a for a CSI report multiplexed with 1-bit HARQ-ACK for normal cyclic prefix
- Format 2b for a CSI report multiplexed with 2-bit HARQ-ACK for normal cyclic prefix
- Format 2 for a CSI report multiplexed with HARQ-ACK for extended cyclic prefix
- Format 3 for up to 10-bit HARQ-ACK for FDD and for up to 20-bit HARQ-ACK for TDD
- Format 3 for up to 11-bit corresponding to 10-bit HARQ-ACK and 1-bit positive/negative SR for FDD and for up to 21-bit corresponding to 20-bit HARQ-ACK and 1-bit positive/negative SR for TDD.

- Format 3 for HARQ-ACK, 1-bit positive/negative SR (if any) and a CSI report for one serving cell.

For a UE configured with PUCCH format 3 and HARQ-ACK transmission on PUSCH or using PUCCH format 3, or for a UE configured with two serving cells and PUCCH format 1b with channel selection and HARQ-ACK transmission on PUSCH, or for UE configured with one serving cell and PUCCH format 1b with channel selection according to Tables 10.1.3-5, 10.1.3-6, 10.1.3-7 and HARQ-ACK transmission on PUSCH:

- if the configured downlink transmission mode for a serving cell supports up to 2 transport blocks and only one transport block is received in a subframe, the UE shall generate a NACK for the other transport block if spatial HARQ-ACK bundling is not applied.
- if neither PDSCH nor PDCCH/EPDCCH indicating downlink SPS release is detected in a subframe for a serving cell, the UE shall generate two NACKs when the configured downlink transmission mode supports up to 2 transport blocks and the UE shall generate a single NACK when the configured downlink transmission mode supports a single transport block.

The scrambling initialization of PUCCH format 2, 2a, 2b and 3 is by C-RNTI.

For a UE that is configured with a single serving cell and is not configured with PUCCH format 3, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, the periodic CSI report is multiplexed with HARQ-ACK on PUCCH if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, otherwise the CSI is dropped.

For TDD and for a UE that is configured with a single serving cell and with PUCCH format 3, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE* or if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*, the periodic CSI report is multiplexed with HARQ-ACK or dropped as described in subclause 7.3, otherwise the CSI is dropped.

For FDD and for a UE that is configured with more than one serving cell, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH,

- if the parameter simultaneousAckNackAndCQI provided by higher layers is set TRUE and if the HARQ-ACK corresponds to a PDSCH transmission or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell,

  then the periodic CSI report is multiplexed with HARQ-ACK on PUCCH using PUCCH format 2/2a/2b

- else if the UE is configured with PUCCH format 3 and if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*, and if PUCCH resource is determined according to subclause 10.1.2.2.2, and
  - if the total number of bits in the subframe corresponding to HARQ-ACKs, SR (if any), and the CSI is not larger than 22 or
  - if the total number of bits in the subframe corresponding to spatially bundled HARQ-ACKs, SR (if any), and the CSI is not larger than 22

    then the periodic CSI report is multiplexed with HARQ-ACK on PUCCH using the determined PUCCH format 3 resource according to [4]

- otherwise,

  CSI is dropped.

For TDD and for a UE that is configured with more than one serving cell, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE* or if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*, the periodic CSI report is multiplexed with HARQ-ACK or dropped as described in subclause 7.3, otherwise the CSI is dropped.

In case of collision between a periodic CSI report and an HARQ-ACK in a same subframe with PUSCH, the periodic CSI is multiplexed with the HARQ-ACK in the PUSCH transmission in that subframe if the UE is not configured by higher layers for simultaneous PUCCH and PUSCH transmissions. Otherwise, if the UE is configured by higher layers

for simultaneous PUCCH and PUSCH transmissions, the HARQ-ACK is transmitted in the PUCCH and the periodic CSI is transmitted in the PUSCH.

## 10.1.2 FDD HARQ-ACK feedback procedures

For FDD and for a UE transmitting HARQ-ACK using PUCCH format 1b with channel selection or PUCCH format 3, the UE shall determine the number of HARQ-ACK bits, $O$, based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that support up to two transport blocks; and one HARQ-ACK bit otherwise.

A UE that supports aggregating at most 2 serving cells with frame structure type 1 shall use PUCCH format 1b with channel selection for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

A UE that supports aggregating more than 2 serving cells with frame structure type 1 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3 for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

The FDD HARQ-ACK feedback procedure for one configured serving cell is given in subclause 10.1.2.1 and procedures for more than one configured serving cell are given in subclause 10.1.2.2.

### 10.1.2.1 FDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 1a/1b.

For FDD and one configured serving cell, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe $n$ for $\tilde{p}$ mapped to antenna port $p$ for PUCCH format 1a/1b [3], where

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$, the UE shall use $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port $p_0$, where $n_{\text{CCE}}$ is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding DCI assignment and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers. For two antenna port transmission the PUCCH resource for antenna port $p_1$ is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.
- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port $p_0$ and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port $p_1$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port $p_0$.
- for a PDSCH transmission indicated by the detection of a corresponding EPDCCH in subframe $n-4$, or for an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$, the UE shall use
  - if EPDCCH-PRB-set $q$ is configured for distributed transmission
    $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{ECCE,q}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$
  - if EPDCCH-PRB-set $q$ is configured for localized transmission
    $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$

for antenna port $p_0$, where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set $q$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for localized EPDCCH transmission which is described in subclause 6.8A.5 in [3]. For two antenna port transmission the PUCCH resource for antenna port $p_1$ is given by

- if EPDCCH-PRB-set $q$ is configured for distributed transmission
  $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)} = n_{\mathrm{ECCE,q}} + 1 + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$
- if EPDCCH-PRB-set $q$ is configured for localized transmission
  $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + n' + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$

**Table 10.1.2.1-1: Mapping of ACK/NACK Resource offset Field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D to $\Delta_{ARO}$ values**

| ACK/NACK Resource offset field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D | $\Delta_{ARO}$ |
|---|---|
| 0 | 0 |
| 1 | -1 |
| 2 | -2 |
| 3 | 2 |

### 10.1.2.2 FDD HARQ-ACK procedures for more than one configured serving cell

The FDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in subclause 10.1.2.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in subclause 10.1.2.2.2.

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 3.

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 1b with channel selection and FDD with two configured serving cells.

#### 10.1.2.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

For FDD with two configured serving cells and PUCCH format 1b with channel selection, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port $p$ using PUCCH format 1b where

- $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)} = n_{\mathrm{PUCCH}}^{(1)}$ for antenna port $p_0$ where $n_{\mathrm{PUCCH}}^{(1)}$ is selected from $A$ PUCCH resources, $n_{\mathrm{PUCCH},j}^{(1)}$ where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Table 10.1.2.2.1-3, Table 10.1.2.2.1-4, Table 10.1.2.2.1-5 in subframe $n$. HARQ-ACK($j$) denotes the ACK/NACK/DTX response for a transport block or SPS release PDCCH/EPDCCH associated with serving cell $c$, where the transport block and serving cell for HARQ-ACK($j$) and $A$ PUCCH resources are given by Table 10.1.2.2.1-1.
- $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port $p_1$, where $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ is selected from $A$ PUCCH resources, $n_{\mathrm{PUCCH},j}^{(1,\tilde{p}_1)}$ configured by higher layers where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Table 10.1.2.2.1-3, Table 10.1.2.2.1-4, Table

10.1.2.2.1-5 by replacing $n^{(1)}_{\text{PUCCH}}$ with $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ and replacing $n^{(1)}_{\text{PUCCH},i}$ with $n^{(1,\tilde{p}_1)}_{\text{PUCCH},i}$ in subframe $n$, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection.

A UE configured with a transmission mode that supports up to two transport blocks on serving cell, $c$, shall use the same HARQ-ACK response for both the transport blocks in response to a PDSCH transmission with a single transport block or a PDCCH/EPDCCH indicating downlink SPS release associated with the serving cell $c$.

**Table 10.1.2.2.1-1: Mapping of Transport Block and Serving Cell to HARQ-ACK(*j*) for PUCCH format 1b HARQ-ACK channel selection**

| A | *HARQ-ACK(j)* | | | |
|---|---|---|---|---|
| | HARQ-ACK(0) | HARQ-ACK(1) | HARQ-ACK(2) | HARQ-ACK(3) |
| 2 | TB1 Primary cell | TB1 Secondary cell | NA | NA |
| 3 | TB1 Serving cell1 | TB2 Serving cell1 | TB1 Serving cell2 | NA |
| 4 | TB1 Primary cell | TB2 Primary cell | TB1 Secondary cell | TB2 Secondary cell |

The UE shall determine the $A$ PUCCH resources, $n^{(1)}_{\text{PUCCH},j}$ associated with HARQ-ACK($j$) where $0 \le j \le A-1$ in Table 10.1.2.2.1-1, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the PUCCH resource is $n^{(1)}_{\text{PUCCH,j}} = n_{\text{CCE}} + N^{(1)}_{\text{PUCCH}}$, and for transmission mode that supports up to two transport blocks, the PUCCH resource $n^{(1)}_{\text{PUCCH},j+1}$ is given by $n^{(1)}_{\text{PUCCH},j+1} = n_{\text{CCE}} + 1 + N^{(1)}_{\text{PUCCH}}$ where $n_{\text{CCE}}$ is the number of the first CCE used for transmission of the corresponding PDCCH and $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers.
- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the value of $n^{(1)}_{\text{PUCCH},j}$ is determined according to higher layer configuration and Table 9.2-2. For transmission mode that supports up to two transport blocks, the PUCCH resource $n^{(1)}_{\text{PUCCH},j+1}$ is given by $n^{(1)}_{\text{PUCCH},j+1} = n^{(1)}_{\text{PUCCH},j} + 1$
- for a PDSCH transmission indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-4$ on the secondary cell, the value of $n^{(1)}_{\text{PUCCH},j}$, and the value of $n^{(1)}_{\text{PUCCH},j+1}$ for the transmission mode that supports up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode that supports up to two transport blocks a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources $(n^{(1)}_{\text{PUCCH},j}, n^{(1)}_{\text{PUCCH},j+1})$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n^{(1)}_{\text{PUCCH},j}$.
- for a PDSCH transmission indicated by the detection of a corresponding EPDCCH in subframe $n-4$ on the primary cell, or for an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the PUCCH resource is given by
  - if EPDCCH-PRB-set $q$ is configured for distributed transmission
    $n^{(1)}_{\text{PUCCH,j}} = n_{\text{ECCE,q}} + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$

- if EPDCCH-PRB-set $q$ is configured for localized transmission

$$n^{(1)}_{\text{PUCCH,j}} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + n' + \Delta_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N^{(e1)}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set $q$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for localized EPDCCH transmission which is described in subclause 6.8A.5 in [3].

For transmission mode that supports up to two transport blocks, the PUCCH resource $n^{(1)}_{\text{PUCCH},\,j+1}$ is given by

- if EPDCCH-PRB-set $q$ is configured for distributed transmission

$$n^{(1)}_{\text{PUCCH,j+1}} = n_{\text{ECCE,q}} + 1 + \Delta_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

- if EPDCCH-PRB-set $q$ is configured for localized transmission

$$n^{(1)}_{\text{PUCCH,j+1}} = \left\lfloor \frac{n_{ECCE,q}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + 1 + n' + \Delta_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

**Table 10.1.2.2.1-2: PUCCH Resource Value for HARQ-ACK Resource for PUCCH**

| Value of 'TPC command for PUCCH' | $n^{(1)}_{\text{PUCCH},\,j}$ or $(n^{(1)}_{\text{PUCCH},\,j}, n^{(1)}_{\text{PUCCH},\,j+1})$ |
|---|---|
| '00' | The 1st PUCCH resource value configured by the higher layers |
| '01' | The 2nd PUCCH resource value configured by the higher layers |
| '10' | The 3rd PUCCH resource value configured by the higher layers |
| '11' | The 4th PUCCH resource value configured by the higher layers |
| NOTE: $(n^{(1)}_{\text{PUCCH},\,j}, n^{(1)}_{\text{PUCCH},\,j+1})$ are determined from the first and second PUCCH resource lists configured by *n1PUCCH-AN-CS-List-r10* in [11], respectively. | |

**Table 10.1.2.2.1-3: Transmission of Format 1b HARQ-ACK channel selection for $A = 2$**

| HARQ-ACK(0) | HARQ-ACK(1) | $n^{(1)}_{\text{PUCCH}}$ | $b(0)b(1)$ |
|---|---|---|---|
| ACK | ACK | $n^{(1)}_{\text{PUCCH,1}}$ | 1,1 |
| ACK | NACK/DTX | $n^{(1)}_{\text{PUCCH,0}}$ | 1,1 |
| NACK/DTX | ACK | $n^{(1)}_{\text{PUCCH,1}}$ | 0,0 |
| NACK | NACK/DTX | $n^{(1)}_{\text{PUCCH,0}}$ | 0,0 |
| DTX | NACK/DTX | No Transmission | |

**Table 10.1.2.2.1-4: Transmission of Format 1b HARQ-ACK channel selection for $A = 3$**

| HARQ-ACK(0) | HARQ-ACK(1) | HARQ-ACK(2) | $n^{(1)}_{\text{PUCCH}}$ | $b(0)b(1)$ |
|---|---|---|---|---|
| ACK | ACK | ACK | $n^{(1)}_{\text{PUCCH},1}$ | 1,1 |
| ACK | NACK/DTX | ACK | $n^{(1)}_{\text{PUCCH},1}$ | 1,0 |
| NACK/DTX | ACK | ACK | $n^{(1)}_{\text{PUCCH},1}$ | 0,1 |
| NACK/DTX | NACK/DTX | ACK | $n^{(1)}_{\text{PUCCH},2}$ | 1,1 |
| ACK | ACK | NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 1,1 |
| ACK | NACK/DTX | NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 1,0 |
| NACK/DTX | ACK | NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 0,1 |
| NACK/DTX | NACK/DTX | NACK | $n^{(1)}_{\text{PUCCH},2}$ | 0,0 |
| NACK | NACK/DTX | DTX | $n^{(1)}_{\text{PUCCH},0}$ | 0,0 |
| NACK/DTX | NACK | DTX | $n^{(1)}_{\text{PUCCH},0}$ | 0,0 |
| DTX | DTX | DTX | No Transmission | |

**Table 10.1.2.2.1-5: Transmission of Format 1b HARQ-ACK channel selection for $A = 4$**

| HARQ-ACK(0) | HARQ-ACK(1) | HARQ-ACK(2) | HARQ-ACK(3) | $n^{(1)}_{\text{PUCCH}}$ | $b(0)b(1)$ |
|---|---|---|---|---|---|
| ACK | ACK | ACK | ACK | $n^{(1)}_{\text{PUCCH},1}$ | 1,1 |
| ACK | NACK/DTX | ACK | ACK | $n^{(1)}_{\text{PUCCH},2}$ | 0,1 |
| NACK/DTX | ACK | ACK | ACK | $n^{(1)}_{\text{PUCCH},1}$ | 0,1 |
| NACK/DTX | NACK/DTX | ACK | ACK | $n^{(1)}_{\text{PUCCH},3}$ | 1,1 |
| ACK | ACK | ACK | NACK/DTX | $n^{(1)}_{\text{PUCCH},1}$ | 1,0 |
| ACK | NACK/DTX | ACK | NACK/DTX | $n^{(1)}_{\text{PUCCH},2}$ | 0,0 |
| NACK/DTX | ACK | ACK | NACK/DTX | $n^{(1)}_{\text{PUCCH},1}$ | 0,0 |
| NACK/DTX | NACK/DTX | ACK | NACK/DTX | $n^{(1)}_{\text{PUCCH},3}$ | 1,0 |
| ACK | ACK | NACK/DTX | ACK | $n^{(1)}_{\text{PUCCH},2}$ | 1,1 |
| ACK | NACK/DTX | NACK/DTX | ACK | $n^{(1)}_{\text{PUCCH},2}$ | 1,0 |
| NACK/DTX | ACK | NACK/DTX | ACK | $n^{(1)}_{\text{PUCCH},3}$ | 0,1 |
| NACK/DTX | NACK/DTX | NACK/DTX | ACK | $n^{(1)}_{\text{PUCCH},3}$ | 0,0 |
| ACK | ACK | NACK/DTX | NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 1,1 |
| ACK | NACK/DTX | NACK/DTX | NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 1,0 |
| NACK/DTX | ACK | NACK/DTX | NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 0,1 |
| NACK/DTX | NACK | NACK/DTX | NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 0,0 |
| NACK | NACK/DTX | NACK/DTX | NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 0,0 |
| DTX | DTX | NACK/DTX | NACK/DTX | No Transmission | |

### 10.1.2.2.2 PUCCH format 3 HARQ-ACK procedure

For FDD with PUCCH format 3, the UE shall use PUCCH resource $n^{(3,\tilde{p})}_{\text{PUCCH}}$ or $n^{(1,\tilde{p})}_{\text{PUCCH}}$ for transmission of HARQ-ACK in subframe $n$ for $\tilde{p}$ mapped to antenna port $p$ where

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ with $n^{(1,\tilde{p}_0)}_{\text{PUCCH}} = n_{\text{CCE}} + N^{(1)}_{\text{PUCCH}}$ for antenna port $p_0$, where $n_{\text{CCE}}$ is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding PDCCH and $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port $p_1$ is given by $n^{(1,\tilde{p}_1)}_{\text{PUCCH}} = n_{\text{CCE}} + 1 + N^{(1)}_{\text{PUCCH}}$.

- for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ where the value of $n^{(1,\tilde{p})}_{\text{PUCCH}}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n^{(1,\tilde{p}_0)}_{\text{PUCCH}}$ for antenna port $p_0$ and the second PUCCH

resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port $p_1$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port $p_0$.

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-4$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For a UE configured for two antenna port transmission for PUCCH format 3, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port $p_0$ and the second PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_1)}$ for antenna port $p_1$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port $p_0$. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in each DCI format of the corresponding secondary cell PDCCH assignments in a given subframe.
- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-4$, or for a EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by
  - if EPDCCH-PRB-set $q$ is configured for distributed transmission
    $$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{ECCE,q}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$
  - if EPDCCH-PRB-set $q$ is configured for localized transmission
    $$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  for antenna port $p_0$, where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set $q$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for localized EPDCCH transmission which is described in subclause 6.8A.5 in [3]. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port $p_1$ is given by.

  - if EPDCCH-PRB-set $q$ is configured for distributed transmission
    $$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{ECCE,q}} + 1 + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$
  - if EPDCCH-PRB-set $q$ is configured for localized transmission
    $$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

**Table 10.1.2.2.2-1: PUCCH Resource Value for HARQ-ACK Resource for PUCCH**

| Value of 'TPC command for PUCCH' or 'HARQ-ACK resource offset' | $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ |
|---|---|
| '00' | The 1st PUCCH resource value configured by the higher layers |
| '01' | The 2nd PUCCH resource value configured by the higher layers |
| '10' | The 3rd PUCCH resource value configured by the higher layers |
| '11' | The 4th PUCCH resource value configured by the higher layers |

## 10.1.3 TDD HARQ-ACK feedback procedures

For TDD and a UE that does not support aggregating more than one serving cell with frame structure type 2, two HARQ-ACK feedback modes are supported by higher layer configuration.

- HARQ-ACK bundling and
- HARQ-ACK multiplexing

For TDD UL/DL configuration 5 and a UE that does not support aggregating more than one serving cell with frame structure type 2, only HARQ-ACK bundling is supported.

A UE that supports aggregating more than one serving cell with frame structure type 2 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3 for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 2.

A UE that supports aggregating more than one serving cell with frame structure type 2 is configured by higher layers to use HARQ-ACK bundling, PUCCH format 1b with channel selection according to the set of Tables 10.1.3-2/3/4 or according to the set of Tables 10.1.3-5/6/7, or PUCCH format 3 for transmission of HARQ-ACK when configured with one serving cell with frame structure type 2.

PUCCH format 1b with channel selection according to the set of Tables 10.1.3-2/3/4 or according to the set of Tables 10.1.3-5/6/7 is not supported for TDD UL/DL configuration 5.

TDD HARQ-ACK bundling is performed per codeword across $M$ multiple DL subframes associated with a single UL subframe *n*, where $M$ is the number of elements in the set $K$ defined in Table 10.1.3.1-1, by a logical AND operation of all the individual PDSCH transmission (with and without corresponding PDCCH/EPDCCH) HARQ-ACKs and ACK in response to PDCCH/EPDCCH indicating downlink SPS release. For one configured serving cell the bundled 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively.

For TDD HARQ-ACK multiplexing and a subframe *n* with $M > 1$, where $M$ is the number of elements in the set $K$ defined in Table 10.1.3.1-1, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. PUCCH format 1b with channel selection is used in case of one configured serving cell. For TDD HARQ-ACK multiplexing and a subframe *n* with $M = 1$, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is not performed, 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively for one configured serving cell.

In the case of TDD and more than one configured serving cell with PUCCH format 1b with channel selection and more than 4 HARQ-ACK bits for $M$ multiple DL subframes associated with a single UL subframe *n*, where $M$ is defined in subclause 10.1.3.2.1, and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a DL subframe for all configured cells is performed and the bundled HARQ-ACK bits for each configured serving cell is transmitted using PUCCH format 1b with channel selection. For TDD and more than one configured serving cell with PUCCH format 1b with channel selection and up to 4 HARQ-ACK bits for $M$ multiple DL subframes associated with a single UL subframe *n*, where $M$ is defined in subclause 10.1.3.2.1, and for the configured serving cells, spatial HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 1b with channel selection.

In the case of TDD and more than one configured serving cell with PUCCH format 3 and more than 20 HARQ-ACK bits for $M$ multiple DL subframes associated with a single UL subframe *n*, where $M$ is the number of elements in the set $K$ defined in subclause 10.1.3.2.2 and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed for each serving cell by a logical AND operation of all of the corresponding individual HARQ-ACKs and PUCCH format 3 is used. For TDD and more than one configured serving cell with PUCCH format 3 and up to 20 HARQ-ACK bits for $M$ multiple DL subframes associated with a single UL

subframe *n*, where $M$ is the number of elements in the set $K$ defined in subclause 10.1.3.2.2 and for the configured serving cells, spatial HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 3.

For TDD with PUCCH format 3, a UE shall determine the number of HARQ-ACK bits, $O$, associated with an UL subframe *n*

according to $O = \sum_{c=1}^{N_{cells}^{DL}} O_c^{ACK}$ where $N_{cells}^{DL}$ is the number of configured cells, and $O_c^{ACK}$ is the number of HARQ-bits for the *c*-th serving cell defined in subclause 7.3.

TDD HARQ-ACK feedback procedures for one configured serving cell are given in subclause 10.1.3.1 and procedures for more than one configured serving cell are given in subclause 10.1.3.2.

### 10.1.3.1 TDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 1a/1b with TDD HARQ-ACK bundling feedback mode and for PUCCH format 3.

A UE that supports aggregating more than one serving cell with frame structure type 2 can be configured by higher layers for HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) for PUCCH format 1b with channel selection.

The TDD HARQ-ACK procedure for a UE configured with PUCCH format 3 is as described in subclause 10.1.3.2.2 when the UE receives PDSCH and/or SPS release PDCCH/EPDCCH only on the primary cell.

For TDD HARQ-ACK bundling or TDD HARQ-ACK multiplexing for one configured serving cell and a subframe *n* with $M = 1$ where $M$ is the number of elements in the set $K$ defined in Table 10.1.3.1-1, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe $n$ for $\tilde{p}$ mapped to antenna port *p* for PUCCH format 1a/1b, where

- If there is PDSCH transmission indicated by the detection of corresponding PDCCH/EPDCCH or there is PDCCH/EPDCCH indicating downlink SPS release within subframe(s) $n-k$, where $k \in K$ and $K$ (defined in Table 10.1.3.1-1) is a set of *M* elements $\{k_0, k_1, \cdots k_{M-1}\}$ depending on the subframe *n* and the UL/DL configuration (defined in Table 4.2-2 in [3]), and if PDCCH indicating PDSCH transmission or downlink SPS release is detected in subframe $n-k_m$, where $k_m$ is the smallest value in set $K$ such that UE detects a PDCCH/EPDCCH indicating PDSCH transmission or downlink SPS release within subframe(s) $n-k$ and $k \in K$, the UE first selects a $c$ value out of {0, 1, 2, 3} which makes $N_c \le n_{\text{CCE}} < N_{c+1}$ and shall use $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = (M-m-1)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port $p_0$, where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\text{CCE}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ and the corresponding *m*. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for HARQ-ACK bundling for antenna port $p_1$ is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = (M-m-1)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.

- If there is only a PDSCH transmission where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and $K$ is defined in Table 10.1.3.1-1, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b and HARQ-ACK bundling, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port $p_0$ and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port $p_1$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port $p_0$.

- If there is PDSCH transmission indicated by the detection of corresponding PDCCH/EPDCCH or there is PDCCH/EPDCCH indicating downlink SPS release within subframe(s) $n-k$, where $k \in K$ and $K$ (defined

in Table 10.1.3.1-1) is a set of $M$ elements $\{k_0, k_1, \cdots k_{M-1}\}$ depending on the subframe $n$ and the UL/DL configuration (defined in Table 4.2-2 in [3]), and if EPDCCH indicating PDSCH transmission or downlink SPS release is detected in subframe $n-k_m$, where $k_m$ is the smallest value in set $K$ such that UE detects a PDCCH/EPDCCH indicating PDSCH transmission or downlink SPS release within subframe(s) $n-k$ and $k \in K$, the UE shall use

- if EPDCCH-PRB-set $q$ is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

- if EPDCCH-PRB-set $q$ is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

for antenna port $p_0$, where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$ in subframe $n-k_m$ and the corresponding $m$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set $q$ in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set $q$ configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set $q$ is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for HARQ-ACK bundling for antenna port $p_1$ is given by

- if EPDCCH-PRB-set $q$ is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{ECCE,q}} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

- if EPDCCH-PRB-set $q$ is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

**Table 10.1.3.1-1: Downlink association set index $K$ : $\{k_0, k_1, \cdots k_{M-1}\}$ for TDD**

| UL/DL Configuration | Subframe *n* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | - | - | 6 | - | 4 | - | - | 6 | - | 4 |
| 1 | - | - | 7, 6 | 4 | - | - | - | 7, 6 | 4 | - |
| 2 | - | - | 8, 7, 4, 6 | - | - | - | - | 8, 7, 4, 6 | - | - |
| 3 | - | - | 7, 6, 11 | 6, 5 | 5, 4 | - | - | - | - | - |
| 4 | - | - | 12, 8, 7, 11 | 6, 5, 4, 7 | - | - | - | - | - | - |
| 5 | - | - | 13, 12, 9, 8, 7, 5, 4, 11, 6 | - | - | - | - | - | - | - |
| 6 | - | - | 7 | 7 | 5 | - | - | 7 | 7 | - |

**Table 10.1.3.1-2: Mapping of ACK/NACK Resource offset Field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D to $\Delta_{ARO}$ values for TDD when $m > 0$**

| ACK/NACK Resource offset field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D | $\Delta_{ARO}$ |
|---|---|
| 0 | 0 |
| 1 | $-\sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} - 2$ |
| 2 | $-\sum_{i1=m-\lceil m/3 \rceil}^{m-1} N_{ECCE,q,n-k_{i1}} - 1$ |
| 3 | 2 |

For TDD HARQ-ACK multiplexing and sub-frame $n$ with $M > 1$ and one configured serving cell, where $M$ is the number of elements in the set $K$ defined in Table 10.1.3.1-1, denote $n^{(1)}_{\text{PUCCH},i}$ as the PUCCH resource derived from sub-frame $n - k_i$ and HARQ-ACK(i) as the ACK/NACK/DTX response from sub-frame $n - k_i$, where $k_i \in K$ (defined in Table 10.1.3.1-1) and $0 \le i \le M-1$.

- For a PDSCH transmission indicated by the detection of corresponding PDCCH or a PDCCH indicating downlink SPS release in sub-frame $n - k_i$ where $k_i \in K$, the PUCCH resource $n^{(1)}_{\text{PUCCH},i} = (M - i - 1) \cdot N_c + i \cdot N_{c+1} + n_{\text{CCE},i} + N^{(1)}_{\text{PUCCH}}$, where $c$ is selected from $\{0, 1, 2, 3\}$ such that $N_c \le n_{\text{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}} \cdot (N^{\text{RB}}_{\text{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, $n_{\text{CCE},i}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_i$, and $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers.
- For a PDSCH transmission where there is not a corresponding PDCCH/EPDCCH detected in subframe $n - k_i$, the value of $n^{(1)}_{\text{PUCCH},i}$ is determined according to higher layer configuration and Table 9.2-2.
- For a PDSCH transmission indicated by the detection of corresponding EPDCCH or a EPDCCH indicating downlink SPS release in sub-frame $n - k_i$ where $k_i \in K$, the UE shall use
  - if EPDCCH-PRB-set $q$ is configured for distributed transmission
    $$n^{(1)}_{\text{PUCCH,i}} = n_{\text{ECCE,q}} + \sum_{i1=0}^{i-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$
  - if EPDCCH-PRB-set $q$ is configured for localized transmission
    $$n^{(1)}_{\text{PUCCH,i}} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{i-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$ in subframe $n-k_i$, $N_{\text{PUCCH,q}}^{(e1)}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set $q$ in subframe $n-k_i$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for EPDCCH transmission in subframe $n-k_i$ which is described in subclause 6.8A.5 in [3]. If $i=0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $i>0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2, where the the variable $m$ in the table is substituted with $i$. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set $q$ configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set $q$ is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0.

If a UE is not configured with two antenna port transmission for PUCCH format 1b with channel selection, based on higher layer signalling the UE configured with a single serving cell will perform channel selection either according to the set of Tables 10.1.3-2, 10.1.3-3, and 10.1.3-4 or according to the set of Tables 10.1.3-5, 10.1.3-6, and 10.1.3-7.

If a UE is configured with two antenna port transmission for PUCCH format 1b with channel selection, then the UE will perform channel selection according to the set of Tables 10.1.3-5, 10.1.3-6, and 10.1.3-7.

For the selected table set, the UE shall transmit $b(0),b(1)$ on PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ in sub-frame $n$ for $\tilde{p}$ mapped to antenna port $p$ using PUCCH format 1b according to subclause 5.4.1 in [3] where

- $n_{\text{PUCCH}}^{(1,\tilde{p})}=n_{\text{PUCCH}}^{(1)}$ for antenna port $p_0$ and the value of $b(0),b(1)$ and the PUCCH resource $n_{\text{PUCCH}}^{(1)}$ are generated by channel selection according to the selected set of Tables for $M$ = 2, 3, and 4 respectively
- $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port $p_1$, where $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ is selected from PUCCH resources $n_{\text{PUCCH},i}^{(1,\tilde{p}_1)}$ configured by higher layers where $0\le i\le M-1$, according to selected set of Tables for $M$ = 2, 3, and 4 respectively by replacing $n_{\text{PUCCH}}^{(1)}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ and replacing $n_{\text{PUCCH},i}^{(1)}$ with $n_{\text{PUCCH},i}^{(1,\tilde{p}_1)}$, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection.

**Table 10.1.3-2: Transmission of HARQ-ACK multiplexing for *M* = 2**

| HARQ-ACK(0), HARQ-ACK(1) | $n_{\text{PUCCH}}^{(1)}$ | $b(0),b(1)$ |
|---|---|---|
| ACK, ACK | $n_{\text{PUCCH},1}^{(1)}$ | 1, 1 |
| ACK, NACK/DTX | $n_{\text{PUCCH},0}^{(1)}$ | 0, 1 |
| NACK/DTX, ACK | $n_{\text{PUCCH},1}^{(1)}$ | 0, 0 |
| NACK/DTX, NACK | $n_{\text{PUCCH},1}^{(1)}$ | 1, 0 |
| NACK, DTX | $n_{\text{PUCCH},0}^{(1)}$ | 1, 0 |
| DTX, DTX | No transmission | |

**Table 10.1.3-3: Transmission of HARQ-ACK multiplexing for *M* = 3**

| HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2) | $n^{(1)}_{\text{PUCCH}}$ | $b(0),b(1)$ |
|---|---|---|
| ACK, ACK, ACK | $n^{(1)}_{\text{PUCCH},2}$ | 1, 1 |
| ACK, ACK, NACK/DTX | $n^{(1)}_{\text{PUCCH},1}$ | 1, 1 |
| ACK, NACK/DTX, ACK | $n^{(1)}_{\text{PUCCH},0}$ | 1, 1 |
| ACK, NACK/DTX, NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 0, 1 |
| NACK/DTX, ACK, ACK | $n^{(1)}_{\text{PUCCH},2}$ | 1, 0 |
| NACK/DTX, ACK, NACK/DTX | $n^{(1)}_{\text{PUCCH},1}$ | 0, 0 |
| NACK/DTX, NACK/DTX, ACK | $n^{(1)}_{\text{PUCCH},2}$ | 0, 0 |
| DTX, DTX, NACK | $n^{(1)}_{\text{PUCCH},2}$ | 0, 1 |
| DTX, NACK, NACK/DTX | $n^{(1)}_{\text{PUCCH},1}$ | 1, 0 |
| NACK, NACK/DTX, NACK/DTX | $n^{(1)}_{\text{PUCCH},0}$ | 1, 0 |
| DTX, DTX, DTX | No transmission | |

**Table 10.1.3-4: Transmission of HARQ-ACK multiplexing for *M* = 4**

| HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3) | $n_{\mathrm{PUCCH}}^{(1)}$ | $b(0), b(1)$ |
|---|---|---|
| ACK, ACK, ACK, ACK | $n_{\mathrm{PUCCH},1}^{(1)}$ | 1, 1 |
| ACK, ACK, ACK, NACK/DTX | $n_{\mathrm{PUCCH},1}^{(1)}$ | 1, 0 |
| NACK/DTX,NACK/DTX,NACK,DTX | $n_{\mathrm{PUCCH},2}^{(1)}$ | 1, 1 |
| ACK, ACK, NACK/DTX, ACK | $n_{\mathrm{PUCCH},1}^{(1)}$ | 1, 0 |
| NACK, DTX, DTX, DTX | $n_{\mathrm{PUCCH},0}^{(1)}$ | 1, 0 |
| ACK, ACK, NACK/DTX, NACK/DTX | $n_{\mathrm{PUCCH},1}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, ACK, ACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, NACK/DTX, NACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 1, 1 |
| ACK, NACK/DTX, ACK, NACK/DTX | $n_{\mathrm{PUCCH},2}^{(1)}$ | 0, 1 |
| ACK, NACK/DTX, NACK/DTX, ACK | $n_{\mathrm{PUCCH},0}^{(1)}$ | 0, 1 |
| ACK, NACK/DTX, NACK/DTX, NACK/DTX | $n_{\mathrm{PUCCH},0}^{(1)}$ | 1, 1 |
| NACK/DTX, ACK, ACK, ACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK, DTX, DTX | $n_{\mathrm{PUCCH},1}^{(1)}$ | 0, 0 |
| NACK/DTX, ACK, ACK, NACK/DTX | $n_{\mathrm{PUCCH},2}^{(1)}$ | 1, 0 |
| NACK/DTX, ACK, NACK/DTX, ACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 1, 0 |
| NACK/DTX, ACK, NACK/DTX, NACK/DTX | $n_{\mathrm{PUCCH},1}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK, ACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK, NACK/DTX | $n_{\mathrm{PUCCH},2}^{(1)}$ | 0, 0 |
| NACK/DTX, NACK/DTX, NACK/DTX, ACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 0, 0 |
| DTX, DTX, DTX, DTX | No transmission | |

**Table 10.1.3-5: Transmission of HARQ-ACK multiplexing for *M* = 2**

| HARQ-ACK(0), HARQ-ACK(1) | $n_{\mathrm{PUCCH}}^{(1)}$ | $b(0)b(1)$ |
|---|---|---|
| ACK, ACK | $n_{\mathrm{PUCCH},1}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX | $n_{\mathrm{PUCCH},0}^{(1)}$ | 1, 1 |
| NACK/DTX, ACK | $n_{\mathrm{PUCCH},1}^{(1)}$ | 0, 1 |
| NACK, NACK/DTX | $n_{\mathrm{PUCCH},0}^{(1)}$ | 0, 0 |
| DTX, NACK/DTX | No Transmission | |

**Table 10.1.3-6: Transmission of HARQ-ACK multiplexing for *M* = 3**

| HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2) | $n_{PUCCH}^{(1)}$ | $b(0)b(1)$ |
|---|---|---|
| ACK, ACK, ACK | $n_{PUCCH,2}^{(1)}$ | 1, 1 |
| ACK, ACK, NACK/DTX | $n_{PUCCH,1}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, ACK | $n_{PUCCH,2}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, NACK/DTX | $n_{PUCCH,0}^{(1)}$ | 1, 1 |
| NACK/DTX, ACK, ACK | $n_{PUCCH,2}^{(1)}$ | 0, 1 |
| NACK/DTX, ACK, NACK/DTX | $n_{PUCCH,1}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK | $n_{PUCCH,2}^{(1)}$ | 0, 0 |
| NACK, NACK/DTX, NACK/DTX | $n_{PUCCH,0}^{(1)}$ | 0, 0 |
| DTX, NACK/DTX, NACK/DTX | No Transmission | |

**Table 10.1.3-7: Transmission of HARQ-ACK multiplexing for *M* = 4**

| HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3) | $n_{PUCCH}^{(1)}$ | $b(0)b(1)$ |
|---|---|---|
| ACK, ACK, ACK, ACK | $n_{PUCCH,1}^{(1)}$ | 1, 1 |
| ACK, ACK, ACK, NACK/DTX | $n_{PUCCH,2}^{(1)}$ | 1, 1 |
| ACK, ACK, NACK/DTX, ACK | $n_{PUCCH,0}^{(1)}$ | 1, 0 |
| ACK, ACK, NACK/DTX, NACK/DTX | $n_{PUCCH,1}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, ACK, ACK | $n_{PUCCH,3}^{(1)}$ | 1, 1 |
| ACK, NACK/DTX, ACK, NACK/DTX | $n_{PUCCH,2}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, NACK/DTX, ACK | $n_{PUCCH,0}^{(1)}$ | 0, 1 |
| ACK, NACK/DTX, NACK/DTX, NACK/DTX | $n_{PUCCH,0}^{(1)}$ | 1, 1 |
| NACK/DTX, ACK, ACK, ACK | $n_{PUCCH,1}^{(1)}$ | 0, 0 |
| NACK/DTX, ACK, ACK, NACK/DTX | $n_{PUCCH,2}^{(1)}$ | 0, 1 |
| NACK/DTX, ACK, NACK/DTX, ACK | $n_{PUCCH,3}^{(1)}$ | 1, 0 |
| NACK/DTX, ACK, NACK/DTX, NACK/DTX | $n_{PUCCH,1}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK, ACK | $n_{PUCCH,3}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK, NACK/DTX | $n_{PUCCH,2}^{(1)}$ | 0, 0 |
| NACK/DTX, NACK/DTX, NACK/DTX, ACK | $n_{PUCCH,3}^{(1)}$ | 0, 0 |
| NACK, NACK/DTX, NACK/DTX, NACK/DTX | $n_{PUCCH,0}^{(1)}$ | 0, 0 |
| DTX, NACK/DTX, NACK/DTX, NACK/DTX | No Transmission | |

### 10.1.3.2 TDD HARQ-ACK procedure for more than one configured serving cell

The TDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in subclause 10.1.3.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in subclause 10.1.3.2.2.

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 3 and TDD with more than one configured serving cell.

If a UE is configured with more than one serving cell and the TDD UL/DL configurations of all serving cells are the same, TDD UL/DL configuration 5 with PUCCH format 3 is only supported for up to two configured serving cells. If a UE is configured with two serving cells and the TDD UL/DL configuration of the two serving cells is the same, TDD UL/DL configuration 5 with PUCCH format 1b with channel selection for two configured serving cells is not supported. If a UE is configured with two serving cells and if the TDD UL/DL configuration of the two serving cells are not the same and if the DL-reference UL/DL configuration (as defined in subclause 10.2) of at least one serving cell is TDD UL/DL Configuration 5, PUCCH format 1b with channel selection is not supported.

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 1b with channel selection and TDD with two configured serving cells.

#### 10.1.3.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

If a UE is configured with two serving cells with the same UL/DL configurations, then $K$ is as defined in Sec 10.2 and $M$ is the number of elements for subframe *n* in the set $K$, and $M_{primary} = M$.

If a UE is configured with two serving cells with different UL/DL configurations,

– then the UE shall determine $M$ for a subframe *n* in this subclause as $M = \max\left(M_{primary}, M_{\sec ondary}\right)$, where

  ▪ $M_{primary}$ is the number of elements for subframe *n* in the set $K$ defined in Table 10.1.3.1-1 for the primary cell TDD UL/DL configuration , and

  ▪ $M_{\sec ondary}$ denotes the number of elements for subframe *n* in the set $K_c$ for the secondary serving cell (as defined in subclause 10.2)

– if $M_{\sec ondary} < M$, then the UE shall, for the secondary serving cell, set HARQ-ACK(j) to DTX for *j* = $M_{\sec ondary}$ to $M-1$.

– if $M_{primary} < M$, then the UE shall, for the primary cell, set HARQ-ACK(j) to DTX for *j* = $M_{primary}$ to $M-1$

If the UE is configured with two serving cells with different UL/DL configurations, then in the rest of this subclause, $K = K_c$ where $K_c$ is defined in subclause 10.2.

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and two configured serving cells and a subframe *n* with $M = 1$, a UE shall determine the number of HARQ-ACK bits, $O$, based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that supports up to two transport blocks; and one HARQ-ACK bit otherwise.

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and two configured serving cells and a subframe *n* with $M \le 2$, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port *p* using PUCCH format 1b where

- $n_{\text{PUCCH}}^{(1,\tilde{p})} = n_{\text{PUCCH}}^{(1)}$ for antenna port $p_0$, where $n_{\text{PUCCH}}^{(1)}$ selected from $A$ PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Tables 10.1.3.2-1, 10.1.3.2-2, and 10.1.3.2-3 in subframe $n$ using PUCCH format 1b.

- $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port $p_1$, where $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ selected from $A$ PUCCH resources, $n_{\text{PUCCH},j}^{(1,\tilde{p}_1)}$ configured by higher layers where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Tables 10.1.3.2-1, 10.1.3.2-2, and 10.1.3.2-3 by replacing $n_{\text{PUCCH}}^{(1)}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ and replacing $n_{\text{PUCCH},i}^{(1)}$ with $n_{\text{PUCCH},i}^{(1,\tilde{p}_1)}$ in subframe $n$, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection,

and for a subframe *n* with $M=1$, HARQ-ACK(*j*) denotes the ACK/NACK/DTX response for a transport block or SPS release PDCCH/EPDCCH associated with serving cell, where the transport block and serving cell for HARQ-ACK(*j*) and $A$ PUCCH resources are given by Table 10.1.2.2.1-1. For a subframe *n* with $M=2$, HARQ-ACK(*j*) denotes the ACK/NACK/DTX response for a PDSCH transmission or SPS release PDCCH/EPDCCH within subframe(s) given by set $K$ on each serving cell, where the subframes on each serving cell for HARQ-ACK(*j*) and $A$ PUCCH resources are given by Table 10.1.3.2-4. The UE shall determine the $A$ PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ associated with HARQ-ACK(*j*) where $0 \le j \le A-1$ in Table 10.1.2.2.1-1 for $M=1$ and Table 10.1.3.2-4 for $M=2$, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ on the primary cell, the PUCCH resource is $n_{\text{PUCCH},j}^{(1)} = \left(M_{primary} - m - 1\right) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$, where $c$ is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$ where $N_{\text{RB}}^{\text{DL}}$ is determined from the primary cell, and for a subframe *n* with $M=1$ and a transmission mode that supports up to two transport blocks on the serving cell where the corresponding PDSCH transmission occurs, the PUCCH resource $n_{\text{PUCCH},j+1}^{(1)}$ is given by $n_{\text{PUCCH},j+1}^{(1)} = \left(M_{primary} - m - 1\right) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + 1 + N_{\text{PUCCH}}^{(1)}$ where $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding DCI assignment and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers.

- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$, the value of $n_{\text{PUCCH},j}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.

- For a PDSCH transmission indicated by the detection of corresponding EPDCCH or a EPDCCH indicating downlink SPS release in sub-frame $n-k_m$ where $k_m \in K$ on the primary cell, the PUCCH resource $n_{\text{PUCCH},j}^{(1)}$ is given by

  - if EPDCCH-PRB-set $q$ is configured for distributed transmission
    $$n_{\text{PUCCH,j}}^{(1)} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - if EPDCCH-PRB-set $q$ is configured for localized transmission
    $$n_{\text{PUCCH,j}}^{(1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$ in subframe $n-k_m$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set $q$ in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], $n'$ is determined

from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set $q$ configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set $q$ is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For a subframe *n* with $M=1$ and a transmission mode that supports up to two transport blocks on the serving cell where the corresponding PDSCH transmission occurs, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},j+1}$ is given by

- if EPDCCH-PRB-set $q$ is configured for distributed transmission

$$n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH}} = n_{\mathrm{ECCE,q}} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

- if EPDCCH-PRB-set $q$ is configured for localized transmission

$$n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$ on the secondary cell, the value of $n^{(1)}_{\mathrm{PUCCH},j}$, and the value of $n^{(1)}_{\mathrm{PUCCH},j+1}$ for a subframe *n* with $M=2$ or for a subframe *n* with $M=1$ and a transmission mode on the secondary cell that supports up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode on the secondary cell that supports up to two transport blocks and a subframe *n* with $M=1$, or for a subframe *n* with $M=2$, a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources $(n^{(1)}_{\mathrm{PUCCH},j}, n^{(1)}_{\mathrm{PUCCH},j+1})$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n^{(1)}_{\mathrm{PUCCH},j}$. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in the TPC field on all PDCCH/EPDCCH assignments on the secondary cell within subframe(s) $n-k$, where $k \in K$.

**Table 10.1.3.2-1: Transmission of HARQ-ACK multiplexing for *A* = 2**

| HARQ-ACK(0), HARQ-ACK(1) | $n^{(1)}_{\mathrm{PUCCH}}$ | $b(0)b(1)$ |
|---|---|---|
| ACK, ACK | $n^{(1)}_{\mathrm{PUCCH,1}}$ | 1, 0 |
| ACK, NACK/DTX | $n^{(1)}_{\mathrm{PUCCH,0}}$ | 1, 1 |
| NACK/DTX, ACK | $n^{(1)}_{\mathrm{PUCCH,1}}$ | 0, 1 |
| NACK, NACK/DTX | $n^{(1)}_{\mathrm{PUCCH,0}}$ | 0, 0 |
| DTX, NACK/DTX | No Transmission | |

**Table 10.1.3.2-2: Transmission of HARQ-ACK multiplexing for *A* = 3**

| HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2) | $n_{\mathrm{PUCCH}}^{(1)}$ | $b(0)b(1)$ |
|---|---|---|
| ACK, ACK, ACK | $n_{\mathrm{PUCCH},2}^{(1)}$ | 1, 1 |
| ACK, ACK, NACK/DTX | $n_{\mathrm{PUCCH},1}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, ACK | $n_{\mathrm{PUCCH},2}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, NACK/DTX | $n_{\mathrm{PUCCH},0}^{(1)}$ | 1, 1 |
| NACK/DTX, ACK, ACK | $n_{\mathrm{PUCCH},2}^{(1)}$ | 0, 1 |
| NACK/DTX, ACK, NACK/DTX | $n_{\mathrm{PUCCH},1}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK | $n_{\mathrm{PUCCH},2}^{(1)}$ | 0, 0 |
| NACK, NACK/DTX, NACK/DTX | $n_{\mathrm{PUCCH},0}^{(1)}$ | 0, 0 |
| DTX, NACK/DTX, NACK/DTX | No Transmission | |

**Table 10.1.3.2-3: Transmission of HARQ-ACK multiplexing for *A* = 4**

| HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3) | $n_{\mathrm{PUCCH}}^{(1)}$ | $b(0)b(1)$ |
|---|---|---|
| ACK, ACK, ACK, ACK | $n_{\mathrm{PUCCH},1}^{(1)}$ | 1, 1 |
| ACK, ACK, ACK, NACK/DTX | $n_{\mathrm{PUCCH},2}^{(1)}$ | 1, 1 |
| ACK, ACK, NACK/DTX, ACK | $n_{\mathrm{PUCCH},0}^{(1)}$ | 1, 0 |
| ACK, ACK, NACK/DTX, NACK/DTX | $n_{\mathrm{PUCCH},1}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, ACK, ACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 1, 1 |
| ACK, NACK/DTX, ACK, NACK/DTX | $n_{\mathrm{PUCCH},2}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, NACK/DTX, ACK | $n_{\mathrm{PUCCH},0}^{(1)}$ | 0, 1 |
| ACK, NACK/DTX, NACK/DTX, NACK/DTX | $n_{\mathrm{PUCCH},0}^{(1)}$ | 1, 1 |
| NACK/DTX, ACK, ACK, ACK | $n_{\mathrm{PUCCH},1}^{(1)}$ | 0, 0 |
| NACK/DTX, ACK, ACK, NACK/DTX | $n_{\mathrm{PUCCH},2}^{(1)}$ | 0, 1 |
| NACK/DTX, ACK, NACK/DTX, ACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 1, 0 |
| NACK/DTX, ACK, NACK/DTX, NACK/DTX | $n_{\mathrm{PUCCH},1}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK, ACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK, NACK/DTX | $n_{\mathrm{PUCCH},2}^{(1)}$ | 0, 0 |
| NACK/DTX, NACK/DTX, NACK/DTX, ACK | $n_{\mathrm{PUCCH},3}^{(1)}$ | 0, 0 |
| NACK, NACK/DTX, NACK/DTX, NACK/DTX | $n_{\mathrm{PUCCH},0}^{(1)}$ | 0, 0 |
| DTX, NACK/DTX, NACK/DTX, NACK/DTX | No Transmission | |

**Table 10.1.3.2-4: Mapping of subframes on each serving cell to HARQ-ACK(*j*) for PUCCH format 1b HARQ-ACK channel selection for TDD with $M = 2$**

| A | HARQ-ACK(j) | | | |
|---|---|---|---|---|
| | HARQ-ACK(0) | HARQ-ACK(1) | HARQ-ACK(2) | HARQ-ACK(3) |
| 4 | The first subframe of Primary cell | The second subframe of Primary cell | The first subframe of Secondary cell | The second subframe of Secondary cell |

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and sub-frame $n$ with $M > 2$ and two configured serving cells, denotes $n^{(1)}_{\text{PUCCH},i}$ $0 \le i \le 3$ as the PUCCH resource derived from the transmissions in $M$ DL sub-frames associated with the UL subframe $n$ . $n^{(1)}_{\text{PUCCH},0}$ and $n^{(1)}_{\text{PUCCH},1}$ are associated with the PDSCH transmission(s) or a PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) on the primary cell and $n^{(1)}_{\text{PUCCH},2}$ and $n^{(1)}_{\text{PUCCH},3}$ are associated with the PDSCH transmission(s) on the secondary cell.

For Primary cell:

- If there is a PDSCH transmission on the primary cell without a corresponding PDCCH/EPDCCH detected within the subframe(s) $n-k$, where $k \in K$,
  - the value of $n^{(1)}_{\text{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2.
  - for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', the PUCCH resource $n^{(1)}_{\text{PUCCH},1} = \left(M_{primary} - m - 1\right)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N^{(1)}_{\text{PUCCH}}$ where $c$ is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}} \cdot (N^{\text{RB}}_{\text{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, where $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ and $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers.
  - for a PDSCH transmission on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X) or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1', the PUCCH resource is given by
    - If EPDCCH-PRB-set $q$ is configured for distributed transmission
      $$n^{(1)}_{\text{PUCCH},1} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$
    - If EPDCCH-PRB-set $q$ is configured for localized transmission
      $$n^{(1)}_{\text{PUCCH},1} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

    where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$ in subframe $n-k_m$, $N^{(\text{e1})}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter

*pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set $q$ in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set $q$ configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set $q$ is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0.

- HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH transmission without a corresponding PDCCH/EPDCCH. For $1 \le j \le M-1$, if a PDSCH transmission with a corresponding PDCCH/EPDCCH and DAI value in the PDCCH/EPDCCH equal to '$j$' or a PDCCH/EPDCCH indicating downlink SPS release and with DAI value in the PDCCH/EPDCCH equal to '$j$' is received, HARQ-ACK(j) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX.

- Otherwise,
  - for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the PDCCH equal to either '1' or '2' or a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resource $n_{\mathrm{PUCCH},i}^{(1)} = \left(M_{primary}-m-1\right)\cdot N_c + m\cdot N_{c+1} + n_{\mathrm{CCE},m} + N_{\mathrm{PUCCH}}^{(1)}$, where $c$ is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\mathrm{RB}}^{\mathrm{DL}}\cdot(N_{\mathrm{sc}}^{\mathrm{RB}}\cdot c-4)]/36 \right\rfloor\right\}$, where $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}, $i=0$ for the corresponding PDCCH with the DAI value equal to '1' and $i=1$ for the corresponding PDCCH with the DAI value equal to '2', and for the primary cell with TDD UL/DL configuration 0 $i=0$ for the corresponding PDCCH.
  - for a PDSCH transmission on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the EPDCCH equal to either '1' or '2' or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}the DAI value in the EPDCCH equal to either '1' or '2', the PUCCH resource is given by
    - If EPDCCH-PRB-set $q$ is configured for distributed transmission

$$n_{\mathrm{PUCCH,i}}^{(1)} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

- If EPDCCH-PRB-set $q$ is configured for localized transmission

$$n_{\text{PUCCH,i}}^{(1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(e1)}$$

where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$ in subframe $n-k_m$, $N_{\text{PUCCH,q}}^{(e1)}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set $q$ in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set $q$ configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set $q$ is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. Here, for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} $i=0$ for the corresponding EPDCCH with the DAI value equal to '1' and $i=1$ for the corresponding EPDCCH with the DAI value equal to '2', and for the primary cell with TDD UL/DL configuration 0 $i=0$ for the corresponding EPDCCH.

  - For $0 \le j \le M-1$ and TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}, if a PDSCH transmission with a corresponding PDCCH/EPDCCH and DAI value in the PDCCH/EPDCCH equal to '$j+1$' or a PDCCH/EPDCCH indicating downlink SPS release and with DAI value in the PDCCH/EPDCCH equal to '$j+1$' is received, HARQ-ACK(j) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX. For $0 \le j \le M-1$ and the primary cell with TDD UL/DL configuration 0, if a PDSCH transmission with a corresponding PDCCH/EPDCCH or a PDCCH/EPDCCH indicating downlink SPS release is received, HARQ-ACK(0) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX.

For Secondary cell:

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH on the primary cell in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resources $n_{\text{PUCCH},i}^{(1)} = \left(M_{primary} - m - 1\right) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$, where $c$ is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE,m}} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, where $N_{\text{RB}}^{\text{DL}}$ is determined from the primary cell, $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, $i=2$ for the corresponding PDCCH with the DAI value equal to '1' and $i=3$ for the corresponding PDCCH with the DAI value equal to '2'.
- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding EPDCCH on the primary cell in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resources are given by

- If EPDCCH-PRB-set $q$ is configured for distributed transmission

$$n^{(1)}_{\text{PUCCH,i}} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

- If EPDCCH-PRB-set $q$ is configured for localized transmission

$$n^{(1)}_{\text{PUCCH,i}} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

- where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$ in subframe $n-k_m$, $N^{(\text{e1})}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set $q$ in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set $q$ configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set $q$ is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. Here, $i=2$ for the corresponding EPDCCH with the DAI value equal to '1' and $i=3$ for the corresponding EPDCCH with the DAI value equal to '2'.
- for a PDSCH transmission indicated by the detection of a corresponding PDCCH/EPDCCH within the subframe(s) $n-k$, where $k \in K$ on the secondary cell, the value of $n^{(1)}_{\text{PUCCH},2}$ and $n^{(1)}_{\text{PUCCH},3}$ is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in the TPC field on all PDCCH/EPDCCH assignments on the secondary cell within subframe(s) $n-k$, where $k \in K$.
- For $0 \le j \le M-1$, if a PDSCH transmission with a corresponding PDCCH/EPDCCH and DAI value in the PDCCH/EPDCCH equal to '$j+1$' is received, HARQ-ACK(j) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX.

A UE shall perform channel selection according to the Tables 10.1.3.2-5, and 10.1.3.2-6 and transmit $b(0),b(1)$ on PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ for $\tilde{p}$ mapped to antenna port $p$ using PUCCH format 1b according to subclause 5.4.1 in [3] where

- $n^{(1,\tilde{p}_0)}_{\text{PUCCH}} = n^{(1)}_{\text{PUCCH}}$ in sub-frame $n$ for $\tilde{p}$ mapped to antenna port $p_0$ where "any" in Tables 10.1.3.2-5, and 10.1.3.2-6 represents any response of ACK, NACK, or DTX. The value of $b(0),b(1)$ and the PUCCH resource $n^{(1)}_{\text{PUCCH}}$ are generated by channel selection according to Tables 10.1.3.2-5, and 10.1.3.2-6 for $M=3$, and 4 respectively.
- $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ for antenna port $p_1$, where $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ selected from PUCCH resources, $n^{(1,\tilde{p}_1)}_{\text{PUCCH},i}$ configured by higher layers where $0 \le i \le 3$ according Tables 10.1.3.2-5, and 10.1.3.2-6 for $M=3$, and 4 respectively by

replacing $n^{(1)}_{\mathrm{PUCCH}}$ with $n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH}}$ and replacing $n^{(1)}_{\mathrm{PUCCH},i}$ with $n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH},i}$, where "any" in Tables 10.1.3.2-5, and 10.1.3.2-6 represents any response of ACK, NACK, or DTX, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection.

**Table 10.1.3.2-5: Transmission of HARQ-ACK multiplexing for *M* = 3**

| Primary Cell | Secondary Cell | Resource | Constellation | RM Code Input Bits |
|---|---|---|---|---|
| **HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)** | **HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)** | $n^{(1)}_{\mathrm{PUCCH}}$ | $b(0),b(1)$ | $o(0),o(1),o(2),o(3)$ |
| ACK, ACK, ACK | ACK, ACK, ACK | $n^{(1)}_{\mathrm{PUCCH},1}$ | 1, 1 | 1,1,1,1 |
| ACK, ACK, NACK/DTX | ACK, ACK, ACK | $n^{(1)}_{\mathrm{PUCCH},1}$ | 0, 0 | 1,0,1,1 |
| ACK, NACK/DTX, any | ACK, ACK, ACK | $n^{(1)}_{\mathrm{PUCCH},3}$ | 1, 1 | 0,1,1,1 |
| NACK/DTX, any, any | ACK, ACK, ACK | $n^{(1)}_{\mathrm{PUCCH},3}$ | 0, 1 | 0,0,1,1 |
| ACK, ACK, ACK | ACK, ACK, NACK/DTX | $n^{(1)}_{\mathrm{PUCCH},0}$ | 1, 0 | 1,1,1,0 |
| ACK, ACK, NACK/DTX | ACK, ACK, NACK/DTX | $n^{(1)}_{\mathrm{PUCCH},3}$ | 1, 0 | 1,0,1,0 |
| ACK, NACK/DTX, any | ACK, ACK, NACK/DTX | $n^{(1)}_{\mathrm{PUCCH},0}$ | 0, 1 | 0,1,1,0 |
| NACK/DTX, any, any | ACK, ACK, NACK/DTX | $n^{(1)}_{\mathrm{PUCCH},3}$ | 0, 0 | 0,0,1,0 |
| ACK, ACK, ACK | ACK, NACK/DTX, any | $n^{(1)}_{\mathrm{PUCCH},2}$ | 1, 1 | 1, 1, 0, 1 |
| ACK, ACK, NACK/DTX | ACK, NACK/DTX, any | $n^{(1)}_{\mathrm{PUCCH},2}$ | 0, 1 | 1, 0, 0, 1 |
| ACK, NACK/DTX, any | ACK, NACK/DTX, any | $n^{(1)}_{\mathrm{PUCCH},2}$ | 1, 0 | 0, 1, 0, 1 |
| NACK/DTX, any, any | ACK, NACK/DTX, any | $n^{(1)}_{\mathrm{PUCCH},2}$ | 0, 0 | 0, 0, 0, 1 |
| ACK, ACK, ACK | NACK/DTX, any, any | $n^{(1)}_{\mathrm{PUCCH},1}$ | 1, 0 | 1, 1, 0, 0 |
| ACK, ACK, NACK/DTX | NACK/DTX, any, any | $n^{(1)}_{\mathrm{PUCCH},1}$ | 0, 1 | 1, 0, 0, 0 |
| ACK, NACK/DTX, any | NACK/DTX, any, any | $n^{(1)}_{\mathrm{PUCCH},0}$ | 1, 1 | 0, 1, 0, 0 |
| NACK, any, any | NACK/DTX, any, any | $n^{(1)}_{\mathrm{PUCCH},0}$ | 0, 0 | 0, 0, 0, 0 |
| DTX, any, any | NACK/DTX, any, any | No Transmission | | 0, 0, 0, 0 |

**Table 10.1.3.2-6: Transmission of HARQ-ACK multiplexing for *M* = 4**

| Primary Cell | Secondary Cell | Resource | Constellation | RM Code Input Bits |
|---|---|---|---|---|
| HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3) | HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3) | $n_{\text{PUCCH}}^{(1)}$ | $b(0), b(1)$ | $o(0), o(1), o(2), o(3)$ |
| ACK, ACK, ACK, NACK/DTX | ACK, ACK, ACK, NACK/DTX | $n_{\text{PUCCH},1}^{(1)}$ | 1, 1 | 1, 1, 1, 1 |
| ACK, ACK, NACK/DTX, any | ACK, ACK, ACK, NACK/DTX | $n_{\text{PUCCH},1}^{(1)}$ | 0, 0 | 1, 0, 1, 1 |
| ACK, DTX, DTX, DTX | ACK, ACK, ACK, NACK/DTX | $n_{\text{PUCCH},3}^{(1)}$ | 1, 1 | 0, 1, 1, 1 |
| ACK, ACK, ACK, ACK | ACK, ACK, ACK, NACK/DTX | $n_{\text{PUCCH},3}^{(1)}$ | 1, 1 | 0, 1, 1, 1 |
| NACK/DTX, any, any, any | ACK, ACK, ACK, NACK/DTX | $n_{\text{PUCCH},3}^{(1)}$ | 0, 1 | 0, 0, 1, 1 |
| (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | ACK, ACK, ACK, NACK/DTX | $n_{\text{PUCCH},3}^{(1)}$ | 0, 1 | 0, 0, 1, 1 |
| ACK, ACK, ACK, NACK/DTX | ACK, ACK, NACK/DTX, any | $n_{\text{PUCCH},0}^{(1)}$ | 1, 0 | 1, 1, 1, 0 |
| ACK, ACK, NACK/DTX, any | ACK, ACK, NACK/DTX, any | $n_{\text{PUCCH},3}^{(1)}$ | 1, 0 | 1, 0, 1, 0 |
| ACK, DTX, DTX, DTX | ACK, ACK, NACK/DTX, any | $n_{\text{PUCCH},0}^{(1)}$ | 0, 1 | 0, 1, 1, 0 |
| ACK, ACK, ACK, ACK | ACK, ACK, NACK/DTX, any | $n_{\text{PUCCH},0}^{(1)}$ | 0, 1 | 0, 1, 1, 0 |
| NACK/DTX, any, any, any | ACK, ACK, NACK/DTX, any | $n_{\text{PUCCH},3}^{(1)}$ | 0, 0 | 0, 0, 1, 0 |
| (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | ACK, ACK, NACK/DTX, any | $n_{\text{PUCCH},3}^{(1)}$ | 0, 0 | 0, 0, 1, 0 |
| ACK, ACK, ACK, NACK/DTX | ACK, DTX, DTX, DTX | $n_{\text{PUCCH},2}^{(1)}$ | 1, 1 | 1, 1, 0, 1 |
| ACK, ACK, ACK, NACK/DTX | ACK, ACK, ACK, ACK | $n_{\text{PUCCH},2}^{(1)}$ | 1, 1 | 1, 1, 0, 1 |
| ACK, ACK, NACK/DTX, any | ACK, DTX, DTX, DTX | $n_{\text{PUCCH},2}^{(1)}$ | 0, 1 | 1, 0, 0, 1 |
| ACK, ACK, NACK/DTX, any | ACK, ACK, ACK, ACK | $n_{\text{PUCCH},2}^{(1)}$ | 0, 1 | 1, 0, 0, 1 |
| ACK, DTX, DTX, DTX | ACK, DTX, DTX, DTX | $n_{\text{PUCCH},2}^{(1)}$ | 1, 0 | 0, 1, 0, 1 |
| ACK, DTX, DTX, DTX | ACK, ACK, ACK, ACK | $n_{\text{PUCCH},2}^{(1)}$ | 1, 0 | 0, 1, 0, 1 |
| ACK, ACK, ACK, ACK | ACK, DTX, DTX, DTX | $n_{\text{PUCCH},2}^{(1)}$ | 1, 0 | 0, 1, 0, 1 |
| ACK, ACK, ACK, ACK | ACK, ACK, ACK, ACK | $n_{\text{PUCCH},2}^{(1)}$ | 1, 0 | 0, 1, 0, 1 |
| NACK/DTX, any, any, any | ACK, DTX, DTX, DTX | $n_{\text{PUCCH},2}^{(1)}$ | 0, 0 | 0, 0, 0, 1 |
| NACK/DTX, any, any, any | ACK, ACK, ACK, ACK | $n_{\text{PUCCH},2}^{(1)}$ | 0, 0 | 0, 0, 0, 1 |
| (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | ACK, DTX, DTX, DTX | $n_{\text{PUCCH},2}^{(1)}$ | 0, 0 | 0, 0, 0, 1 |
| (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | ACK, ACK, ACK, ACK | $n_{\text{PUCCH},2}^{(1)}$ | 0, 0 | 0, 0, 0, 1 |
| ACK, ACK, ACK, NACK/DTX | NACK/DTX, any, any, any | $n_{\text{PUCCH},1}^{(1)}$ | 1, 0 | 1, 1, 0, 0 |
| ACK, ACK, ACK, NACK/DTX | (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | $n_{\text{PUCCH},1}^{(1)}$ | 1, 0 | 1, 1, 0, 0 |
| ACK, ACK, NACK/DTX, any | NACK/DTX, any, any, any | $n_{\text{PUCCH},1}^{(1)}$ | 0, 1 | 1, 0, 0, 0 |

| | | | | |
|---|---|---|---|---|
| ACK, ACK, NACK/DTX, any | (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | $n^{(1)}_{PUCCH,1}$ | 0, 1 | 1, 0, 0, 0 |
| ACK, DTX, DTX, DTX | NACK/DTX, any, any, any | $n^{(1)}_{PUCCH,0}$ | 1, 1 | 0, 1, 0, 0 |
| ACK, DTX, DTX, DTX | (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | $n^{(1)}_{PUCCH,0}$ | 1, 1 | 0, 1, 0, 0 |
| ACK, ACK, ACK, ACK | NACK/DTX, any, any, any | $n^{(1)}_{PUCCH,0}$ | 1, 1 | 0, 1, 0, 0 |
| ACK, ACK, ACK, ACK | (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | $n^{(1)}_{PUCCH,0}$ | 1, 1 | 0, 1, 0, 0 |
| NACK, any, any, any | NACK/DTX, any, any, any | $n^{(1)}_{PUCCH,0}$ | 0, 0 | 0, 0, 0, 0 |
| NACK, any, any, any | (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | $n^{(1)}_{PUCCH,0}$ | 0, 0 | 0, 0, 0, 0 |
| (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | NACK/DTX, any, any, any | $n^{(1)}_{PUCCH,0}$ | 0, 0 | 0, 0, 0, 0 |
| (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | $n^{(1)}_{PUCCH,0}$ | 0, 0 | 0, 0, 0, 0 |
| DTX, any, any, any | NACK/DTX, any, any, any | No Transmission | | 0, 0, 0, 0 |
| DTX, any, any, any | (ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX) | No Transmission | | 0, 0, 0, 0 |

#### 10.1.3.2.2 PUCCH format 3 HARQ-ACK procedure

If a UE is configured with one serving cell, or if a UE is configured with more than one serving cells and the UL/DL configuration of all serving cells is same, then $K$ is defined in Sec 10.2, and $M$ is the number of elements in the set $K$.

If a UE is configured with more than one serving cell and if at least two cells have different UL/DL configurations, then $K$ in this subclause refers to $K_c$ (as defined in subclause 10.2) , and $M$ is the number of elements in the set $K$.

For TDD HARQ-ACK transmission with PUCCH format 3 and sub-frame $n$ with $M \geq 1$ and more than one configured serving cell, where $M$ is the number of elements in the set $K$, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ or $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe $n$ for $\tilde{p}$ mapped to antenna port $p$ where

- for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1' (defined in Table 7.3-X), or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1', the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with
  $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = (M-m-1)\cdot N_c + m\cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$ for antenna port $p_0$, where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, $c$ is selected from {0, 1, 2, 3} such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$,
  $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ where $k_m \in K$. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port $p_1$ is given by
  $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$
- for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1' (defined in Table 7.3-X), or for a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1', the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by
  - If EPDCCH-PRB-set $q$ is configured for distributed transmission
    $n_{\text{PUCCH}}^{(1,\tilde{p})} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$
  - If EPDCCH-PRB-set $q$ is configured for localized transmission
    $n_{\text{PUCCH}}^{(1,\tilde{p})} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$

  where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$ in subframe $n-k_m$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter pucch-ResourceStartOffset-r11 , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set $q$ in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, $\Delta_{ARO}$ is determined from

the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set $q$ configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set $q$ is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port $p_1$ is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$.

- for a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port $p_0$ and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port $p_1$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port $p_0$.

- for $M > 1$ and a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', the UE shall transmit $b(0), b(1)$ in subframe $n$ using PUCCH format 1b on PUCCH resource $n_{\text{PUCCH}}^{(1)}$ selected from $A$ PUCCH resources $n_{\text{PUCCH},i}^{(1)}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A=2$ and $A=3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A=3$; otherwise, $A=2$.

  - The PUCCH resource $n_{\text{PUCCH},0}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n_{\text{PUCCH},1}^{(1)}$ is determined as $n_{\text{PUCCH},1}^{(1)} = (M-m-1)\cdot N_c + m\cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$, where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, $c$ is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ where $k_m \in K$. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n_{\text{PUCCH},2}^{(1)}$ is determined as $n_{\text{PUCCH},2}^{(1)} = n_{\text{PUCCH},1}^{(1)} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding PDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1' or for the PDCCH indicating downlink SPS release for which the value of the DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1'.

- for $M > 1$ and a PDSCH transmission only on the primary cell where there is not a corresponding EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI

value in the EPDCCH equal to '1' (defined in Table 7.3-X) or a EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1', the UE shall transmit $b(0),b(1)$ in subframe $n$ using PUCCH format 1b on PUCCH resource $n_{\text{PUCCH}}^{(1)}$ selected from $A$ PUCCH resources $n_{\text{PUCCH},i}^{(1)}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A=2$ and $A=3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A=3$; otherwise, $A=2$.

- The PUCCH resource $n_{\text{PUCCH},0}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n_{\text{PUCCH},1}^{(1)}$ is determined as

  - If EPDCCH-PRB-set $q$ is configured for distributed transmission

    $$n_{\text{PUCCH},1}^{(1)} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - If EPDCCH-PRB-set $q$ is configured for localized transmission

    $$n_{\text{PUCCH},1}^{(1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set $q$ in subframe $n-k_m$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set $q$ is configured by the higher layer parameter pucch-ResourceStartOffset-r11, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set $q$ in subframe $n-k_m$ is given in subclause 6.8A.1 in [3], $n'$ is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in subclause 6.8A.5 in [3]. If $m=0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, $\Delta_{ARO}$ is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set $q$ configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set $q$ is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n_{\text{PUCCH},2}^{(1)}$ is determined as $n_{\text{PUCCH},2}^{(1)} = n_{\text{PUCCH},1}^{(1)} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding EPDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1' or for the EPDCCH indicating downlink SPS release for which the value of the DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1'.

- for $M>1$ and a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH greater than '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$,

where $k_m \in K$ with the DAI value in the PDCCH greater than '1', the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in a PDCCH assignment with DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments used to determine the PUCCH resource values within the subframe(s) $n-k$, where $k \in K$.

- for $M > 1$ and a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH greater than '1' (defined in Table 7.3-X) or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH greater than '1', the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments used to determine the PUCCH resource values within the subframe(s) $n-k$, where $k \in K$.

- If the UL/DL configurations of all serving cells are the same, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For TDD UL/DL configurations 1-6, if a PDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or a PDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the TPC field in the PDCCH with the DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$. For TDD UL/DL configurations 1-6, if an EPDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with the DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$.

- If the UL/DL configurations of at least two serving cells are different, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For a UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} as defined in subclause 10.2, if a PDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or a PDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the TPC field in the PDCCH with the DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$. For a UL/DL

configuration of the primary cell belonging to {1,2,3,4,5,6} as defined in subclause 10.2, if an EPDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or an EPDCCH indicating downlink SPS release (defined in subclause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with the DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$.

- For PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ and a UE configured for two antenna port transmission, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port $p_0$ and the second PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_1)}$ for antenna port $p_1$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port $p_0$.

## 10.1.4 HARQ-ACK Repetition procedure

HARQ-ACK repetition is enabled or disabled by a UE specific parameter *ackNackRepetition* configured by higher layers. Once enabled, the UE shall repeat any HARQ-ACK transmission with a repetition factor $N_{\text{ANRep}}$, where $N_{\text{ANRep}}$ is provided by higher layers and includes the initial HARQ-ACK transmission, until HARQ-ACK repetition is disabled by higher layers. For a PDSCH transmission without a corresponding PDCCH/EPDCCH detected, the UE shall transmit the corresponding HARQ-ACK response $N_{\text{ANRep}}$ times using PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ configured by higher layers. For a PDSCH transmission with a corresponding PDCCH/EPDCCH detected, or for a PDCCH/EPDCCH indicating downlink SPS release, the UE shall first transmit the corresponding HARQ-ACK response once using PUCCH resource derived from the corresponding PDCCH CCE index or EPDCCH ECCE index (as described in subclauses 10.1.2 and 10.1.3), and repeat the transmission of the corresponding HARQ-ACK response $N_{\text{ANRep}}-1$ times always using PUCCH resource $n_{\text{PUCCH, ANRep}}^{(1,\tilde{p})}$, where $n_{\text{PUCCH, ANRep}}^{(1,\tilde{p})}$ is configured by higher layers.

HARQ-ACK repetition is only applicable for UEs configured with one serving cell for FDD and TDD. For TDD, HARQ-ACK repetition is only applicable for HARQ-ACK bundling.

HARQ-ACK repetition can be enabled with PUCCH format 1a/1b on two antenna ports. For a UE configured for two antenna port transmission for HARQ-ACK repetition with PUCCH format 1a/1b, a PUCCH resource value $n_{\text{PUCCH, ANRep}}^{(1,\tilde{p})}$ maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH, ANRep}}^{(1,\tilde{p}_0)}$ for antenna port $p_0$ and the second PUCCH resource $n_{\text{PUCCH, ANRep}}^{(1,\tilde{p}_1)}$ for antenna port $p_1$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH, ANRep}}^{(1,\tilde{p}_0)}$ for antenna port $p_0$.

## 10.1.5 Scheduling Request (SR) procedure

A UE is configured by higher layers to transmit the SR on one antenna port or two antenna ports.
The scheduling request shall be transmitted on the PUCCH resource(s) $n_{\mathrm{PUCCH}}^{(1,\tilde{p})} = n_{\mathrm{PUCCH,SRI}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port $p$ as defined in [3], where $n_{\mathrm{PUCCH,SRI}}^{(1,\tilde{p})}$ is configured by higher layers unless the SR coincides in time with the transmission of HARQ-ACK using PUCCH Format 3 in which case the SR is multiplexed with HARQ-ACK according to subclause 5.2.3.1 of [4]. The SR configuration for SR transmission periodicity $SR_{\mathrm{PERIODICITY}}$ and SR subframe offset $N_{\mathrm{OFFSET,SR}}$ is defined in Table 10.1.5-1 by the parameter *sr-ConfigIndex* $I_{SR}$ given by higher layers.

SR transmission instances are the uplink subframes satisfying
$\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{\mathrm{OFFSET,SR}}\right) \bmod SR_{\mathrm{PERIODICITY}} = 0$ .

**Table 10.1.5-1: UE-specific SR periodicity and subframe offset configuration**

| SR configuration Index $I_{SR}$ | SR periodicity (ms) $SR_{\mathrm{PERIODICITY}}$ | SR subframe offset $N_{\mathrm{OFFSET,SR}}$ |
|---|---|---|
| 0 – 4 | 5 | $I_{SR}$ |
| 5 – 14 | 10 | $I_{SR} - 5$ |
| 15 – 34 | 20 | $I_{SR} - 15$ |
| 35 – 74 | 40 | $I_{SR} - 35$ |
| 75 – 154 | 80 | $I_{SR} - 75$ |
| 155 – 156 | 2 | $I_{SR} - 155$ |
| 157 | 1 | $I_{SR} - 157$ |

## 10.2 Uplink HARQ-ACK timing

For FDD, the UE shall upon detection of a PDSCH transmission in subframe *n-4* intended for the UE and for which an HARQ-ACK shall be provided, transmit the HARQ-ACK response in subframe *n*. If HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission in subframe *n-4* intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe $n$ corresponding to a PDSCH transmission in subframes $n - N_{\text{ANRep}} - 3, \ldots, n-5$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-4$) on PUCCH in subframes $n$, $n+1$, …, $n + N_{\text{ANRep}} - 1$;
- shall not transmit any other signal in subframes $n$, $n+1$, …, $n + N_{\text{ANRep}} - 1$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n-3$, …, $n + N_{\text{ANRep}} - 5$.

For TDD, if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations and if a serving cell is a primary cell, then the primary cell UL/DL configuration is the DL-reference UL/DL configuration for the serving cell.

For TDD if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations and if a serving cell is a secondary cell

- if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration ) belongs to Set 1 in Table 10.2-1 or
- if the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, and if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration ) belongs to Set 2 or Set 3 in Table 10.2-1 or
- if the UE is configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, and if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration) belongs to Set 4 or Set 5 in Table 10.2-1

then the DL-reference UL/DL configuration for the serving cell is defined in the corresponding Set in Table 10.2-1.

For TDD if a UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations and if the DL-reference UL/DL configuration for at least one serving cell is TDD UL/DL Configuration 5, then the UE is not expected to be configured with more than two serving cells.

For TDD, if a UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configurations of all serving cells is same, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and $K$ is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*.

For TDD, if a UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$ for serving cell *c*, where $k \in K_c$ intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*, wherein set $K_c$ contains values of $k \in K$ such that subframe *n-k* corresponds to a DL subframe or a special subframe for serving cell *c*, $K$ defined in Table 10.1.3.1-1 (where "UL/DL configuration" in Table 10.1.3.1-1 refers to the "DL-reference UL/DL configuration") is associated with subframe *n.*

For TDD, if HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and $K$ is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe $n$ corresponding to a PDSCH transmission in a DL subframe earlier than subframe $n-k$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-k$ ) on PUCCH in UL subframe $n$ and the next $N_{\text{ANRep}}-1$ UL subframes denoted as $n_1$, …, $n_{N_{\text{ANRep}}-1}$;
- shall not transmit any other signal in UL subframe $n$, $n_1$, …, $n_{N_{\text{ANRep}}-1}$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n_i-k$, where $k \in K_i$, $K_i$ is the set defined in Table 10.1.3.1-1 corresponding to UL subframe $n_i$, and $1 \le i \le N_{\text{ANRep}}-1$.

For TDD, HARQ-ACK bundling, if the UE detects that at least one downlink assignment has been missed as described in subclause 7.3, the UE shall not transmit HARQ-ACK on PUCCH if HARQ-ACK is the only UCI present in a given subframe.

The uplink timing for the ACK corresponding to a detected PDCCH/EPDCCH indicating downlink SPS release shall be the same as the uplink timing for the HARQ-ACK corresponding to a detected PDSCH, as defined above.

**Table 10.2-1: DL-reference UL/DL configuration for serving cell based on pair formed by (primary cell UL/DL configuration, secondary cell UL/DL configuration)**

| Set # | (Primary cell UL/DL configuration, Secondary cell UL/DL configuration) | DL-reference UL/DL configuration |
|---|---|---|
| Set 1 | (0,0) | 0 |
| | (1,0),(1,1),(1,6) | 1 |
| | (2,0),(2,2),(2,1),(2,6) | 2 |
| | (3,0),(3,3),(3,6) | 3 |
| | (4,0),(4,1),(4,3),(4,4),(4,6) | 4 |
| | (5,0),(5,1),(5,2),(5,3),(5,4),(5,5),(5,6) | 5 |
| | (6,0),(6,6) | 6 |
| Set 2 | (0,1),(6,1) | 1 |
| | (0,2),(1,2),(6,2) | 2 |
| | (0,3),(6,3) | 3 |
| | (0,4),(1,4),(3,4),(6,4) | 4 |
| | (0,5),(1,5),(2,5),(3,5),(4,5),(6,5) | 5 |
| | (0,6) | 6 |
| Set 3 | (3,1),(1,3) | 4 |
| | (3,2),(4,2),(2,3),(2,4) | 5 |
| Set 4 | (0,1),(0,2),(0,3),(0,4),(0,5),(0,6) | 0 |
| | (1,2),(1,4),(1,5) | 1 |
| | (2,5) | 2 |
| | (3,4),(3,5) | 3 |
| | (4,5) | 4 |
| | (6,1),(6,2),(6,3),(6,4),(6,5) | 6 |
| Set 5 | (1,3) | 1 |
| | (2,3),(2,4) | 2 |
| | (3,1),(3,2) | 3 |
| | (4,2) | 4 |

# 11 Physical Multicast Channel (PMCH) related procedures

## 11.1 UE procedure for receiving the PMCH l

The UE shall decode the PMCH when configured by higher layers. The UE may assume that an eNB transmission on the PMCH is performed according to subclause 6.5 of [3].

The $I_{\mathrm{MCS}}$ for the PMCH is configured by higher layers. The UE shall use $I_{\mathrm{MCS}}$ for the PMCH and Table 7.1.7.1-1 to determine the modulation order ( $Q_m$ ) and TBS index ( $I_{\mathrm{TBS}}$ ) used in the PMCH.

The UE shall then follow the procedure in subclause 7.1.7.2.1 to determine the transport block size, assuming $N_{\mathrm{PRB}}$ is equal to $N_{\mathrm{RB}}^{\mathrm{DL}}$ . The UE shall set the redundancy version to 0 for the PMCH.

## 11.2 UE procedure for receiving MCCH change notification

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the M-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 11.2-1.

**Table 11.2-1: PDCCH configured by M-RNTI**

| DCI format | Search Space |
|---|---|
| DCI format 1C | Common |

The 8-bit information for MCCH change notification [11], as signalled on the PDCCH, shall be delivered to higher layers.

# 12 Assumptions independent of physical channel

A UE shall not assume that two antenna ports are quasi co-located unless specified otherwise.

A UE may assume the antenna ports 0 – 3 of a serving cell are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

# Annex A (informative): Change history

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 2006-09 | | | | | Draft version created | | 0.0.0 |
| 2006-10 | | | | | Endorsed by RAN1 | 0.0.0 | 0.1.0 |
| 2007-01 | | | | | Inclusion of decisions from RAN1#46bis and RAN1#47 | 0.1.0 | 0.1.1 |
| 2007-01 | | | | | Endorsed by RAN1 | 0.1.1 | 0.2.0 |
| 2007-02 | | | | | Inclusion of decisions from RAN1#47bis | 0.2.0 | 0.2.1 |
| 2007-02 | | | | | Endorsed by RAN1 | 0.2.1 | 0.3.0 |
| 2007-02 | | | | | Editor's version including decisions from RAN1#48 & RAN1#47bis | 0.3.0 | 0.3.1 |
| 2007-03 | | | | | Updated Editor's version | 0.3.1 | 0.3.2 |
| 2007-03 | RAN-35 | RP-070171 | | | For information at RAN#35 | 0.3.2 | 1.0.0 |
| 2007-03 | | | | | Random access text modified to better reflect RAN1 scope | 1.0.0 | 1.0.1 |
| 2007-03 | | | | | Updated Editor's version | 1.0.1 | 1.0.2 |
| 2007-03 | | | | | Endorsed by RAN1 | 1.0.2 | 1.1.0 |
| 2007-05 | | | | | Updated Editor's version | 1.1.0 | 1.1.1 |
| 2007-05 | | | | | Updated Editor's version | 1.1.1 | 1.1.2 |
| 2007-05 | | | | | Endorsed by RAN1 | 1.1.2 | 1.2.0 |
| 2007-08 | | | | | Updated Editor's version | 1.2.0 | 1.2.1 |
| 2007-08 | | | | | Updated Editor's version – uplink power control from RAN1#49bis | 1.2.1 | 1.2.2 |
| 2007-08 | | | | | Endorsed by RAN1 | 1.2.2 | 1.3.0 |
| 2007-09 | | | | | Updated Editor's version reflecting RAN#50 decisions | 1.3.0 | 1.3.1 |
| 2007-09 | | | | | Updated Editor's version reflecting comments | 1.3.1 | 1.3.2 |
| 2007-09 | | | | | Updated Editor's version reflecting further comments | 1.3.2 | 1.3.3 |
| 2007-09 | | | | | Updated Editor's version reflecting further comments | 1.3.3 | 1.3.4 |
| 2007-09 | | | | | Updated Edtior's version reflecting further comments | 1.3.4 | 1.3.5 |
| 2007-09 | RAN-37 | RP-070731 | | | Endorsed by RAN1 | 1.3.5 | 2.0.0 |
| 2007-09 | RAN-37 | RP-070737 | | | For approval at RAN#37 | 2.0.0 | 2.1.0 |
| 12/09/07 | RP-37 | RP-070737 | - | - | Approved version | 2.1.0 | 8.0.0 |
| 28/11/07 | RP-38 | RP-070949 | 0001 | 2 | Update of 36.213 | 8.0.0 | 8.1.0 |
| 05/03/08 | RP-39 | RP-080145 | 0002 | - | Update of TS 36.213 according to changes listed in cover sheet | 8.1.0 | 8.2.0 |
| 28/05/08 | RP-40 | RP-080434 | 0003 | 1 | PUCCH timing and other formatting and typo corrections | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0006 | 1 | PUCCH power control for non-unicast information | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0008 | - | UE ACK/NACK Procedure | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0009 | - | UL ACK/NACK timing for TDD | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0010 | - | Specification of UL control channel assignment | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0011 | - | Precoding Matrix for 2Tx Open-loop SM | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0012 | - | Clarifications on UE selected CQI reports | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0013 | 1 | UL HARQ Operation and Timing | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0014 | - | SRS power control | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0015 | 1 | Correction of UE PUSCH frequency hopping procedure | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0017 | 4 | Blind PDCCH decoding | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0019 | 1 | Tx Mode vs DCI format is clarified | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0020 | - | Resource allocation for distributed VRB | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0021 | 2 | Power Headroom | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0022 | - | Clarification for RI reporting in PUCCH and PUSCH reporting modes | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0025 | - | Correction of the description of PUSCH power control for TDD | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0026 | - | UL ACK/NACK procedure for TDD | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0027 | - | Indication of radio problem detection | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0028 | - | Definition of Relative Narrowband TX Power Indicator | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0029 | - | Calculation of $\Delta_{TF}(i)$ for UL-PC | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0030 | - | CQI reference and set S definition, CQI mode removal, and Miscellanious | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0031 | - | Modulation order and TBS determination for PDSCH and PUSCH | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080434 | 0032 | - | On Sounding RS | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080426 | 0033 | - | Multiplexing of rank and CQI/PMI reports on PUCCH | 8.2.0 | 8.3.0 |
| 28/05/08 | RP-40 | RP-080466 | 0034 | - | Timing advance command responding time | 8.2.0 | 8.3.0 |
| 09/09/08 | RP-41 | RP-080670 | 37 | 2 | SRS hopping pattern for closed loop antenna selection | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 39 | 2 | Clarification on uplink power control | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 41 | - | Clarification on DCI formats using resource allocation type 2 | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 43 | 2 | Clarification on tree structure of CCE aggregations | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 46 | 2 | Correction of the description of PUCCH power control for TDD | 8.3.0 | 8.4.0 |

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 09/09/08 | RP-41 | RP-080670 | 47 | 1 | Removal of CR0009 | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 48 | 1 | Correction of mapping of cyclic shift value to PHICH modifier | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 49 | - | TBS disabling for DCI formats 2 and 2A | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 50 | - | Correction of maximum TBS sizes | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 51 | - | Completion of the table specifying the number of bits for the periodic feedback | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 54 | - | Clarification of RNTI for PUSCH/PUCCH power control with DCI formats 3/3A | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 55 | 1 | Clarification on mapping of Differential CQI fields | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 59 | 1 | PUSCH Power Control | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 60 | - | RB restriction and modulation order for CQI-only transmission on PUSCH | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 61 | - | Modulation order determination for uplink retransmissions | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 62 | 2 | Introducing missing L1 parameters into 36.213 | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 63 | 2 | Correcting the range and representation of delta_TF_PUCCH | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 64 | 1 | Adjusting TBS sizes to for VoIP | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 67 | - | Correction to the downlink resource allocation | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 68 | - | Removal of special handling for PUSCH mapping in PUCCH region | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 69 | - | Correction to the formulas for uplink power control | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 70 | 1 | Definition of Bit Mapping for DCI Signalling | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 71 | - | Clarification on PUSCH TPC commands | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 72 | 1 | Reference for CQI/PMI Reporting Offset | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 74 | - | Correction to the downlink/uplink timing | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 75 | - | Correction to the time alignment command | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 77 | 1 | Correction of offset signalling of UL Control information MCS | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 78 | 2 | DCI format1C | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 80 | - | Correction to Precoder Cycling for Open-loop Spatial Multiplexing | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 81 | 1 | Clarifying Periodic CQI Reporting using PUCCH | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 84 | 1 | CQI reference measurement period | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 86 | - | Correction on downlink multi-user MIMO | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 87 | - | PUCCH Reporting | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 88 | 1 | Handling of Uplink Grant in Random Access Response | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 89 | - | Correction to UL Hopping operation | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 90 | - | DRS EPRE | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 92 | - | Uplink ACK/NACK mapping for TDD | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 93 | - | UL SRI Parameters Configuration | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 94 | - | Miscellaneous updates for 36.213 | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 95 | - | Clarifying Requirement for Max PDSCH Coding Rate | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 96 | - | UE Specific SRS Configuration | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 97 | - | DCI Format 1A changes needed for scheduling Broadcast Control | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 98 | - | Processing of TPC bits in the random access response | 8.3.0 | 8.4.0 |
| 09/09/08 | RP-41 | RP-080670 | 100 | 1 | Support of multi-bit ACK/NAK transmission in TDD | 8.3.0 | 8.4.0 |
| 03/12/08 | RP-42 | RP-081075 | 82 | 3 | Corrections to RI for CQI reporting | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 83 | 2 | Moving description of large delay CDD to 36.211 | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 102 | 3 | Reception of DCI formats | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 105 | 8 | Alignment of RAN1/RAN2 specification | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 107 | 1 | General correction of reset of power control and random access response message | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 108 | 2 | Final details on codebook subset restrictions | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 109 | - | Correction on the definition of Pmax | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 112 | 2 | CQI/PMI reference measurement periods | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 113 | - | Correction of introduction of shortened SR | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 114 | - | RAN1/2 specification alignment on HARQ operation | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 115 | - | Introducing other missing L1 parameters in 36.213 | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 116 | - | PDCCH blind decoding | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 117 | - | PDCCH search space | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 119 | - | Delta_TF for PUSCH | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 120 | - | Delta_preamble_msg3 parameter values and TPC command in RA response | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 122 | 1 | Correction of offset signaling of uplink control information MCS | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 124 | - | Miscellaneous Corrections | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 125 | - | Clarification of the uplink index in TDD mode | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 126 | - | Clarification of the uplink transmission configurations | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 127 | 2 | Correction to the PHICH index assignment | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 128 | - | Clarification of type-2 PDSCH resource allocation for format 1C | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 129 | - | Clarification of uplink grant in random access response | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 130 | - | UE sounding procedure | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 134 | - | Change for determining DCI format 1A TBS table column indicator for broadcast control | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 135 | - | Clarifying UL VRB Allocation | 8.4.0 | 8.5.0 |

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 03/12/08 | RP-42 | RP-081075 | 136 | 1 | Correction for Aperiodic CQI | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 137 | 1 | Correction for Aperiodic CQI Reporting | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 138 | 1 | Correction to PUCCH CQI reporting mode for N^DL_RB <= 7 | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 140 | 1 | On sounding procedure in TDD | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 141 | 1 | Alignment of RAN1/RAN3 specification | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 143 | 1 | TTI bundling | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 144 | 1 | ACK/NACK transmission on PUSCH for LTE TDD | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 145 | 1 | Timing relationship between PHICH and its associated PUSCH | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 147 | 1 | Definition of parameter for downlink reference signal transmit power | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 148 | 1 | Radio link monitoring | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 149 | 1 | Correction in 36.213 related to TDD downlink HARQ processes | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 151 | - | Nominal PDSCH-to-RS EPRE Offset for CQI Reporting | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 152 | 1 | Support of UL ACK/NAK repetition in Rel-8 | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 155 | - | Clarification of misconfiguration of aperiodic CQI and SR | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 156 | 1 | Correction of control information multiplexing in subframe bundling mode | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 157 | - | Correction to the PHICH index assignment | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 158 | 1 | UE transmit antenna selection | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 159 | - | Clarification of spatial different CQI for CQI reporting Mode 2-1 | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 160 | 1 | Corrections for TDD ACK/NACK bundling and multiplexing | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 161 | - | Correction to RI for Open-Loop Spatial Multiplexing | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 162 | - | Correction of differential CQI | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 163 | - | Inconsistency between PMI definition and codebook index | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 164 | - | PDCCH validation for semi-persistent scheduling | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 165 | 1 | Correction to the UE behavior of PUCCH CQI piggybacked on PUSCH | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 166 | - | Correction on SRS procedure when shortened PUCCH format is used | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 167 | 1 | Transmission overlapping of physical channels/signals with PDSCH for transmission mode 7 | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 169 | - | Clarification of SRS and SR transmission | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 171 | - | Clarification on UE behavior when skipping decoding | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 172 | 1 | PUSCH Hopping operation corrections | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 173 | - | Clarification on message 3 transmission timing | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 174 | - | MCS handling for DwPTS | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 175 | - | Clarification of UE-specific time domain position for SR transmission | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 176 | 1 | Physical layer parameters for CQI reporting | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 177 | - | A-periodic CQI clarification for TDD UL/DL configuration 0 | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 179 | 1 | Correction to the definitions of rho_A and rho_B (downlink power allocation) | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 180 | - | Clarification of uplink A/N resource indication | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 181 | - | PDCCH format 0 for message 3 adaptive retransmission and transmission of control information in message 3 during contention based random access procedure | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081075 | 182 | - | To Fix the Discrepancy of Uplink Power Control and Channel Coding of Control Information in PUSCH | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081122 | 183 | 1 | CQI reporting for antenna port 5 | 8.4.0 | 8.5.0 |
| 03/12/08 | RP-42 | RP-081110 | 168 | 1 | Clarification on path loss definition | 8.4.0 | 8.5.0 |
| 04/03/09 | RP-43 | RP-090236 | 184 | 1 | Corrections to Transmitted Rank Indication | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 185 | 4 | Corrections to transmission modes | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 186 | 2 | Delta_TF configuration for control only PUSCH | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 187 | 1 | Correction to concurrent SRS and ACK/NACK transmission | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 191 | 1 | PDCCH release for semi-persistent scheduling | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 192 | 1 | Correction on ACKNACK transmission on PUSCH for LTE TDD | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 193 | - | Correction to subband differential CQI value to offset level mapping for aperiodic CQI reporting | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 194 | - | Correction for DRS Collision handling | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 196 | 2 | Alignment of RAN1/RAN4 specification on UE maximum output power | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 197 | - | Transmission scheme for transmission mode 7 with SPS C-RNTI | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 198 | - | Clarifying bandwidth parts for periodic CQI reporting and CQI refererence period | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 199 | 2 | Correction to the ACK/NACK bundling in case of transmission mode 3 and 4 | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 200 | - | ACK/NAK repetition for TDD ACK/NAK multiplexing | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 201 | - | Clarifying UL ACK/NAK transmission in TDD | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 202 | - | Corrections to UE Transmit Antenna Selection | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 203 | - | Correction to UE PUSCH hopping procedure | 8.5.0 | 8.6.0 |

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 04/03/09 | RP-43 | RP-090236 | 204 | - | Correction to PHICH resource association in TTI bundling | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 205 | - | Clarification of the length of resource assignment | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 206 | - | Correction on ACK/NACK transmission for downlink SPS resource release | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 207 | - | Introduction of additional values of wideband CQI/PMI periodicities | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 208 | 2 | Correction to CQI/PMI/RI reporting field | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 209 | 2 | Correction to rho_A definition for CQI calculation | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 210 | - | Correction to erroneous cases in PUSCH linear block codes | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 211 | 1 | Removing RL monitoring start and stop | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 214 | 1 | Correction to type-1 and type-2 PUSCH hopping | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 215 | - | Contradicting statements on determination of CQI subband size | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 216 | - | Corrections to SRS | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 219 | 2 | Miscellaneous corrections on TDD ACKNACK | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 221 | 1 | CR for Redundancy Version mapping function for DCI 1C | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 223 | - | Scrambling of PUSCH corresponding to Random Access Response Grant | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 225 | - | Removal of SRS with message 3 | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 226 | 3 | PRACH retransmission timing | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 227 | - | Clarifying error handling of PDSCH and PUSCH assignments | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 228 | - | Clarify PHICH index mapping | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 229 | - | Correction of CQI timing | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 230 | - | Alignment of CQI parameter names with RRC | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 231 | 1 | Removal of 'Off' values for periodic reporting in L1 | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 232 | - | Default value of RI | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 233 | 1 | Clarification of uplink timing adjustments | 8.5.0 | 8.6.0 |
| 04/03/09 | RP-43 | RP-090236 | 234 | - | Clarification on ACK/NAK repetition | 8.5.0 | 8.6.0 |
| 27/05/09 | RP-44 | RP-090529 | 235 | 1 | Correction to the condition of resetting accumulated uplink power correction | 8.6.0 | 8.7.0 |
| 27/05/09 | RP-44 | RP-090529 | 236 | - | Correction to the random access channel parameters received from higher layer | 8.6.0 | 8.7.0 |
| 27/05/09 | RP-44 | RP-090529 | 237 | - | Correction on TDD ACKNACK | 8.6.0 | 8.7.0 |
| 27/05/09 | RP-44 | RP-090529 | 238 | 1 | Correction on CQI reporting | 8.6.0 | 8.7.0 |
| 27/05/09 | RP-44 | RP-090529 | 239 | - | Correction on the HARQ process number | 8.6.0 | 8.7.0 |
| 27/05/09 | RP-44 | RP-090529 | 241 | 1 | CR correction of the description on TTI-bundling | 8.6.0 | 8.7.0 |
| 27/05/09 | RP-44 | RP-090529 | 242 | 1 | Clarify latest and initial PDCCH for PDSCH and PUSCH transmisisons, and NDI for SPS activation | 8.6.0 | 8.7.0 |
| 27/05/09 | RP-44 | RP-090529 | 243 | - | Clarify DRS EPRE | 8.6.0 | 8.7.0 |
| 27/05/09 | RP-44 | RP-090529 | 244 | 1 | Clarification on TPC commands for SPS | 8.6.0 | 8.7.0 |
| 15/09/09 | RP-45 | RP-090888 | 245 | 1 | Correction to PUSCH hopping and PHICH mapping procedures | 8.7.0 | 8.8.0 |
| 15/09/09 | RP-45 | RP-090888 | 246 | - | Clarification on subband indexing in periodic CQI reporting | 8.7.0 | 8.8.0 |
| 15/09/09 | RP-45 | RP-090888 | 247 | 2 | Correction to DVRB operation in TDD transmission mode 7 | 8.7.0 | 8.8.0 |
| 15/09/09 | RP-45 | RP-090888 | 249 | - | Clarification of concurrent ACKNACK and periodic PMI/RI transmission on PUCCH for TDD | 8.7.0 | 8.8.0 |
| 15/09/09 | RP-45 | RP-090888 | 250 | - | Clarify Inter-cell synchronization text | 8.7.0 | 8.8.0 |
| 01/12/09 | RP-46 | RP-091172 | 248 | 1 | Introduction of LTE positioning | 8.8.0 | 9.0.0 |
| 01/12/09 | RP-46 | RP-091172 | 254 | - | Clarification of PDSCH and PRS in combination for LTE positioning | 8.8.0 | 9.0.0 |
| 01/12/09 | RP-46 | RP-091177 | 255 | 5 | Editorial corrections to 36.213 | 8.8.0 | 9.0.0 |
| 01/12/09 | RP-46 | RP-091257 | 256 | 1 | Introduction of enhanced dual layer transmission | 8.8.0 | 9.0.0 |
| 01/12/09 | RP-46 | RP-091177 | 257 | 1 | Add shorter SR periodicity | 8.8.0 | 9.0.0 |
| 01/12/09 | RP-46 | RP-091256 | 258 | - | Introduction of LTE MBMS | 8.8.0 | 9.0.0 |
| 17/12/09 | RP-46 | RP-091257 | 256 | 1 | Correction by MCC due to wrong implementation of CR0256r1 – Sentence is added to Single-antenna port scheme subclause 7.1.1 | 9.0.0 | 9.0.1 |
| 16/03/10 | RP-47 | RP-100211 | 259 | 3 | UE behavior when collision of antenna port 7/8 with PBCH or SCH happened and when distributed VRB is used with antenna port 7 | 9.0.1 | 9.1.0 |
| 16/03/10 | RP-47 | RP-100210 | 260 | 1 | MCCH change notification using DCI format 1C | 9.0.1 | 9.1.0 |
| 16/03/10 | RP-47 | RP-100211 | 263 | - | Correction on PDSCH EPRE and UE-specific RS EPRE for Rel-9 enhanced DL transmissions | 9.0.1 | 9.1.0 |
| 01/06/10 | RP-48 | RP-100589 | 265 | - | Clarification for TDD when multiplexing ACK/NACK with SR of ACK/NACK with CQI/PMI or RI | 9.1.0 | 9.2.0 |
| 01/06/10 | RP-48 | RP-100590 | 268 | 1 | Clarification of PRS EPRE | 9.1.0 | 9.2.0 |
| 14/09/10 | RP-49 | RP-100900 | 269 | - | Clarification on Extended CP support with Transmission Mode 8 | 9.2.0 | 9.3.0 |
| 07/12/10 | RP-50 | RP-101320 | 270 | - | Introduction of Rel-10 LTE-Advanced features in 36.213 | 9.3.0 | 10.0.0 |
| 27/12/10 | - | - | - | - | Editorial change to correct a copy/past error in subclause 7.2.2 | 10.0.0 | 10.0.1 |
| 15/03/11 | RP-51 | RP-110255 | 271 | 1 | A clarification for redundancy version of PMCH | 10.0.1 | 10.1.0 |
| 15/03/11 | RP-51 | RP-110258 | 272 | - | RLM Procedure with restricted measurements | 10.0.1 | 10.1.0 |
| 15/03/11 | RP-51 | RP-110256 | 273 | - | Corrections to Rel-10 LTE-Advanced features in 36.213 | 10.0.1 | 10.1.0 |
| 01/06/11 | RP-52 | RP-110819 | 274 | 3 | Correction to HARQ-ACK procedure for TDD mode b with M=2 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 275 | 3 | Determination of PUSCH A/N codebook size for TDD | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110823 | 276 | - | The triggering of aperiodic SRS in DCI formats 2B and 2C | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 278 | 3 | Corrections to power headroom | 10.1.0 | 10.2.0 |

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 01/06/11 | RP-52 | RP-110819 | 279 | 1 | Removal of square brackets for PUCCH format 3 ACK/NACK | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 281 | 1 | Correction of AN repetition and PUCCH format 3 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 282 | 2 | Correction to timing for secondary cell activation and deactivation | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110823 | 283 | 1 | Correction to MCS offset for multiple TBs | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110820 | 286 | 1 | Miscellaneous Corrections | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 288 | 1 | Corrections on UE procedure for determining PUCCH Assignment | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 289 | 2 | Correction to Multi-cluster flag in DCI format 0 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 290 | 2 | Joint transmission of ACK/NACK and SR with PUCCH format 3 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 291 | 3 | Correction of uplink resource allocation type 1 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110821 | 292 | 1 | Correction on CSI-RS configuration | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110818 | 294 | - | ACK/NACK and CQI simultaneous transmission in ACK/NACK bundling in TDD | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110823 | 295 | - | UE specific disabling of UL DMRS sequence hopping | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110821 | 296 | - | PDSCH transmission in MBSFN subframes | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 297 | - | Introduction of PCMAX for PUSCH power scaling | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 298 | - | Power control for SR and ACK/NACK with PUCCH format 3 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 299 | 2 | CR on power control for HARQ-ACK transmission on PUCCH | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 300 | 2 | Correction to handling of search space overlap | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 301 | 1 | Correction to simultaneous transmission of SRS and PUCCH format 2/2a/2b | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 302 | 1 | Correction for Simultaneous PUCCH and SRS Transmissions on CA | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110821 | 303 | - | Correction on 8Tx Codebook Sub-sampling for PUCCH Mode 1-1 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110821 | 304 | 1 | Corrections on CQI type in PUCCH mode 2-1 and clarification on simultaneous PUCCH and PUSCH transmission for UL-SCH subframe bundling | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110818 | 305 | 1 | Correction on UE behaviour upon reporting periodic CSI using PUCCH Mode1-1 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110818 | 306 | - | Clarification for the definition of CQI | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110818 | 307 | - | Clarification for the definition of Precoding Matrix Indicator | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 308 | - | Simultaneous SRS transmissions in more than one cell | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 310 | 1 | Miscellaneous Corrections for TS 36.213 | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110821 | 311 | 1 | Configuration of pmi-RI-Report | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 312 | 1 | Correction on the support of PUCCH format 3 and channel selection | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110821 | 313 | - | Correction on UE behaviour during DM-RS transmission on subframes carrying synchronization signals | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110820 | 314 | 1 | 36.213 CR on antenna selection | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110823 | 316 | 1 | Number of HARQ process for UL spatial multiplexing | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 317 | - | PUCCH format 3 Fallback procedure in TDD | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 318 | - | Clarification on CSI reporting under an invalid downlink subframe | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 320 | - | Multiple Aperiodic SRS Triggers for Same Configuration | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110823 | 321 | - | UE antenna switch in UL MIMO | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110819 | 322 | - | UE behaviour for PDSCH reception with limited soft buffer in CA | 10.1.0 | 10.2.0 |
| 01/06/11 | RP-52 | RP-110859 | 323 | - | Joint transmission of ACK/NACK and SR or CSI with PUCCH format 3 and channel selection | 10.1.0 | 10.2.0 |
| 15/09/11 | RP-53 | RP-111229 | 277 | 1 | Correction to reception of PRS in MBSFN subframes | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111230 | 325 | 3 | Corrections on UE procedure for reporting HARQ-ACK | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111230 | 326 | 2 | Corrections on Physical Uplink Control Channel Procedure | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111231 | 331 | 1 | Correction to uplink transmission scheme usage for random access response and PHICH-triggered retransmissions | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111229 | 336 | - | Corrections on transmission mode 9 | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111230 | 339 | - | Corrections on HARQ-ACK codebook size determination | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111230 | 340 | - | Corrections on TDD PUCCH format 1b with channel selection and HARQ-ACK transmission on PUSCH | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111230 | 341 | - | Corrections on NACK generation | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111230 | 342 | - | Corrections on power headroom reporting | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111229 | 346 | - | Correction on TBS translation table | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111229 | 347 | 2 | Correction to the condition of enabling PMI feedback | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111232 | 348 | - | Miscellaneous corrections to 36.213 | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111229 | 349 | - | Corrections on PUSCH and PUCCH modes | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111231 | 350 | 1 | CR on UL HARQ ACK determination | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111231 | 351 | 1 | Correction on UL DMRS resources for PHICH-triggered retransmission | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111230 | 352 | - | Clarification on the common search space description | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111232 | 353 | 1 | Clarification on ambiguous DCI information between UE-specific search space and common search space for DCI formats 0 and 1A | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111229 | 354 | - | Clarification of Reference PDSCH Power for CSI-RS based CSI Feedback | 10.2.0 | 10.3.0 |
| 15/09/11 | RP-53 | RP-111230 | 355 | 2 | Corrections on reporting Channel State Information | 10.2.0 | 10.3.0 |

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 05/12/11 | RP-54 | RP-111669 | 324 | 3 | Accumulation of power control commands from DCI format 3/3A | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 357 | 1 | Miscellaneous corrections on uplink power control | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 358 | - | Corrections on N_c^{received} | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 359 | - | Corrections on TDD PUCCH format 1b with channel selection and two configured serving cells | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 360 | - | Corrections on the notation of k and k_m | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111668 | 361 | 1 | Corrections on PUCCH mode 2-1 | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111668 | 362 | 3 | A correction to PDSCH transmission assumption for CQI calculation | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 363 | 1 | Corrections on PUCCH Resource Notation | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111667 | 364 | - | Correction on the notation of SRS transmission comb | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 365 | - | Clarification on the HARQ-ACK procedure of TDD UL-DL configuration 5 | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 366 | 2 | Clarification on the determination of resource for PUCCH Format 1b with channel selection in TDD mode | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 367 | 1 | Correction on HARQ-ACK procedure | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 368 | - | Correction for A/N on PUSCH with W=1,2 in case of TDD channel selection | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111668 | 369 | - | Clarification of PUCCH 2-1 Operation | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111668 | 370 | 1 | Correction on PMI index | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 371 | 2 | Correction to periodic CSI reports for carrier aggregation | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 373 | 1 | Removal of square bracket in HARQ-ACK procedure | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 374 | 1 | Clarification on UE's capability of supporting PUCCH format 3 | 10.3.0 | 10.4.0 |
| 05/12/11 | RP-54 | RP-111666 | 375 | 1 | Clarifications of UE behavior on PUSCH power control | 10.3.0 | 10.4.0 |
| 28/02/12 | RP-55 | RP-120286 | 376 | 1 | RNTI Configuration associated with DL Resource Allocation Type 2 | 10.4.0 | 10.5.0 |
| 28/02/12 | RP-55 | RP-120283 | 377 | 2 | Correction for ACK/NACK related procedure in case of TDD UL-DL configuration 0 | 10.4.0 | 10.5.0 |
| 13/06/12 | RP-56 | RP-120737 | 378 | 3 | Correction of FDD channel selection HARQ-ACK and SR transmission | 10.5.0 | 10.6.0 |
| 13/06/12 | RP-56 | RP-120738 | 379 | - | Removal of description with square brackets | 10.5.0 | 10.6.0 |
| 13/06/12 | RP-56 | RP-120738 | 381 | - | Correction on transmission mode 9 with a single antenna port transmission | 10.5.0 | 10.6.0 |
| 04/09/12 | RP-57 | RP-121265 | 382 | - | Clarification of codebook subsampling for PUCCH 2-1 | 10.6.0 | 10.7.0 |
| 04/09/12 | RP-57 | RP-121266 | 383 | - | Correction to UE transmit antenna selection | 10.6.0 | 10.7.0 |
| 04/09/12 | RP-57 | RP-121264 | 384 | - | TDD HARQ-ACK procedure for PUCCH format 1b with channel selection in carrier aggregation | 10.6.0 | 10.7.0 |
| 04/09/12 | RP-57 | RP-121265 | 385 | - | Corrections for Handling CSI-RS patterns | 10.6.0 | 10.7.0 |
| 04/09/12 | RP-57 | RP-121264 | 386 | 1 | Reference serving cell for pathloss estimation | 10.6.0 | 10.7.0 |
| 04/09/12 | RP-57 | RP-121264 | 387 | - | Power control for PUCCH format 3 with single configured cell | 10.6.0 | 10.7.0 |
| 04/09/12 | RP-57 | RP-121264 | 388 | - | ACK/NACK resource in case of channel selection | 10.6.0 | 10.7.0 |
| 04/09/12 | RP-57 | RP-121274 | 380 | 4 | Introduction of an additional special subframe configuration | 10.7.0 | 11.0.0 |
| 04/09/12 | RP-57 | RP-121272 | 389 | - | Introduction of Rel-11 features | 10.7.0 | 11.0.0 |
| 04/12/12 | RP-58 | RP-121839 | 393 | - | Correction to the parameter ue-Category-v10xy | 11.0.0 | 11.1.0 |
| 04/12/12 | RP-58 | RP-121837 | 395 | - | Correction of reference signal scrambling sequence initialization for SPS in transmission mode 7 | 11.0.0 | 11.1.0 |
| 04/12/12 | RP-58 | RP-121846 | 396 | - | Finalisation for introducing Rel-11 features | 11.0.0 | 11.1.0 |
| 26/02/13 | RP-59 | RP-130254 | 398 | - | Correction on UE procedure for reporting HARQ-ACK | 11.1.0 | 11.2.0 |
| 26/02/13 | RP-59 | RP-130252 | 400 | - | Corrections for SRS power scaling in UpPTS | 11.1.0 | 11.2.0 |
| 26/02/13 | RP-59 | RP-130252 | 403 | - | CR on UE specific search and Common search space overlap on PDCCH | 11.1.0 | 11.2.0 |
| 26/02/13 | RP-59 | RP-130358 | 404 | - | Additional clarifications/corrections for introducing Rel-11 features | 11.1.0 | 11.2.0 |
| 11/06/13 | RP-60 | RP-130752 | 405 | - | Correction to EPDCCH monitoring in case of cross-carrier scheduling | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130751 | 407 | 1 | Correction on the RI bit width | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130750 | 408 | - | Correction on parallel reception of PDSCH and Msg 2 | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130747 | 409 | - | Correction on zero power CSI-RS resource configuration | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130750 | 410 | 1 | Corrections on different TDD UL-DL configurations on different bands | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130752 | 411 | - | Correction on EPDCCH PRB pair indication | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130752 | 412 | - | Correction on EPDCCH hashing function | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130752 | 413 | - | Correction on PUCCH resource determination for FDD EPDCCH | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130752 | 414 | 2 | CR on ambiguity in EPDCCH decoding candidates under two overlapped EPDCCH resource sets | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130749 | 415 | - | Removal of the case for spatial domain bundling in TDD UL/DL configuration 0 | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130752 | 416 | - | Corrections to EPDCCH PRB pair indication | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130753 | 417 | 1 | Correction to PUSCH/PUCCH transmit power after PRACH power ramping | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130747 | 418 | - | CR on RI-Reference CSI Process with Subframe Sets | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130747 | 420 | - | Correction on UE-specific RS scrambling for SPS PDSCH in TM10 | 11.2.0 | 11.3.0 |

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| 11/06/13 | RP-60 | RP-130747 | 421 | - | CR on resolving ambiguous UE capability signaling for CoMP | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130750 | 422 | - | Correction of valid downlink subframe | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130749 | 424 | - | Correction on HARQ-ACK transmission for a UE configured with PUCCH format 3 | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130750 | 425 | - | Correction of PHICH resource for half duplex TDD UE | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130750 | 426 | - | Correction on n_{HARQ} for TDD CA with different UL-DL configurations | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130750 | 427 | - | Correction on implicit HARQ-ACK resource determination for PUCCH format 1b with channel selection for TDD CA with different UL-DL configurations | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130750 | 428 | - | Correction on SRS power scaling with multiple TAGs | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130747 | 429 | - | Correction on MBSFN subframe configuration | 11.2.0 | 11.3.0 |
| 11/06/13 | RP-60 | RP-130749 | 430 | - | CR on SCell activation timing | 11.2.0 | 11.3.0 |
| 03/09/13 | | | | | MCC clean-up | 11.3.0 | 11.4.0 |
| 03/09/13 | RP-61 | RP-131249 | 432 | - | Correction for EPDCCH Search Space | 11.3.0 | 11.4.0 |
| 03/09/13 | RP-61 | RP-131250 | 433 | - | Correction to QCL behaviour on CRS | 11.3.0 | 11.4.0 |
| 03/09/13 | RP-61 | RP-131250 | 434 | - | Correction on PUCCH power control | 11.3.0 | 11.4.0 |
| 03/09/13 | RP-61 | RP-131248 | 435 | - | Correction on the ratio of PDSCH EPRE to CRS EPRE for TM10 | 11.3.0 | 11.4.0 |
| 03/09/13 | RP-61 | RP-131249 | 436 | - | CR on EPDCCH Search Space for Cross-Carrier Scheduling | 11.3.0 | 11.4.0 |
| 03/09/13 | RP-61 | RP-131249 | 437 | - | Correction to the UE behaviour in case of collision between PRS and EPDCCH in different CP case | 11.3.0 | 11.4.0 |
| 03/09/13 | RP-61 | RP-131249 | 438 | - | On correction to higher layer parameter name for EPDCCH resource mapping | 11.3.0 | 11.4.0 |
| 03/09/13 | RP-61 | RP-131248 | 439 | - | Correction to PDSCH mapping for CoMP | 11.3.0 | 11.4.0 |
| 03/12/13 | RP-62 | RP-131893 | 440 | 1 | Correction on parameter ue-Category | 11.4.0 | 11.5.0 |
| 03/12/13 | RP-62 | RP-131892 | 442 | 1 | Correction on determination of modulation order and transport block size | 11.4.0 | 11.5.0 |
| 03/12/13 | RP-62 | RP-132024 | 445 | 3 | Correction on CSI reporting type and parameters | 11.4.0 | 11.5.0 |
| 03/12/13 | RP-62 | RP-131894 | 446 | - | Correction on deriving the length of the non-MBSFN region | 11.4.0 | 11.5.0 |
| 03/03/14 | RP-63 | RP-140287 | 449 | 1 | Common search space monitoring for MBMS | 11.5.0 | 11.6.0 |
| 03/03/14 | RP-63 | RP-140290 | 451 | - | Introduction of new UE categories | 11.5.0 | 11.6.0 |
| 03/03/14 | RP-63 | RP-140288 | 454 | 1 | Modification to I_SRS = 0 for trigger type 1 SRS and TDD | 11.5.0 | 11.6.0 |
| 03/03/14 | RP-63 | RP-140289 | 457 | - | Correction to CSI processing in TM10 | 11.5.0 | 11.6.0 |

# Appendix 1

# Curriculum Vitae


**Name:** Craig Bishop

**Contact Tel No.:** +44 (0)7984 564949 (mobile)

**Email**: craig@bishopcom.co.uk

**Current job title:** Independent Consulting Engineer, CEO

**Address:** 43 Ospringe Street, Faversham, Kent, ME13 8TW


**Key Skills and Experience**

- 33 years Telecoms, Radio and Broadcast experience
- 26 years experience of 2G/3G/4G telecoms standardisation
- Extensive knowledge of 3GPP and ETSI specifications and procedures including document handling and publication practices
- Sound understanding of 3GPP systems, including Radio Access Interfaces and Networks, Access Stratum protocols, Core Networks, Non-Access Stratum protocols, and IMS
- Experience of ETSI role from regulatory perspective (harmonised standards, mandates, spectrum, etc)
- Depositions, reports, and declarations as expert witness in cases on 3GPP technologies and on 3GPP & ETSI practices and procedures.
- Intellectual property analysis including prior art search and evaluation of patent essentiality
- Application of data analytics and machine learning techniques to standards and IP data
- Programming in Java, Python, C, Octave (Matlab)

**Career History**

## Bishop Communications Ltd. 01/13 –

## Independent Telecommuncations Standards and Intellectual Property Consultant

Company is a full ETSI member

Activities have included:

- Provision of expertise for EC funded ETSI Specialist Task Force (STF489) to produce implementation guidelines for Total Conversation for emergency services. Project delivered on time / budget and well received. Ouput published March 2016 as ETSI TR 103 201.
- Provision of expertise for ETSI Specialist Task Force (STF555) assessing the impact on existing standards of communications involving IoT devices in all types of emergency situations. Project delivered on time / budget and well received. Ouput published July 2019 as ETSI TR 103 582.
- Provision of expert support for IPR litigation from standards landscape analysis / background technical reports to expert testimony reports / declarations and depositions on matters including the public availability of 3GPP and ETSI prior art.
- Intellectual property analysis assessing strengths and weaknesses of patents and patent portfolios, conducting searches for prior art, evaluating patent essentiality, and acquring relevant documentation.
- Provision of standards consultancy services for Samsung Electronics in ETSI including membership of the ETSI Board until November 2014

Technologies covered in patent related work include: 3GPP GSM, UMTS, LTE radio interface technologies (Phy, MAC, RLC, RRC), 3GPP access and core networks (GPRS/UMTS & EPC NAS), IMS. Organisations covered include 3GPP & ETSI.

Clients served during last 10 years include: Addy Hart LLP, Alston & Bird LLP, AT&T, Baker Botts LLP, Banner Witcoff LLP, DLA Piper LLP, European Telecommunications Standards Institute (ETSI),

Fish & Richardson P.C., Gibson Dunn LLP, Haynes and Boone LLP, Hillebrand-CE GmbH (working for third party clients as Consulting Engineer for Hillebrand-CE), Kilpatrick Townsend & Stockton, Kirkland & Ellis LLP, K&L Gates LLP, Morgan, Lewis & Bokius LLP, MckoolSmith LLP, PV Law LLP, Paul Hastings LLP, Perkins Coie LLP, Powell Gilbert LLP, Sidley Austin LLP, Samsung Electronics Research & Development Institute UK (SRUK), Taylor Wessing LLP, Williams & Connolly LLP, WilmerHale LLP.

Expert testimony through deposition:

- *Huawei Technologies Co. Ltd. vs. T-Mobile US, Inc., et al.*, Case Nos. 2:16-cv-0052-JRG-RSP, 2:16-cv-0055-JRG-RSP, 2:16-cv-0056-JRG-RSP, and 2:16-cv-0057-JRG-RSP (E.D. Tex.). On behalf of T-Mobile US Inc.
- *T-Mobile US, Inc., et al.* v. *Huawei Technologies Co. Ltd.*, Case Nos. IPR2017-00696 and IPR2017-00697 (PTAB). On behalf of T-Mobile US Inc.
- *LG Electronics, Inc., v. Koninklijke KPN N.V.*, Case No. IPR2018-00558 (PTAB). On behalf of LG Electronics, Inc.
- *Nokia of America Corp. and Ericsson Inc. v. IPCOM, GMBH & Co.,* Case No. IPR2021-00533 (PTAB). On behalf of Ericsson Inc.
- *IPCom, GmbH & Co., Plaintiff, v. AT&T Inc., et al, Defendant, Nokia of America Corp., Intervenor, Ericsson Inc., Intervenor.,* Civil Action No. 2:20-CV-322-JRG*, and IPCom, GmbH & Co., Plaintiff, v. Verizon Communications, et al., Defendant, Nokia of America Corp., Intervenor, Ericsson* nc*., Intervenor.,* Civil Action No. 2:20-CV-323-JRG. On behalf of Ericsson Inc.
- *Ericsson Inc. v. Koninklijke KPN N.V.,* Case No. IPR2022-00069 (PTAB). On behalf of Ericsson Inc.

Expert testimony in court:

- *Between IPCom GmbH and Vodafone, et al.,* Claim No. HP-2018-000030 Claim No. HP-2018-000031, High Court of Justice, Business & Property Courts of England and Wales, Intellectual Property List (ChD), Patents Court. Retained by Vodafone.
- *Between (1) Mitsubishi Electric Corporation (2) Sisvel International SA and Oneplus Mobiletech UK Limited, Oppo Mobile UK Ltd, Xiaomi Technology UK Limited, et al.,* Claim No. HP-2019-000014, High Court of Justice, Business & Property Courts of England and Wales, Intellectual Property List (ChD), Patents Court. Retained by Oneplus, Oppo, and Xiaomi (trial held remotely due to COVID-19 restrictions)

## Samsung Electronics Research Institute (SERI) 12/96 – 01/13

## Director Standards and Industry Affairs 03/11 – 01/13

Mission and Tasks as for previous role plus:

- Proactive member of ETSI Board following election as Board member in November 2011
- Worked with Samsung internal and external legal counsel in response to EC investigation into Samsung suspected abuse of Standards Essential Patents.
- Deposed by Apple as fact witness in ITC investigation 337-TA-794.

## Head of Advanced Technologies Standards & Regulation 09/05 - 03/11

Mission: To help position Samsung and SERI at the forefront of mobile telecommunication developments through participation in and leadership of mobile communications standards and European regulatory affairs

Key tasks:

- Developed standards and research strategy and coordinated activites with head office, acting as official Samsung contact for the European Telecommunications Standars Institute.
- Programme managed standardisation and regulation projects covering 3GPP (RAN2, CT1, SA2, SA1, SA, RAN, CT), OMA, and mobile Broadcast strategies and technologies (DVB Forum),

European Framework projects (FP7), Spectrum Management (CEPT, ETSI EM, TFES, BRAN, …) and European Regulatory affairs (Digital Europe, relations with European Commission, …). - Grew department from 3 to 12 persons to cater for these activities.

- Participated and actively contributed to 3GPP SA1 (11/08 – 11/11), SA2 (10/05 – 08/11) , SA and ETSI TC SCP groups on issues including IMS / CS Interworking (VCC / SRVCC, VoLTE, T-ADS, ICS), Local IP Access & Selected IP Traffic Offload (LIPA-SIPTO), MOSAP, M2M/MTC, Embedded / 4FF UICC.
- Drafted and filed communication technology related patents related to 3GPP SA2 and CT1 technologies – 18 filed, mainly IMS and 3GPP NAS related
- Supported Samsung IP team with analysis of Samsung and 3rd party communication technology related patents and claim charts including GSM/GPRS, UTRAN, NAS, and IMS patents
- Chaired SERI Patent Committee from 2007-2009 - SERI achieved patent targets for first time in 2007 and did so in every year following

## Standards consultant – part time 09/04 – 09/05

(Whilst studying fulltime for MSC)

During this time, I conducted a review of the wireless communication technolgies and the associated standards space, with a particular emphasis on 802.16a, as well as 3G and 802.11 evolutions. I was also involved in analysis of 3rd party patents and claim charts on request from Samsung IP team.

## Technology Manager System Engineering group 06/03 – 09/04

Mission: To establish a System Engineering group within SERI to support development of SERI's dual mode GSM/UMTS radio modem platform.

Key Tasks:

- Defined and implemented System Engineering group strategy including recruitment and line management of the group which grew from 3 to 10 engineers during this period.
- Developed detailed system requirements for SERI's dual mode 2G/3G radio modem platform(s) including production of background documentation describing system wide behaviour
- Defined system test programme for platform, including example test cases using off the shelf test equipment. This project outsourced (under my supervision) to a third party company for completion.
- Provided continued support to development engineers in terms of understanding specification and system requirements, particularly with respect to Access Stratum and Non Access Stratum specifications and protocols.
- Instigated and managed studies investigating optimised system architecture for future Samsung mobile platforms.
- Analysed Samsung and 3rd party 3GPP technology related patents and claim charts on request by Samsung IP team and reported on their value and standards essentiality.

## Technology Manager Standards & System Group 04/02 – 06/03

Mission: To provide Standards support to SERI development teams and Samsung's global standardisation activities.

Key Tasks:

- Devised and implemented revised strategy to improve the focus of activities and provide improved support for software developers from a system perspective.
- Attended 3GPP TSG SA plenary and occasional SA WG1 meetings - acted as rapporteur for 3GPP Evolution technical report 3GPP TR 21.902.

- Analysed 3rd party GSM/GPRS technology related patents and claim charts on request by Samsung IP team and reported on their value and standards essentiality.
- Line managed 3 engineers, ensuring that the group provided expert support for SERI SW and HW developers in terms of standards interpretation and system requirements, particularly with respect to the Radio Access Network.

## Project Manager 04/00 – 04/02

Mission: To establish and manage development of a dual mode GSM/UMTS modem platform.

Key tasks:

- Defined and managed work relating to core technology development for Samsung's 3G handsets.
- Determined major technical architecture and parameters for the platform producing high level system requirements specification and project development plan.
- As a technical authority on UMTS, supported the project in terms of requirements specification and interpretation (L1, MAC/RLC, RRC, and NAS specifications), and contributed towards the training of UMTS project team members.
- Acting in a consultative capacity, interfaced with other departments in Samsung and with external customers/suppliers on issues relating to 2G and 3G technologies
- Responsible for the overall planning, work allocation and co-ordination of engineers for the project, as well as being involved in recruitment – during this period the number of engineers working on the project increased from 10 to over 40.
- Instigated, defined and managed a feasibility study involving HW and SW engineers, as essential preparation for the development of a dual mode GSM/UMTS radio modem platform.

## Senior/Principal Standards Engineer 12/96 – 04/00

Mission: To support Samsung standards and development activities in ETSI and 3GPP.

Key Tasks:

- Gathered and disseminated information throughout Samsung concerning latest specifications and trends in telecommunications, providing advice to Senior Management on future strategies for telecommunications development.
- Acted as sole Samsung representative in ETSI TC SMG2 from December 1996 and during the selection phase for the UMTS Radio Acces Technology providing training for Samsung engineers on elaborated technologies
- Participated in 3GPP TSG RAN WG1 (UTRA Physical Layer), and RAN WG2 (L2/3) contributing specifically in areas related to FEC, Common Packet Channel, and Transmit Diversity
- In 3GPP TSG T WG2 I initiated and acted as rapporteur for the UE capabilities work item. I also acted as liaison officer between TSG T WG2, TSG RAN WG1 and TSG SA WG1 (Service Aspects) on issues of common interest
- Acted as main spokesperson for and advisor on Samsung strategic activities in, 3GPP TSG RAN from 3GPP's creation until April 2000
- Acted in a consultative capacity advising the company on technical, commercial and regulatory issues relating to 3rd generation telecommunications development and implementation.
- Developed and promoted programme to co-ordinate standards activities throughout Samsung. – Samsung Global Standards Strategy Group established in September 1998.
- Attended ETSI TCs, SMG1, SMG4, SMG5, SMG7, SMG9 and SMG11 as required by Samsung to keep abreast of developments prior to establishment of 3GPP

## Radiocommunications Agency 06/93 -11/96

### HPTO Spectrum Engineer

- Responsible for the management of spectrum for use by PMR and Wireless LAN technologies.
- Defined and instigated development of an improved assignment methodology for Private Mobile Radio (PMR) channels, promoting increased quality and spectrum efficiency.
- Managed research projects involving the assessment and selection of bids from external companies, submitted under competitive tender.
- Represented the Agency in the National and International fora associated with the use of Land Mobile Radio, acting as rapporteur for PMR voice and data standards in ETSI Sub-Technical-Committee RES02, and as chairman of a sub-working group under ITU WP8A drafting the recommendation for use of the radio spectrum by Radio LANs.
- Involved in CEPT Spectrum Engineering Project Teams, dealing with spectrum for Narrow band PMR technology and co-ordination between that technology and T-DAB transmissions in Band III.
- Dispensed technical advice both within the Agency and to external customers, on national and international PMR standards, assessing requests for additional frequencies, and providing technical justification for assignments and wider spectrum policy

## BBC Radio 11/89 – 05/93

**Radio Operations Engineer**

- Worked on projects requiring the design, development, maintenance and testing of equipment for use within the broadcasting chain.
- Responsible for acceptance testing of new studios for Radio 5, and in particular redesign of outside source circuits for the main sports continuity studio.
- Involved in acceptance testing for NICAM transmission routers. Designed and implemented modifications to synchronise transmission feeds, resulting in seamless switching between routers.

## Education

1. MSC in Computer Science from the University of Kent

   Awarded (with distinction): 07/2006

   Dissertation title: Roles Variables and Program Analysis – Received prize for outstanding achievement

2. B.Eng. (Hons) in Electronic Engineering from the Polytechnic of Central London

   Awarded: 07/1989

3. In house and external technical and management training including: Learning Tree courses on System Analysis and Design, User Requirements, UML, and Project Management.
4. On-line courses from: Cousera, Udemy, and Zenva courses covering Machine Learning, Python, Data Science, and Natural Language Processing

# Appendix 2

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# THIRD GENERATION PARTNERSHIP PROJECT (3GPP)

## PARTNERSHIP PROJECT DESCRIPTION

**During the meeting held in Copenhagen, 2 - 4 December 1998 ARIB, ETSI, T1, TTA and TTC agreed this Partnership Project Description.**

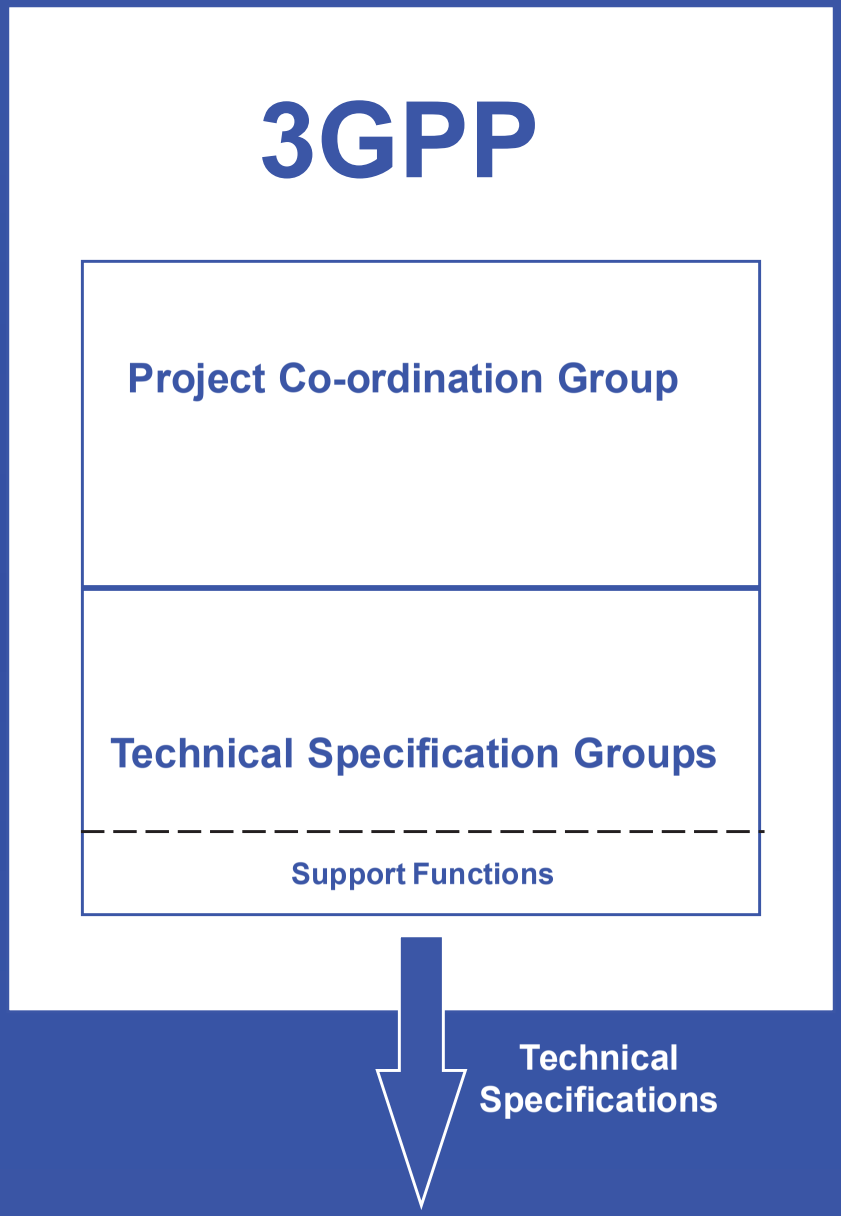
# *Preamble*

Standards organizations and other related bodies have agreed to co-operate for the production of a complete set of globally applicable Technical Specifications for a 3rd Generation Mobile System based on the evolved GSM core networks and the radio access technologies supported by 3GPP partners (i.e., UTRA both FDD and TDD modes).

The Project is entitled the “Third Generation Partnership Project” and may be known by the acronym “3GPP”.

3GPP has been established for the preparation and maintenance of the above mentioned Technical Specifications, and is not a legal entity.

# 3GPP Overview



## *Definition of the Third Generation Partnership Project*

**3GPP will provide globally applicable Technical Specifications for a 3rd Generation Mobile System based on the evolved GSM core network, and the Universal Terrestrial Radio Access (UTRA), to be transposed by relevant standardization bodies (Organizational Partners) into appropriate deliverables (e.g., standards).**

# *Scope and objectives (1)*

**The Technical Specifications will be developed in view of global roaming and circulation of terminals.**

**The 3rd Generation Mobile System and its capabilities will be developed in a phased approach. Initially, 3GPP will elaborate, approve and maintain the necessary set of Technical Specifications for the first phase of a 3rd Generation Mobile System including:**

- **UTRAN (including UTRA; W-CDMA in Frequency Division Duplex (FDD) mode and TD-CDMA in Time Division Duplex (TDD) mode)**
- **3GPP Core Network (Third Generation networking capabilities evolved from GSM . These capabilities include mobility management and global roaming.)**
- **Terminals for access to the above (including specifications for a UIM)**
- **System and service aspects**

## *Scope and objectives (2)*

**The set of global specifications for the first phase of the 3GPP core network and the specifications for the GSM core network should be common to the largest extent possible and should not be needlessly different.**

**The results of the 3GPP work will form the basis of member contributions to the ITU in accordance with existing procedures.**

**3GPP will take account of emerging ITU recommendations on interworking between IMT-2000 family members.**

**In the framework of agreed relationships, 3GPP will elaborate Technical Specifications that will form the basis of standards, or parts of standards, of the Organizational Partners.**

## *Characteristics of 3GPP (1)*

**3GPP is characterized by the following attributes:**

- **Minimum production time for Technical Specifications from conception to approval**
- **Fast, electronic based approval process**
- **Maximum use of modern (electronic) working methods**
- **Minimum number of hierarchical levels with decision making taking place at the lowest appropriate levels**

## *Characteristics of 3GPP (2)*

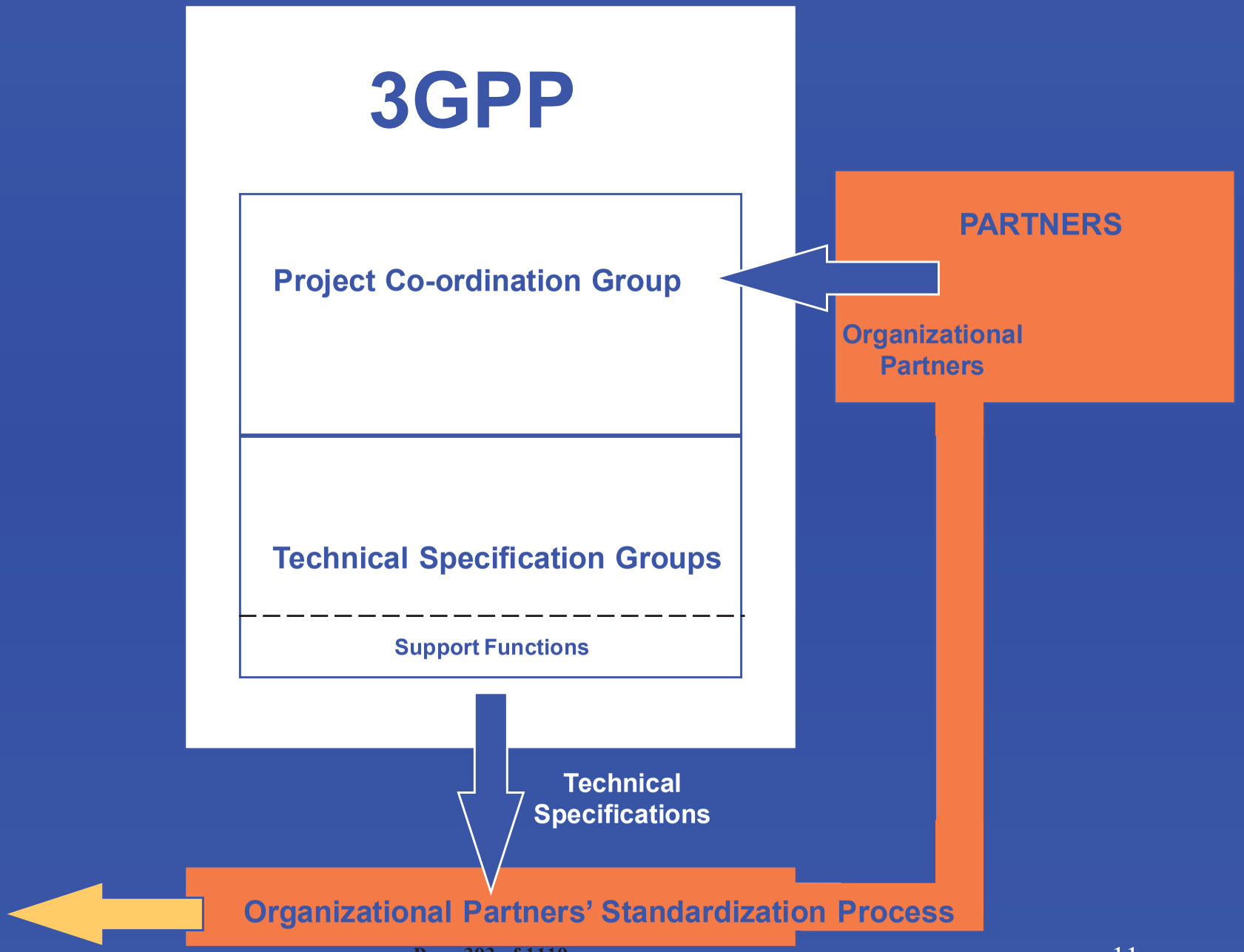
- **A Project Co-ordination function and a Technical Specification function**
- **Task oriented, ensuring that on completion of the tasks the future of the project is re-evaluated**
- **Cost effective use of financial/human resources provided by Partner Organizations (if required)**

## *Partnership and Membership*

**3GPP comprises of:**

- **Partners:**
  - **Organizational Partners**
    - **3GPP is open to all standards organizations irrespective of the geographical location.**
  - **Market Representation Partners**
- **Individual Members**

# Organizational Partners (1)



## *Organizational Partners (2)*

**An Organizational Partner is:**

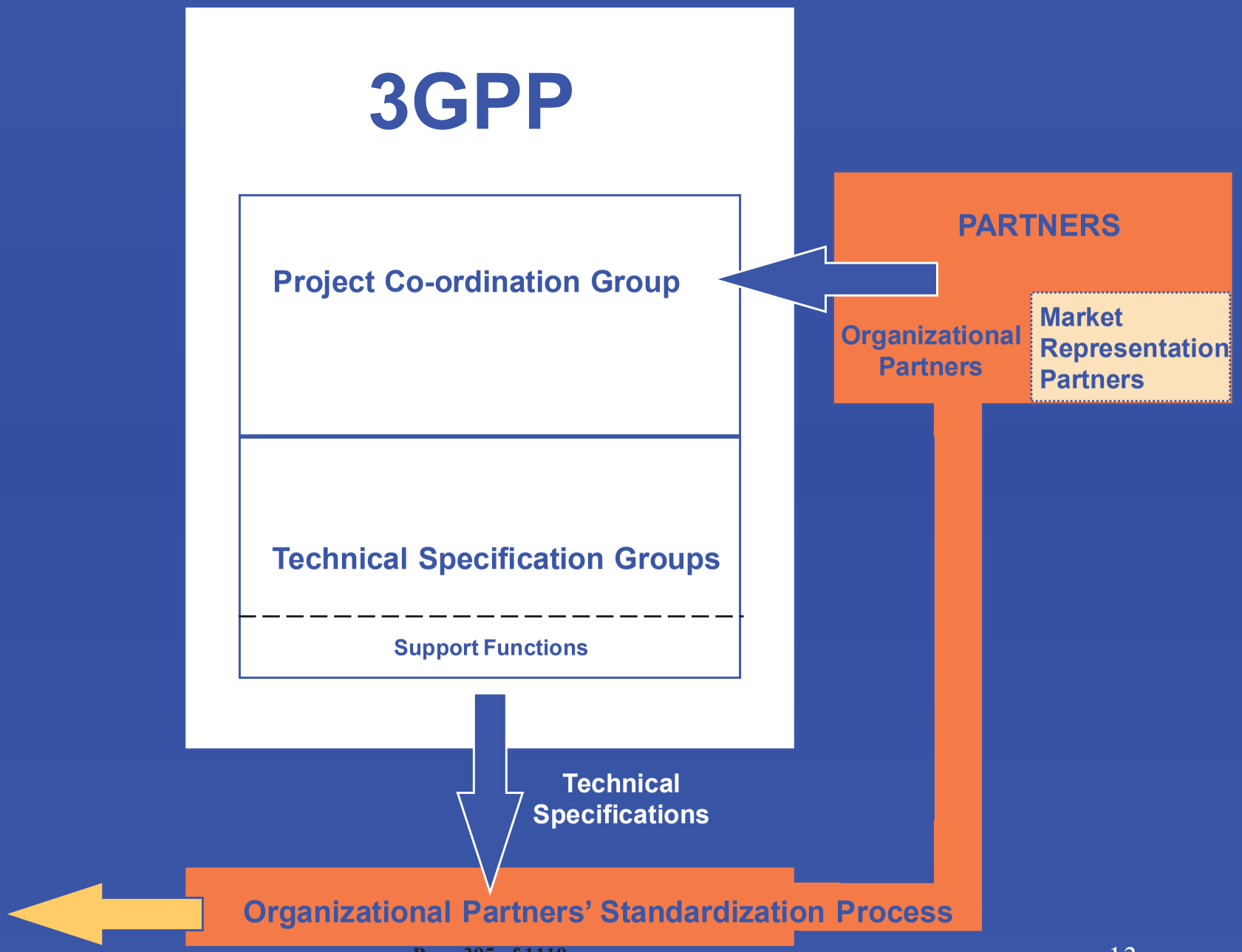
**An open standards organization with a national, regional or other officially recognized status (in their country or region)**

**that:**

- **has the capability and authority to define, publish and set standards nationally or regionally and**
- **has signed (or whose sponsor has signed) the Partnership Project Agreement**

**Organizational Partners will meet as approriate and make decisions by consensus.**

# Market Representation Partners (1)



# *Market Representation Partners (2)*

**Standardization should meet market needs.**

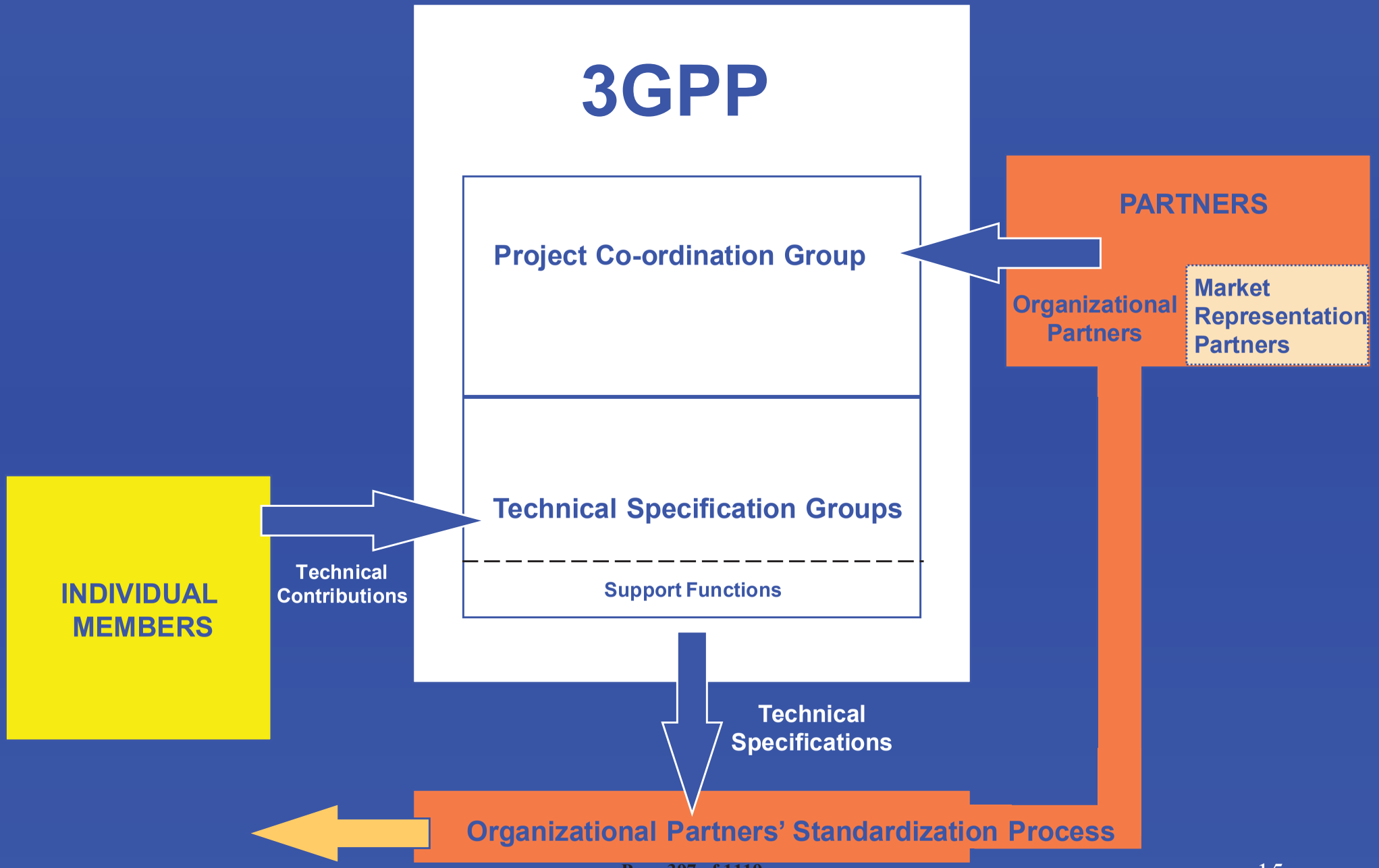
**In order to identify market requirements, the high competence of Market Representation Partners should be used.**

**A Market Representation Partner is an organization invited to participate by the Organizational Partners to offer market advice to 3GPP and to bring into 3GPP a consensus view of market requirements (e.g. services, features and functionality) falling within the 3GPP scope.**

**A Market Representation Partner:**

- **does not have the capability and authority to define, publish and set standards nationally or regionally**
- **has signed (or whose sponsor has signed) the Partnership Project Agreement**
- **has committed itself to the 3GPP scope**

# Individual Members (1)



# *Individual Members (2)*

**Membership in an Organizational Partner is a pre-requisite for Individual Membership in 3GPP.**

**Individual Membership is open to legal entities committed to support 3GPP and to:**

- **contribute technically or otherwise to one or more of the Technical Specification Groups within the 3GPP scope**
- **use the 3GPP results to the extent feasible**

**Individual Membership in 3GPP will be terminated by dissolution, abolition, resignation or expulsion from the related Organizational Partner.**

## *Individual Members (3)*

**All entities registered as members of an Organizational Partner and eligible for participation in the technical work of that Partner, can become Individual Members of 3GPP. Individual members shall apply to their Organizational Partner to participate in 3GPP.**

**Individual Members act in the 3GPP in their own right; they carry the full responsibility for their contributions.**

**Individual Membership applicants residing in a country/area without an Organizational Partner can apply for membership in an Organizational Partner according to the rules of each Partner. (e.g. ETSI Associate Membership is available)**

## *Observership*

In order to ensure globally applicable Technical Specifications, the status of "Observer" may be granted by the Organizational Partners to an entity which has the qualifications to become a future Organizational Partner. The status of "Observer" includes obligations to:

- identify as early as possible any regulatory requirements that may lead to options within Technical Specifications
- make their IPR policy available for consideration
- contribute to the common objective of the 3GPP and avoid duplication of work related to the 3GPP

The participation rights of an Observer will be decided on a case by case basis.

## The following 3 documents describe 3GPP:

- The Partnership Project Agreement
- The Partnership Project Description (this present document)
- The Partnership Project Working Procedures

## *The Partnership Project Agreement (1)*

**The Partnership Project Agreement is a concise legal document signed by participating Partners (or their sponsor).**

**It contains the minimum legal text necessary for 3GPP to function correctly.**

**The Partnership Project Agreement refers to the Partnership Project Description and the Partnership Project Working Procedures.**

## *The Partnership Project Agreement (2)*

**The Partnership Project Agreement includes obligations on Organizational Partners to commit themselves to the 3GPP scope:**

- **to encourage their members to contribute to the common set of Technical Specifications and to avoid duplication of work**
- **to convert / transpose / adopt all relevant Technical Specifications resulting from 3GPP into their own relevant deliverables through their normal processes**
- **to identify as early as possible, any national / regional regulatory requirements that may lead to options within the Technical Specifications**
- **to make their IPR Policy available for consideration**

## *The Partnership Project Agreement (3)*

**The Partnership Project Agreement includes obligations on Market Representation Partners to identify market and service requirement of 3GPP and to contribute to:**

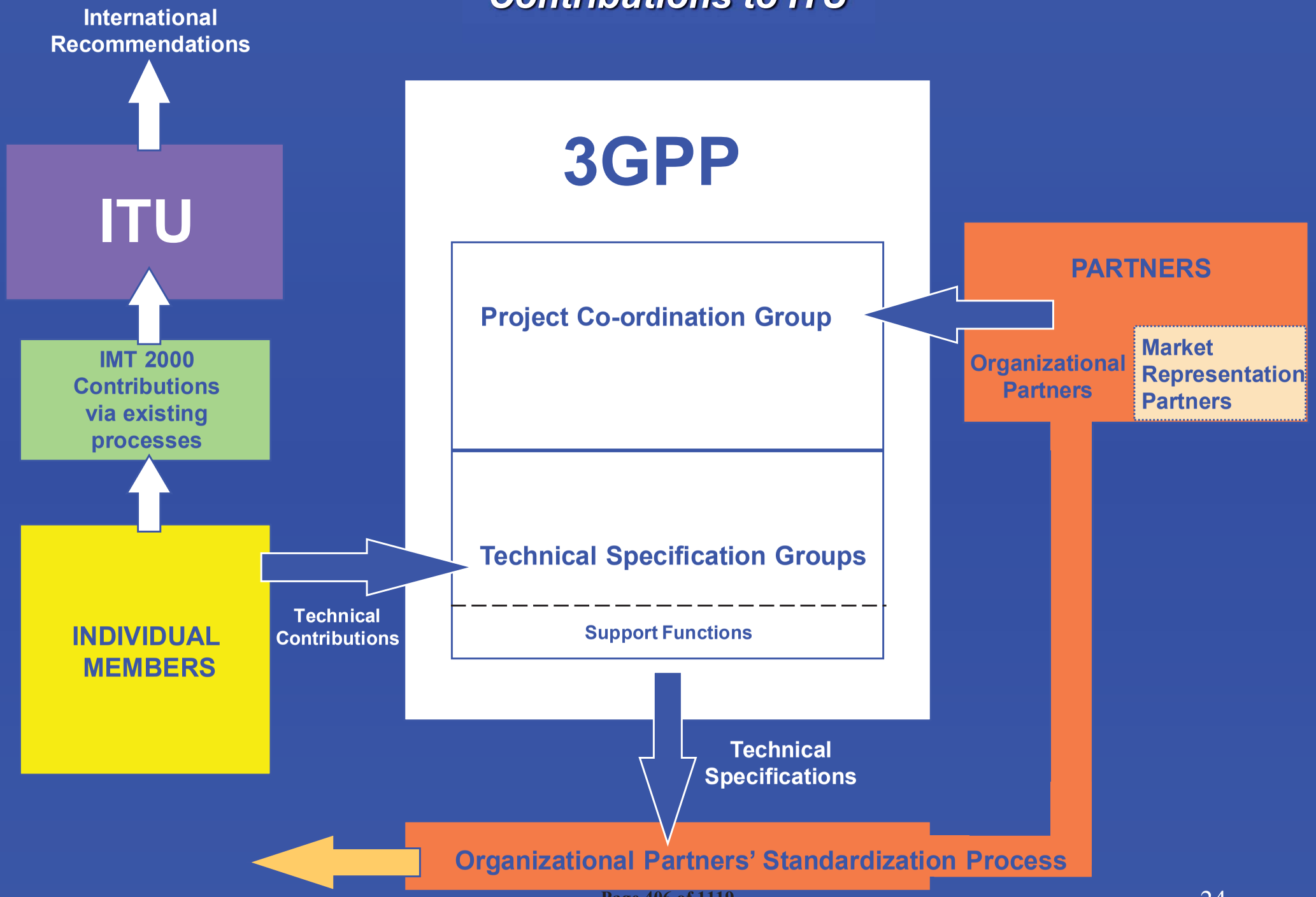
- **the promotion of 3GPP**
- **the definition of 3GPP System and Service scenarios**

**The Market Representation Partners should also encourage their members to contribute to the common objectives of 3GPP and to avoid duplication of work.**

## *Ownership of the Partnership Project results*

**The Organizational Partners of 3GPP will have joint ownership (including copyright) of the Technical Specifications.**

# Contributions to ITU

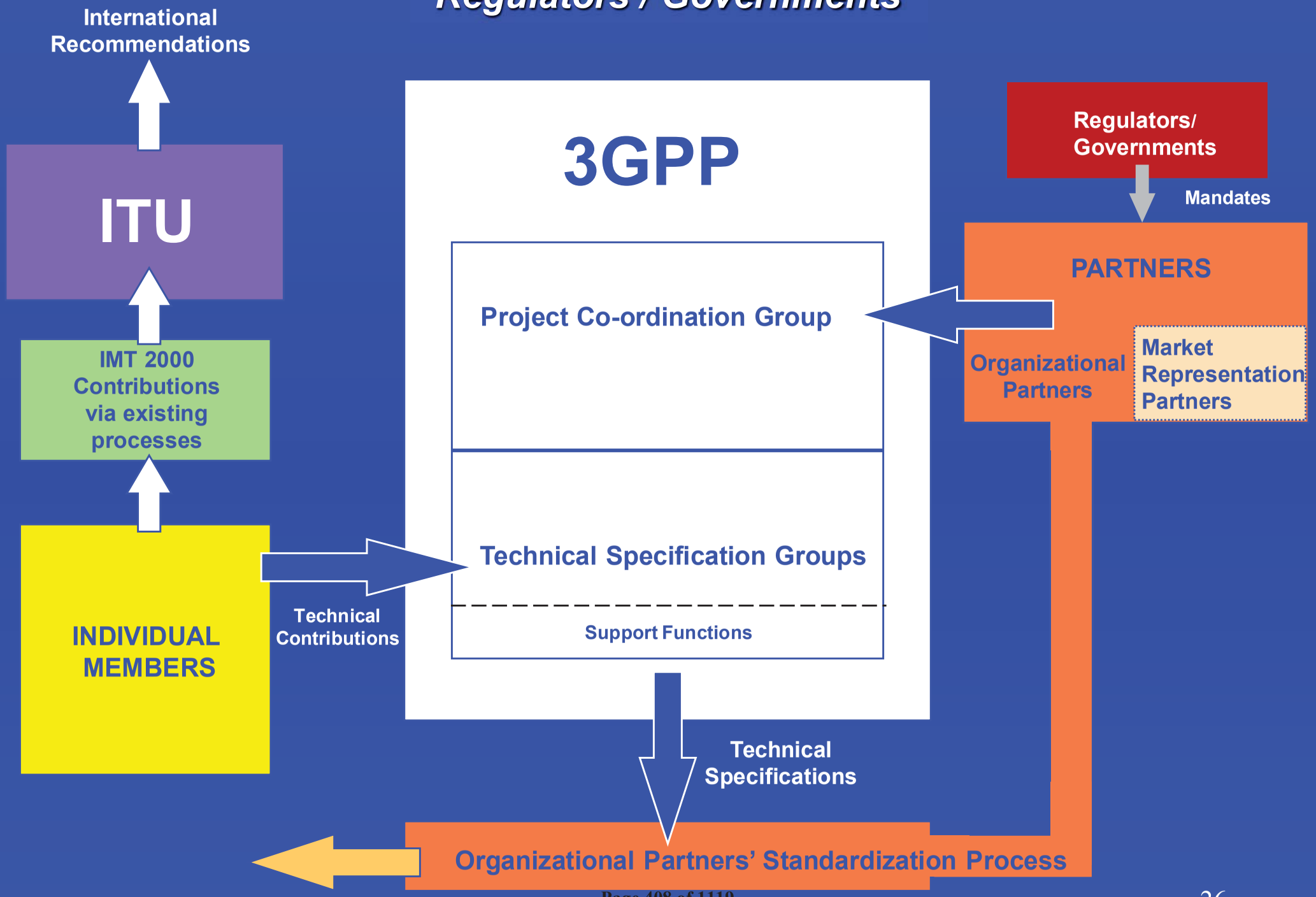


## *Submission of 3GPP results to ITU*

**3GPP will not contribute directly to the ITU.**

**Formal contributions to ITU Study Groups are made by ITU members following existing national/regional processes.**

# Regulators / Governments



## *National / regional regulatory requirements*

**Variations imposed by national / regional regulatory requirements will be included in the Technical Specifications as defined by the Technical Specification Groups.**

## *Resource requirements for establishing 3GPP*

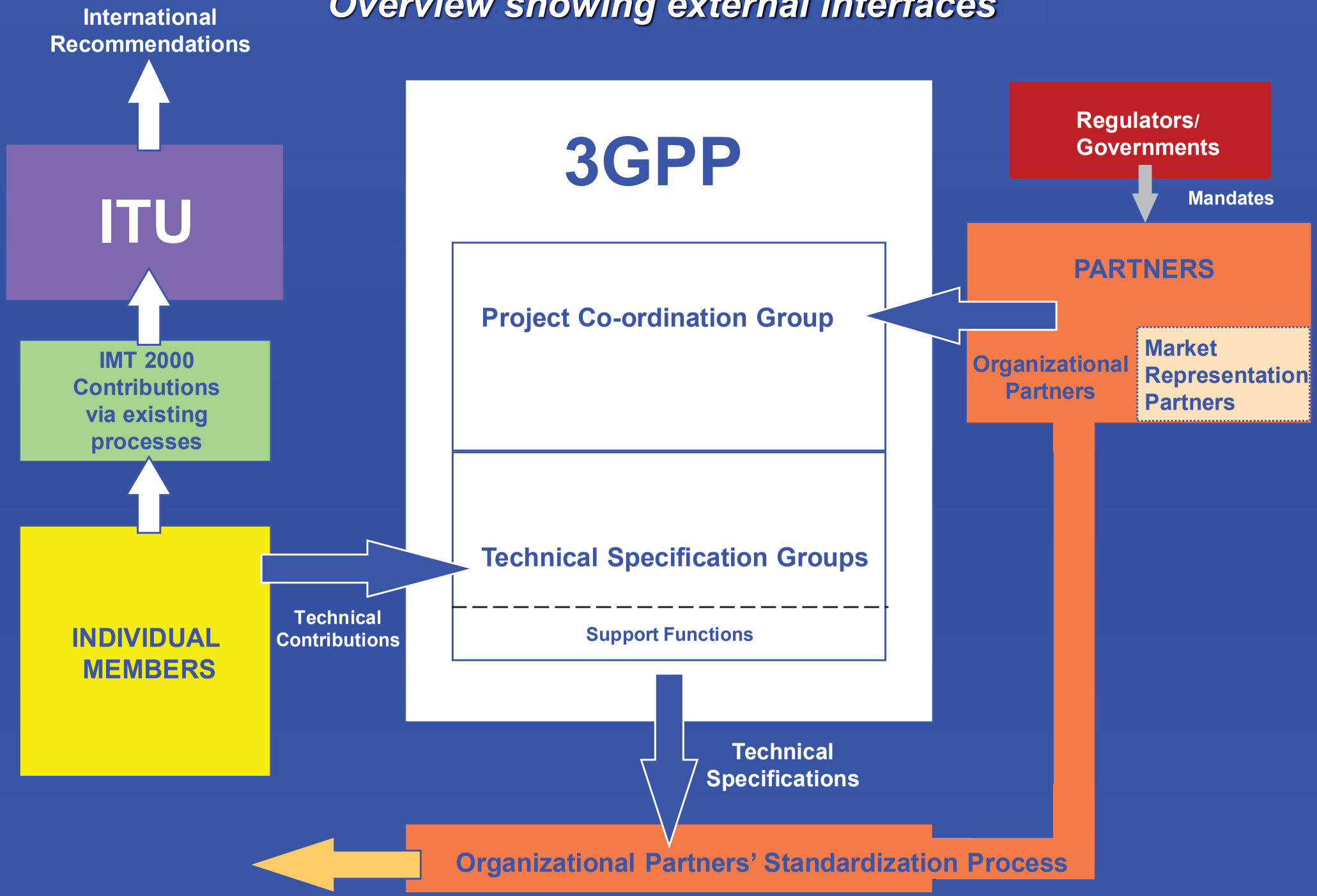
**ETSI will absorb the initial cost of establishing the 3GPP, if required.**

**Thereafter, the costs will be shared by the Organizational Partners. There will be no direct 3GPP membership fee for Individual Members.**

**Partners and Individual Members may provide support functions to the extent that they are able (eg hosting of meetings and provision of Secretariat support).**

**The longer term financial requirements are for further study.**

# Overview showing external interfaces

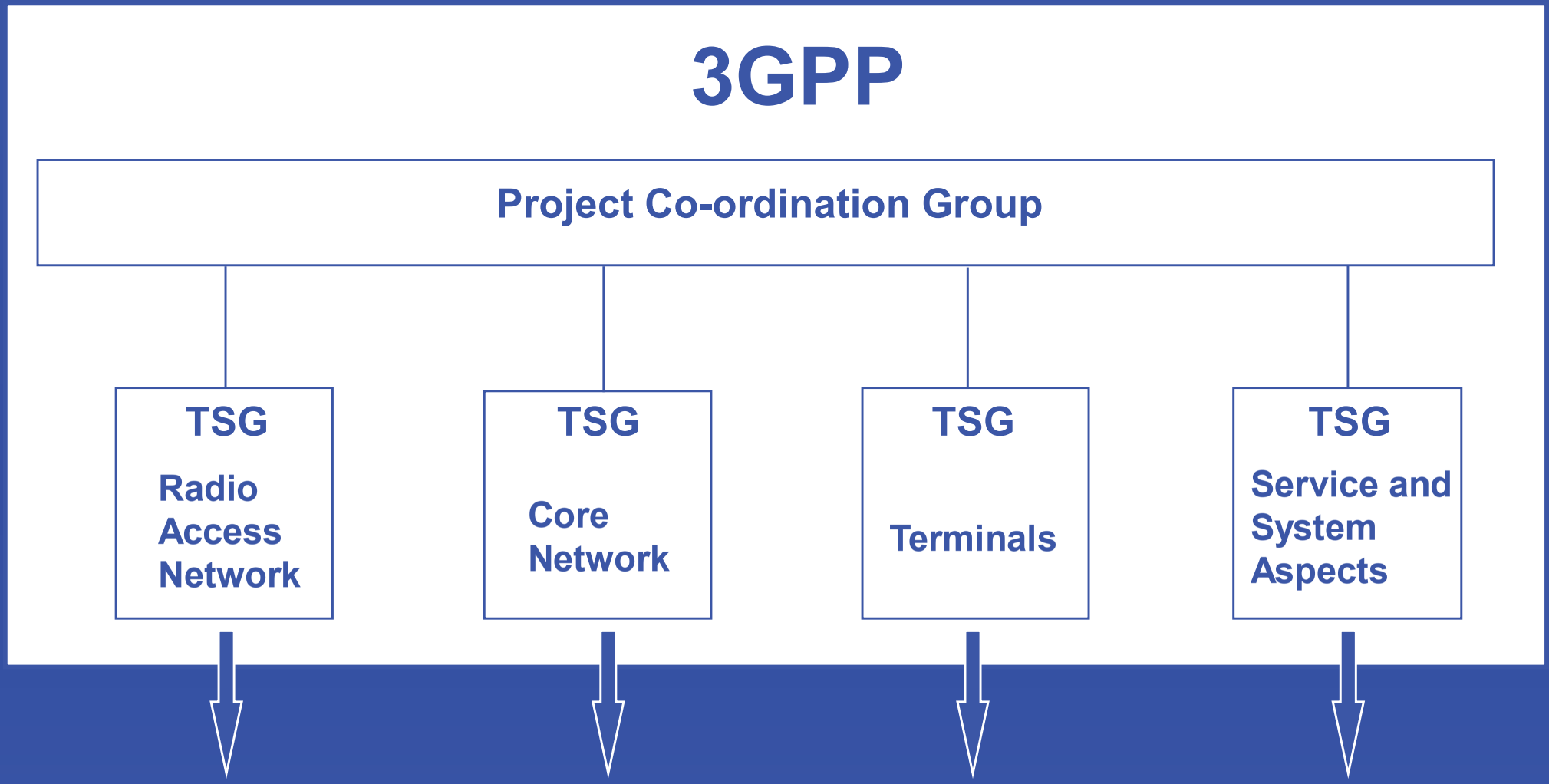


## *Internal structure of 3GPP (1)*

**3GPP consists of a Project Co-ordination Group (PCG) and Technical Specification Groups (TSGs).**

**To assist in the co-ordination of the technical activities, the TSGs are encouraged to meet at the same time and place, as and when appropriate (e.g. twice per year).**

# *Internal structure of 3GPP (2)*



## *Work areas to be covered by the Radio Access Network TSG*

- Radio Layer 1 specification
- Radio Layer 2 specification
- Radio Layer 3 RR specification
- Iub specification
- Iur Interface
- Iu Interface
- UTRAN O&M requirements
- Base station radio performance specification
- Conformance test specification for testing of radio aspects of base stations
- Specifications for radio performance aspects from the system point of view

## *Work areas to be covered by the Core Network TSG*

- **Mobility management, call connection control signalling between the user equipment and the core network**
- **Core network signalling between the core network nodes. the signalling supports functionality such as user location information, subscription information and control of network services**
- **Definition of interworking functions between the core network and external networks**
- **Packet related questions such as mapping of QoS ( e.g. transparency for IP domain applications, general for bearer types, special for optimized applications such as Voice over IP)**
- **Core network aspects of the Iu interface**
- **Core network O&M requiremnents**

## *Work areas to be covered by the Terminal TSG*

- **Service capability protocols**
- **Messaging**
- **Services end-to-end interworking**
- **USIM to Mobile Terminal interface**
- **Model/framework for terminal interfaces and services (application) execution**
- **Conformance test specifications of terminals, including radio aspects**

# *Work areas to be covered by the Service and System Aspects TSG*

- **Service capabilities**
  - **Definition of services and feature requirements**
  - **Development of service capabilities and a service architecture for cellular, fixed (and cordless) applications**
- **Stage one and two descriptions for:**
  - **Charging and accounting**
  - **Network Management**
  - **Security Aspects**
- **Architecture**
  - **Definition, evolution, and maintenance of overall architecture, including assignment of functions to particular sub-systems and identification of key information flows**
  - **In co-operation with other TSGs, define required services, service capabilities and bearer capabilities offered by the different sub-systems**
- **Codec aspects**
  - **Principles for definition of end-to-end transmission**
  - **Definition, evolution and maintenance of relevant specifications**
- **Project co-ordination**
  - **High level co-ordination of the work performed in other TSGs and monitoring of progress**

## *Primary responsibilities of PCG and TSGs (1)*

**The primary responsibilities of PCG, TSGs and Organizational Partners are given in the following tables:**

| | Function | Org Partners collectively | PCG | TSGs |
|---|---|---|---|---|
| 1 | Approval of new Partners for 3GPP | X | | |
| 2 | Approval of Organizational Partner funding requirements and contributions | X | | |
| 3 | Allocation of human and financial resources provided by Partners to PCG | X | | |
| 4 | Allocation of resources to TSGs | | X | |
| 5 | Allocation of resources within TSGs | | | X |

# *Primary responsibilities of PCG and TSGs (2)*

| | Function | Org Partners collectively | PCG | TSGs |
|---|---|---|---|---|
| 6 | Allocation of voluntary human and financial resources by Market Representation Partners and Individual Members | | X | X |
| 7 | Handling of appeals from Individual Members on procedural matters | 2nd step | 1st step | |
| 8 | Handling of appeals from Individual Members on technical matters | | 2nd step | 1st step |
| 9 | Determine overall time frame and manage overall work progress | | X | |

# Primary responsibilities of PCG and TSGs (3)

| | Function | Org Partner collectively | PCG | TSGs |
|---|---|---|---|---|
| 10 | Detailed time frame and manage detailed work progress | | | X |
| 11 | Approval of Technical Specifications | | | X |
| 12 | Proposal and approval of work items within the agreed scope and terms of reference | | | X |
| 13 | Final adoption of work items within the agreed scope and terms of reference | | X | |
| 14 | Management of work items | | | X |

# *Primary responsibilities of PCG and TSGs (4)*

| | Function | Org Partners collectively | PCG | TSGs |
|---|---|---|---|---|
| 15 | Technical Co-ordination (System Aspects TSG will play a role here) | | | X |
| 16 | Appointment of Org Partners meeting Chairman (provided by host on a rotational basis) | X | | |
| 17 | Appointment of PCG Chairman (for one year term) | | X | |
| 18 | Election of TSG Chairman and Vice Chairmen | | | X |
| 19 | Creation of TSGs and approval of their terms of reference | X | | |

# Primary responsibilities of PCG and TSGs (5)

| | Function | Org Partners collectively | PCG | TSGs |
|---|---|---|---|---|
| 20 | Creation of TSG working groups and approval of their terms of reference | | | X |
| 21 | Election of TSG Working Group Chairmen and Vice Chairmen | | | X |
| 22 | Confirmation of individual member participation rights | X | | |
| 23 | Approval of 3GPP scope and terms of reference | X | | |
| 24 | Maintain Partnership Project Agreement, Project Description and Working Procedures (consensus agreement by all Partners) | X | | |

# *Participation rights in PCG and TSGs*

**The following have a right to participate in the PCG:**

- **Representatives of participating Organizational Partners**
- **Representatives of participating Market Representation Partners**
- **Chairman and Vice Chairmen of the TSGs, as ex-officio members**

**The following have a right to participate in the TSGs :**

- **Representatives of members of participating Organizational Partners (i.e. Individual Members)**
- **Representatives of participating Organizational and Market Representation Partners**

## *Principles for decision making within 3GPP*

**Decision making within PCGs**

- **By consensus amongst the Organizational Partners**
- **By vote amongst the Organizational Partners in unavoidable cases**

**Decision making within TSGs**

- **By consensus amongst the Individual Members**
- **By vote amongst the Individual Members in unavoidable cases**

**The Organizational Partners will conduct a fairness review of the decision making process six months after 3GPP start-up, taking into account all concerns raised**

**(Note: voting will not be permitted on National/Regional regulatory requirements)**

## *Principles for voting within TSGs*

**The following principles will be applied for voting within the TSGs**

- **One "Individual company Member", one vote**
- **Organizational Partners to interpret " Individual company Member" according to its own rules of membership**
- **The PCG will maintain a register of eligible voters for the TSGs**
- **Each Individual Member may carry the proxy for up to five other Individual Members**

## *Working language for 3GPP*

**The working language for 3GPP shall be English**

- **Meetings of the PCG and TSGs shall be conducted in English**
- **3GPP Technical Specifications shall be prepared in English**

## *Relationship with other groups*

**3GPP will establish and maintain good relationships with groups working on standards for other IMT-2000 family members.**

## *Intellectual Property Rights (IPR) Principles (1)*

**The Individual Members of 3GPP are bound by the IPR Policies of their respective Organizational Partner.**

**Individual Members are encouraged to declare at the earliest opportunity, any IPRs which they may have and believe to be essential, or potentially essential, to any work ongoing within 3GPP.**

**After comparing their respective IPR policies, ARIB, ETSI, T1, TTA and TTC have agreed that their IPR policies share common principles are quite similar and have agreed on the following additional principles to maximize the success of 3GPP.**

## *Intellectual Property Rights (IPR) Principles (2)*

(i) **To encourage their respective members' declaration of willingness to grant licences on fair, reasonable terms and conditions on a non-discriminatory basis, and consistent with the respective Organizational Partners' IPR policies.**

(ii) **To encourage their respective members who may have IPR which they believe to be essential, or potentially essential, and are unwilling to license such IPR, that early indication of such unwillingness be provided to their respective Organizational Partners.**

(iii) **To understand that essential IPRs mean essential IPRs relative to any or all parts of the content of the 3GPP technical specifications.**

(iv) **A mechanism for exchanging information associated with the patent statement among the Organizational Partners will be introduced so that such information may be used when adopting relevant standards in each Partner Organization.**

# Appendix 3

# Introducing 3GPP



The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as “Organizational Partners” providing their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies.

3GPP specifications cover cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications. The 3GPP specifications also provide hooks for non-radio access to the core network, and for interworking with non-3GPP networks

## The Project’s Scope

The original scope of 3GPP (1998) was to produce Technical Specifications and Technical Reports for a 3G Mobile System based on evolved GSM core networks and the radio access technologies that they support (i.e., Universal Terrestrial Radio Access (UTRA) both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes).

The scope was subsequently amended to include the maintenance and development of the Technical Specifications and Technical Reports for evolved 3GPP technologies, beyond 3G.

- The latest 3rd Generation Partnership Project Agreement (Annex 42).
- The discussions that led to the signing of the 3GPP Project Agreement were recorded in a series of slides called the “Partnership Project Description” that describes the basic principles and ideas on which the project is based. The document has not been maintained since its first creation, but the principles within do still remain valid.

## Organizing the work

The 3GPP Working Procedures are the rule book of 3GPP, with sections covering:

- Description, Purpose, Scope and objectives
- Participation
- Structure
- Partners' collective responsibilities
- Project Coordination Group (PCG)
- Technical Specification Groups (Incl. Elections)
- Work Programme & technical co-ordination
- Deliverables (Technical Specifications and Technical Reports)
- Reporting

The 3GPP production of specifications and studies (TRs) are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group (TSG) level. The Technical Specification Groups in 3GPP are:

- Radio Access Networks (RAN)
- Services & Systems Aspects (SA)
- Core Network & Terminals (CT)

The Working Groups, within the TSGs, meet regularly and come together for their quarterly TSG Plenary meeting, where their work is presented for information, discussion and approval. The last meeting of the week of TSG Plenary meetings is TSG SA, which also has responsibility for the overall coordination of the technical work and for the monitoring of its progress.

## Generational Approach

The 3GPP technologies from these groups are constantly evolving through Generations of commercial cellular / mobile systems (see table below). With LTE and 5G work, 3GPP has become the focal point for the vast majority of mobile systems beyond 3G.

Although these Generations have become an adequate descriptor for the type of network under discussion, real progress on 3GPP standards is measured by the milestones achieved in particular Releases. New features

are 'functionality frozen' and are ready for implementation when a Release is completed. 3GPP works on a number of Releases in parallel, starting future work well in advance of the completion of the current Release. Although this adds some complexity to the work of the groups, such a way of working ensures that progress is continuous & stable.

## Backward Compatibility

The major focus for all 3GPP Releases is to make the system backwards and forwards compatible where possible, to ensure that the operation of user equipment is uninterrupted.

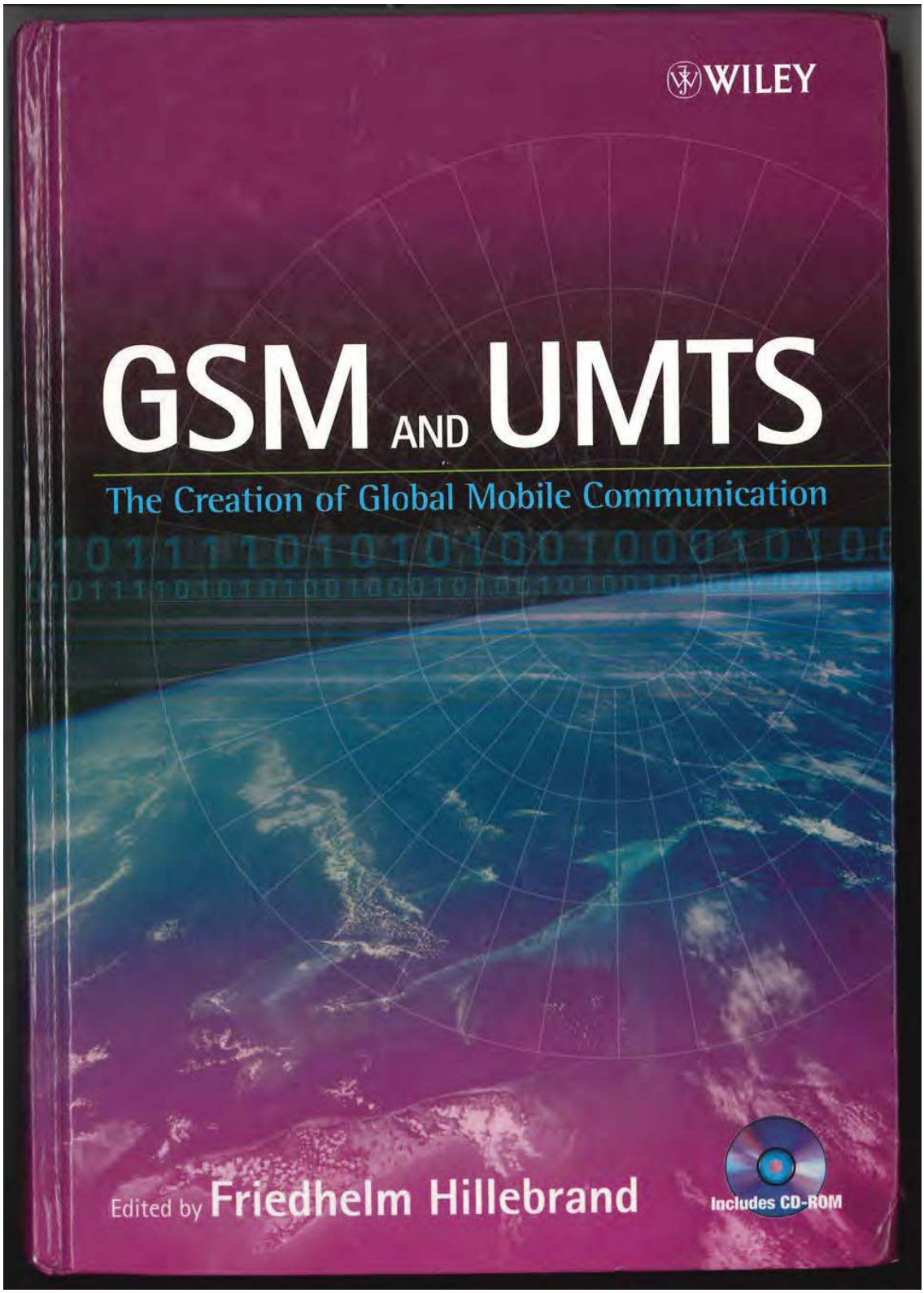
For 5G, many operators are starting with dual connectivity between LTE and 5G NR equipment – using the 'Non-Standalone' work completed early in Release 15. In the process of completing the early drop of 5G NR care has been taken to build 'forward compatibility' into Non-Standalone NR equipment, to ensure that it will be fit for use on Standalone 5G NR systems.

For details of the contents of each Release, see the appropriate 'Release Description' document or go to our dedicated Release page.

Details of all 3GPP Work Items are in the 3GPP Work Plan, which provides details of the cooperation between all of the 3GPP groups on "Features", defined as 'new or substantially enhanced functionality which represents added value to the existing 3GPP system'.

Previous Next

# Appendix 4


WILEY
GSM AND UMTS
The Creation of Global Mobile Communication
Edited by Friedhelm Hillebrand
Includes CD-ROM

# GSM and UMTS

## The Creation of Global Mobile Communication

Edited by

**Friedhelm Hillebrand**
*Consulting Engineer, Germany*

With contributions from 37 key players involved in the work for GSM and UMTS



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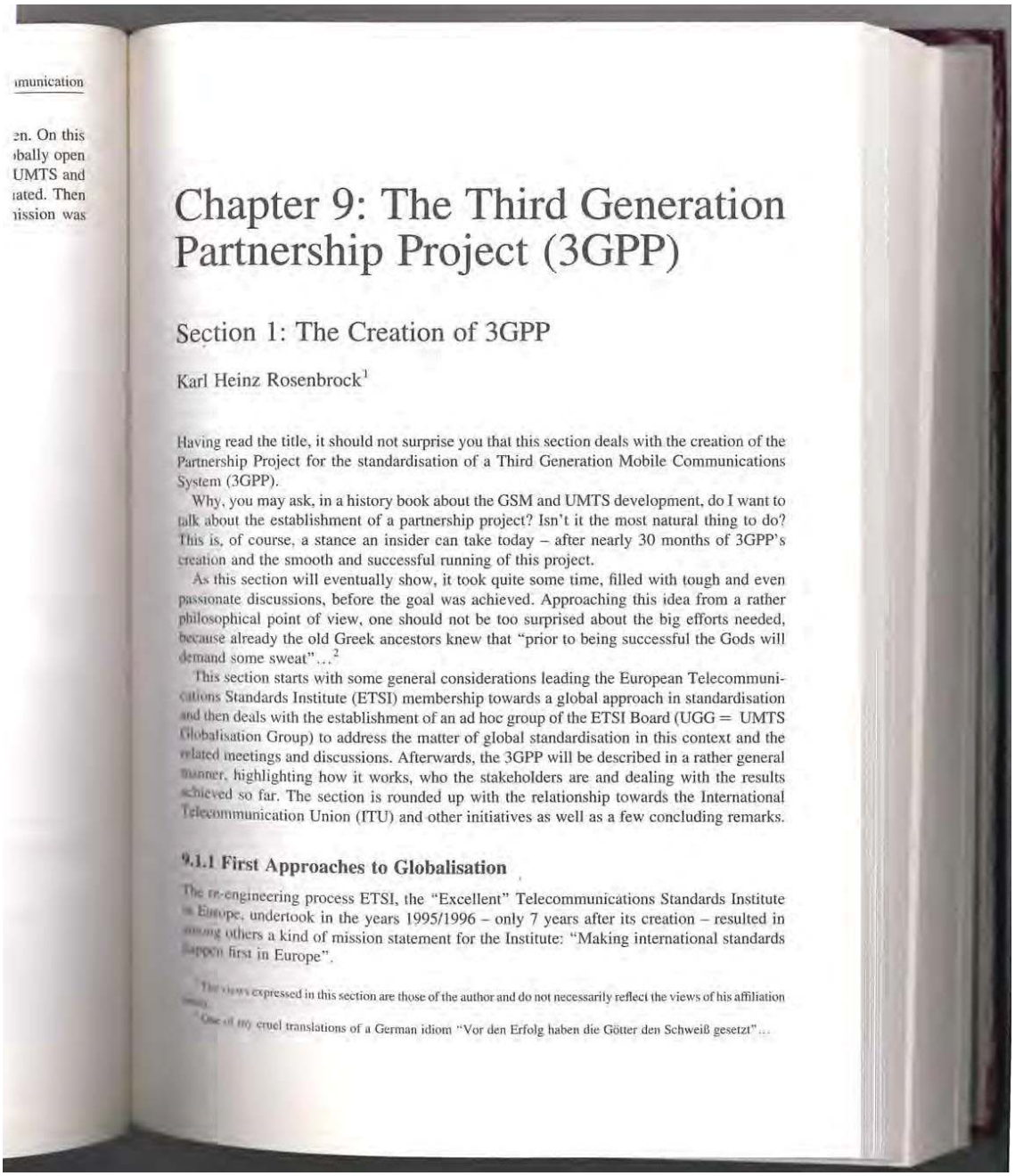
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# Chapter 9: The Third Generation Partnership Project (3GPP)

## Section 1: The Creation of 3GPP

Karl Heinz Rosenbrock[1]

Having read the title, it should not surprise you that this section deals with the creation of the Partnership Project for the standardisation of a Third Generation Mobile Communications System (3GPP).

Why, you may ask, in a history book about the GSM and UMTS development, do I want to talk about the establishment of a partnership project? Isn't it the most natural thing to do? This is, of course, a stance an insider can take today – after nearly 30 months of 3GPP's creation and the smooth and successful running of this project.

As this section will eventually show, it took quite some time, filled with tough and even passionate discussions, before the goal was achieved. Approaching this idea from a rather philosophical point of view, one should not be too surprised about the big efforts needed, because already the old Greek ancestors knew that "prior to being successful the Gods will demand some sweat"...[2]

This section starts with some general considerations leading the European Telecommunications Standards Institute (ETSI) membership towards a global approach in standardisation and then deals with the establishment of an ad hoc group of the ETSI Board (UGG = UMTS Globalisation Group) to address the matter of global standardisation in this context and the related meetings and discussions. Afterwards, the 3GPP will be described in a rather general manner, highlighting how it works, who the stakeholders are and dealing with the results achieved so far. The section is rounded up with the relationship towards the International Telecommunication Union (ITU) and other initiatives as well as a few concluding remarks.

### 9.1.1 First Approaches to Globalisation

The re-engineering process ETSI, the "Excellent" Telecommunications Standards Institute in Europe, undertook in the years 1995/1996 – only 7 years after its creation – resulted in among others a kind of mission statement for the Institute: "Making international standards happen first in Europe".

[1] The views expressed in this section are those of the author and do not necessarily reflect the views of his affiliation company.

[2] One of my cruel translations of a German idiom "Vor den Erfolg haben die Götter den Schweiß gesetzt"...

- unanimously requested the ETSI Board (through its UMTS Globalisation Group) to complete the negotiations with potential partners and to oversee the creation of the Partnership Project;
- unanimously requested the ETSI Board to agree and maintain on behalf of ETSI the final versions of the Partnership Project Description, the Partnership Project Working Procedures, and the Partnership Project Agreement;
- unanimously authorised the director-general to sign the Partnership Project Agreement.

#### 9.1.2.4.14 Happy End in Copenhagen

It was in Copenhagen where the last 3GPP preparatory meeting with all six OPs took place on 2–4 December 1998.

Here, the final fine-tuning of the 3GPP documentation was achieved. In addition, the 3GPP agreement[8] was signed (in a nice framework provided by the host, TeleDenmark) by the following OPs: ARIB, ETSI, T1, TTA, and TTC.

Unfortunately, the partners from CWTS (China) were not authorised to sign the 3GPP agreement yet. Furthermore, owing to the fact that the UMTS Forum was unable to participate in Copenhagen, they were prevented from co-signing the 3GPP agreement as a first Market Representative Partner (MRP).

During that Copenhagen meeting, another discussion ensued about the role the MRPs should play. Finally, it was concluded that the high competence of MRPs should be used in order to identify market requirements, thus enabling 3GPP standardisation to meet the needs of the market. An MRP is an organisation invited by the OPs to participate in 3GPP with the objective of offering market advice to 3GPP and to bring into 3GPP a consensus view of market requirements.

### 9.1.3 What is 3GPP?

The 3GPP is a global standardisation initiative created in December 1998. Its task was to develop a complete set of globally applicable Technical Specifications for a third generation (3G) mobile telecommunications system based on the evolved GSM core network and an innovative radio interface known as UTRA. The Project is based on a concept devised by ETSI aimed at facilitating better co-operation between regional standards organisations, fora and other industry groupings. 3GPP is a collaborative activity between officially recognised SDOs, with the participation of other industry groups and individual members.

Partnership in 3GPP is open to all national, regional or other SDOs, irrespective of their geographical location – within the project the participating SDOs are referred to as OPs. The OPs may invite MRPs to participate: these may be any organisation from anywhere in the world that can offer market advice to 3GPP and bring a consensus view of market requirements that fall within the project's scope. Individual membership is open to companies and organisations within the communications industry that are active members of one of the OPs. The truly global nature and the breadth of the market interest in the task of specifying this 3G system is evident from the identity of the 3GPP partners (see further in sub-paragraph 9.1.3.2) and all agree that 3GPP is proving a highly successful initiative.

[8] The 3GPP Agreement and the 3GPP Project Description can be found on the attached CD-ROM in

The 3GPP has no legal status. Ownership (including copyright) of the specifications and reports it produces is shared between the partners. The 3GPP process includes a conversion (transposition) of the project's output into official standards and reports by one or more of the OPs.

The specifications being prepared by 3GPP are evolved in part from the enormously successful GSM standard, which is currently (February 2001) serving over 400 million subscribers in more than 140 countries. Building on this massive installed base, the system being specified by 3GPP will be an attractive upgrade path for existing operators and users. It also has an assured compatibility with GSM – good news for both operators and users who are unable, or unwilling, to upgrade to 3G.

Paramount among the 3GPP specifications is the definition of UTRA, the innovative radio access technology that is the key to the new system's high data rates and dramatically improved performance. UTRA is spectrum-efficient and supports FDD and TDD modes. This interface has been accepted by ITU as a member of the IMT-2000 family – or more correctly, as *two* family members: IMT-DS, the FDD mode; and IMT-TC, the TDD mode. IMT-2000 family membership requires the ability for users to roam globally and seamlessly, which implies interoperability with other family members: 3GPP thus co-operates closely with the 3GPP2 project which is specifying another family member, a 3G CDMA system based on an evolution of the ANSI-41 architecture.

### *9.1.3.1 How Does 3GPP Work?*

3GPP has been designed to minimise delays and inefficiencies. As a result, it has a "flat" organisational structure and a large degree of distributed autonomy. Overall project planning and co-ordination is the responsibility of the PCG, with input primarily from the OPs, guided by the MRPs. It is mainly at this level that regulatory requirements, provided by the telecommunications administrations and governments around the world, are taken into account.

The development of the specifications is performed by TSGs and their subordinate working groups. Here, the main participation is by technical experts from the individual members of the OPs. Individual members in their capacity as ITU members are also responsible for carrying the results of the 3GPP work to the ITU.

At the time of the creation, 3GPP had structured around four principal aspects of the 3G system being defined as TSGs:

- TSG CN: core network
- TSG RAN: radio access network
- TSG SA: services and systems aspects
- TSG T: terminals

Each TSG is authorised to develop and approve specifications and reports within its scope, and TSG SA also has a role of co-ordinating the work of the TSGs at a more detailed level than the PCG. The result is a process that is able to rapidly produce and approve specifications and reports in response to the needs of the market, although it is important to note that the deliverables do not have a formal status until they have been transposed by one or more of the OPs.

The formal status is necessary for regulatory and other purposes in the various regions, and all the OPs have committed themselves to complete this process rapidly. Each OP will apply

its own procedures, appropriate to their respective regions. As the official European SDO within 3GPP, ETSI recognises the 3GPP output as ETSI Technical Specifications and ETSI Technical Reports without a need for any further endorsement within the Institute. This means that the 3GPP documents are published – within a matter of a few weeks – as identical text directly as ETSI deliverables. In addition, ETSI is transposing, i.e. adapting, a few of the initial 3GPP specifications into ENs for specific European regulatory requirements. This is happening in parallel with the publication of the initial Technical Specifications and will not impede the implementation of 3G in Europe.

#### 9.1.3.1.1 Electronic Working

3GPP has taken a leading role in changing the traditional ways of standards making. A very heavy dependence is now placed on electronic working, both outside and within meetings, advancing a trend that started in ETSI a year or two ago. This means that paper copies of draft documents have been almost entirely eliminated, saving time and expense, and making a significant contribution to the environment.

Given that 3GPP has participants from all over the world, the use of the Internet, e-mail exploders and other such facilities have proved invaluable for distributing and sharing information, working drafts and so on. Delegates to meetings had already become used to downloading working documents from the Internet and having updates to the documents distributed in meetings on CD-ROM. But in recent months, in meetings around the world participants have experienced the benefits of a local area network (LAN) solution as the latest step in improving working methods. ETSI's headquarters premises already have LANs in all its meeting rooms, but most other venues currently rely on temporary LANs (wired or radio), using equipment and support kindly donated by individual members.

Such facilities permit delegates to access all the meeting documents electronically from their laptop computers. As a result, the huge burden of producing paper copies (as many as 10 000 pages per delegate for some meetings) can be eliminated. Delegates can access new documents as soon as they are available, rather than having to wait for paper copies to be made or for the documents to be distributed by other means, such as diskette or CD-ROM.

#### 9.1.3.1.2 Project Support

For administrative and support purposes the 3GPP Partners have established a Mobile Competence Centre (MCC) which is hosted by ETSI at its premises in Sophia Antipolis, Southern France. The MCC was created in March 1999 to provide support not only to the 3GPP but also to ETSI's own studies in mobile technologies. A full description of MCC including the financing is given in Chapter 15, Section 3.

### *9.1.3.2 Who are the Stakeholders in 3GPP?*

3GPP has attracted a very strong commitment from organisations and companies around the world, reflecting the truly global nature of the project. There are currently six OPs (in alphabetical order):

- The Association of Radio Industries and Businesses (ARIB), Japan

being TD-SCDMA, proposed by CWTS. A similar group, 3GPP2, is preparing the cdma2000 specifications, UWC-136 TDMA specifications are being developed principally by UWCC, and DECT specifications are defined by a set of ETSI standards (Figure 9.1.1).

Since the UWCC and ETSI are both partners in 3GPP (as an MRP and OP respectively), there is direct liaison between the Project and these two sources of specifications for other IMT-2000 family members.

When 3GPP and 3GPP2 were created it was felt that the interests of each group were sufficiently different to require them to remain separate but here again many of the OPs and MRPs are common to both groups, so there are natural channels for information exchange. Particular instances of formal co-operation between the groups were the two joint 3GPP-3GPP2 workshops held in 1999 to address the "Hooks and Extensions" issue aimed at ensuring interworking between the respective technologies.

In addition to all this, the 3GPP TSGs and their working groups are encouraged to liase directly with relevant technical bodies within the Project as well as among the Partners.

### 9.1.6 Conclusions

The attentive reader, and let's assume that you are one, may still be astonished to learn what big efforts have been necessary in order to establish 3GPP.

In the meantime, i.e. in the course of year 2000 nearly the whole work of the former ETSI TC SMG has been incorporated into 3GPP, to a large extent within the new TSG GERAN.

Well, our Japanese friends were not happy about this shift because they feared that it could result in delays in the 3G introduction in their country. They accepted this because a separate TSG for the GSM work was created.

Trying to recall the heated discussions within ETSI about the scope of 3GPP from 1998, one has to admit that such a move would have been violently rejected by a lot of ETSI members, maybe even by the majority. Using a philosophic approach, one can, of course, state that time helps healing (even wounds).

Today, i.e. February 2001, we can conclude from ETSI's point of view that all standardisation work related to further evolution of the second generation mobile system, i.e. GSM, and to UMTS is being done well within 3GPP. Thus, the objective to avoid parallel work within ETSI TBs and 3GPP has been fully achieved.

The ability of organisations and individuals around the world to co-operate and make available a full set of stable, agreed 3GPP specifications in 1 year is a remarkable achievement, one that is unprecedented in the world of standardisation. 3GPP meetings have taken place in many parts of the world, emphasising the strong commitment of the SDOs from China, Europe, Japan, Korea and the US. The MRPs have also lent very strong support to the work. Thanks to this widespread and determined commitment it has been possible to meet the very aggressive targets for 3G.

But Release 99 was only the first step – the workload has continued to intensify this year, as the initial specifications are refined and many new ones added, opening the path to full, seamless, global 3G services, changing forever the way that people communicate.

In the meantime, 3GPP has changed the designation of the releases and dropped to mention the year in order to avoid irritations and wrong expectations. Release 99 was first established in December 1999 and got its maturity in the course of year 2000. In 2000, more than 5700 change requests were implemented. The next big event will be Release #4 as a result of the

series of TSG meetings scheduled for March 2001 in Palm Springs, US. This will obviously result in a further stabilisation and extension of the UMTS specifications.

3GPP is running very well. The individual members from the six OPs seem to be very satisfied with this arrangement – and the production line is in full swing.

Without exaggeration, one can give 3GPP the attribute of a success story. One may quote again here Mr Ed Roney who even addressed the 3GPP concept – prior to its realisation – as a "paradigm shift".

As the results of the GSM and UMTS related standardisation work represent a great part of ETSI's deliverables, it might be justified to note here that during the year 2000, ETSI published more than seven new deliverables each working day (Monday through Friday), i.e. one deliverable per hour!

Further information may be found on the 3GPP website at http://www.3gpp.org.

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# Chapter 9: The Third Generation Partnership Project (3GPP)

## Section 2: UMTS in 3GPP (December 1998–May 2001)

Niels Peter Skov Andersen[1]

### 9.2.1 A Change of Environment

In the period 1982 until end of 1998 the work on the GSM standard, and in the later part of the period on UMTS, had been performed in the same environment, starting under CEPT and later transferred into ETSI. The Technical Committee GSM, during this period renamed to SMG, and its working groups (Sub Technical Committees) had continuously existed and evolved. The same was the case for the working methods and procedures used within the work. Over time with the success of the GSM system more and more interested parties became involved in the work including parties from outside the original CEPT area. However, this was all a relatively slow evolution and no major revolutions in the organisation or the working methods occurred in this period.

After all these years of continuity in the work the discussions around the creation of 3GPP and the decision to establish 3GPP for the initial phase of UMTS[2] naturally created some uncertainty amongst the members of SMG. Especially the resulting split of the GSM standardisation, with the responsibility for the GSM core network transferred to 3GPP, but the responsibility for the GSM radio access Network maintenance remained in ETSI in SMG. This caused some concern amongst many delegates. Also the internal structure for the technical work within 3GPP was different from the well-known structure in SMG. SMG was based on a technical plenary with a number of working groups (SMG1, SMG2, ..., SMG12) performing the detailed technical work. The SMG plenary was the approving authority for the results of the work performed by the working groups. Also the plenary was the group responsible for approval of all new work items and the content of the releases. The structure for the work in 3GPP, as agreed by the partners, was quite different. The project

[1] The views expressed in this section are those of the author and do not necessarily reflect the views of his affiliation [illegible].

[2] The term UMTS is throughout this section used to keep consistency of terminology with the other chapters and sections. The term UMTS do not appear in the in 3GPP agreement, which defines the system as a third generation mobile system based on an evolved GSM core network and UTRAN (including UTRAN (FDD and TDD modes)).

was organised with four equal Technical Specification Groups (TSGs), who had complete autonomy for their area of responsibility, i.e. they were responsible for approval of new work items and final approval of deliverables. The four technical groups originally defined were:

| | |
|---|---|
| TSG CN | Responsible for the core network development |
| TSG-RAN | Responsible for the radio access network based on UTRAN (FDD and TDD modes) |
| TSG-SA | Responsible for services and system aspects |
| TST-T | Responsible for Terminal and UIM |

In addition to the technical groups the 3GPP organisation has a Project Coordination Group (PCG). However, the role of this PCG cannot be compared to the role the SMG plenary played. The SMG plenary was an open technical group with the approving authority in all technical questions including approval of new work items. The 3GPP PCG is a closed group with a defined membership consisting of a limited number representative of each of the partners (SDOs, MRPs) and the leadership (chairman and two vice-chairmen) of each TSG. Thus as a closed group the role of the PCG becomes more like a board overlooking the overall well being of the project.

This structure made many long-term SMG delegates concerned about how the overall coordination of the project could be ensured. This new structure was not introduced to overcome known deficits of the SMG organisation, but in my opinion, by political considerations to ensure than no single individual, individual member, organisational partner could obtain a controlling position in the project.

### 9.2.2 The First Two TSG Meetings

The inauguration meeting of the 3GPP TSGs was held in December 1998 in Sophia Antipolis, France. In the process of creation of 3GPP this was the first time that the 3GPPs real work force – the technical experts – met. The main objectives for this first meeting was to get the work started. One of the elements of the meeting was a presentation from the different partners on the status of their work on the third generation mobile system, the work, which they now were in the process of handing over to 3GPP.

Listening to the presentations and the discussions during the breaks it was very obvious that the background for standardization amongst the delegates was quite different. As an example, I remember that during the coffee break just after I, as chairman of ETSI SMG2, had presented the status of the UMTS radio work in ETSI, and had ended my presentation by stating that the UMTS radio work would only be on the agenda of one more meeting of ETSI SMG2. This was in order to complete the documentation to be handed over to 3GPP and then the work on UMTS radio in ETSI would cease, a small group of non-ETSI delegates came to me and asked "if all work on UMTS radio in ETSI ceases, how do the Europeans then co-ordinate their views on 3GPP?" Coming from the ETSI SMG background this was a completely unexpected question, as the working procedures for 3GPP were very similar to those of ETSI, it was clear to me that the contributions to 3GPP in general should come from the individual members – the companies, regulators etc. – in their own name and not as regional contributions. I explained this, but I also understood that for delegates with a background in international standardization from, e.g. ITU this was the normal way of thinking. During the

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# Annex 2: Organisation Evolution of the Technical Groups

## Section 3: 3GPP

Adrian Scrase[1]

### A2.3.1 December 1998 to Mid-1999

During the preparatory talks that led to the creation of 3GPP, many discussions took place to find the optimum organizational structure. The ETSI TC SMG model had worked well for many years and it was very tempting to adopt a similar structure and just widen the sphere of participation. However, some voices called for a more radical approach in order to streamline the structure and to reduce the time taken for specifications production. As a result of these discussions, the following key principles were established on which 3GPP was structured:

- Minimum number of hierarchical levels;
- Large degree of distributed autonomy;
- Clear separation of technical activities from political and administrative activities.

When 3GPP was created, four Technical Specification Groups (TSGs) were formed to undertake the preparation of technical specifications. The four TSGs were as follows:

- TSG CN – core network
- TSG RAN – radio access network
- TSG SA – services and system aspects
- TSG T – terminals

Each of the TSGs was authorized to develop and approve specifications and reports within its terms of reference. This represented a departure from the more traditional approach where a single entity (i.e. a plenary) within a project has the authority to approve a project's output. It was believed that by distributing the approval authority, the time taken to produce specifications would be reduced since this effectively removes one level of hierarchy from the approval procedure. However, it was apparent from the outset that distributing the approval of specifications would lead to a greater requirement for technical co-ordination and thus TSG SA was tasked to perform a co-ordination role across all TSGs. This co-ordination role

[1] The views expressed in this section are those of the author and do not necessarily reflect the views of his affiliation entity.

# Appendix 5



# Third Generation Partnership Project

# 3GPP

## Working Procedures

01 September 2022

# Foreword

These Working Procedures of the Third Generation Partnership Project (3GPP) are effective from 01 September 2022.

An electronic version of these Partnership Project Working Procedures is available from the following address:

http://www.3gpp.org

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# SECTION A: GENERAL

## Article 1: Description

The Partnership Project is not a legal entity but is a collaborative activity between the following recognized Standards Development Organizations:

ARIB (Japan)

CCSA (China)

ETSI (Europe)

ATIS (US)

TTA (Korea)

TTC (Japan)

TSDSI (India)

The Partnership Project is entitled the "THIRD GENERATION PARTNERSHIP PROJECT" and may be known by the acronym "3GPP".

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## Article 2: Purpose

The purpose of 3GPP is to prepare, approve and maintain globally applicable Technical Specifications and Technical Reports for

- a 3rd Generation Mobile System based on the evolved GSM core network, and the Universal Terrestrial Radio Access (UTRA),
- further development of radio technologies such as LTE, coupled with evolution of core network elements such as the Evolved Packet Core (EPC),
- continuing evolution of the 2nd generation GSM/EDGE Radio Access Network (GERAN),

to be transposed by the Organizational Partners into appropriate deliverables (e.g., standards).

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## Article 3: Scope and objectives

The 3rd Generation Mobile System and its capabilities shall be developed in a phased approach. Initially, 3GPP shall prepare, approve and maintain the necessary set of Technical Specifications and Technical Reports for a 3rd Generation Mobile System including:

- UTRAN (including UTRA; in Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes);
- 3GPP Core Network (Third Generation networking capabilities evolved from GSM. These capabilities include mobility management, global roaming, and utilisation of relevant Internet Protocols);
- Terminals for access to the above (including specifications for a UIM); and
- System and service aspects.

3GPP shall prepare, approve and maintain the necessary set of Technical Specifications and Technical Reports for:

- the Global System for Mobile communication (GSM) including GSM evolved radio access technologies (e.g., General Packet Radio Service (GPRS) and Enhanced Data rates for GSM Evolution (EDGE)).

3GPP shall consider the long term evolution.

The Technical Specifications and Technical Reports shall be developed in view of global roaming and circulation of terminals.

The set of 3GPP Technical Specifications and Technical Reports for the 3GPP core network and the specifications for the GSM core network should be common to the greatest extent possible and should not be unnecessarily different.

Options in the form of a regulatory requirement particular to one or more regions / nations shall be included in 3GPP specifications. TSGs should not debate the inclusion or rejection of such options.

The results of the 3GPP work shall form the basis of member contributions to the ITU in accordance with existing procedures.

3GPP shall take account of emerging ITU recommendations on interworking between IMT-2000 family members.

In the framework of agreed relationships, the 3GPP Technical Specifications and Technical Reports will form the basis of standards, or parts of standards, of the Organizational Partners.

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# SECTION B: PARTICIPATION

## Article 4: Categories

Participation in 3GPP shall be classified into one of the following categories:

- Partners;
- Individual Members;
- ITU Representatives;
- Observers;
- Guests.

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## Article 5: Partnership

Partners in 3GPP shall be classified into one of the following two categories:

- Organizational Partners;
- Market Representation Partners.

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## Article 6: Organizational Partnership

Organizational Partnership is open to any Standards Organization, irrespective of its geographical location, which has:

- a national, regional or other officially recognized status and the capability and authority to define, publish and set standards within the 3GPP scope, in that nation or region;
- an Intellectual Property Rights (IPR) Policy which is compatible with those of the Organizational Partners;
- committed itself to all or part of the 3GPP scope;
- signed the Partnership Project Agreement.

Standards Organizations may apply to become an Organizational Partner by writing to any of the existing Organizational Partners.

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# Article 7: Market Representation Partnership

The Organizational Partners may invite Market Representation Partners to take part in 3GPP.

An invitation for Market Representation Partnership is open to any organization, irrespective of its geographical location, which:

- has the ability to offer market advice to 3GPP and to bring into 3GPP a consensus view of market requirements (e.g., services, features and functionality) falling within the 3GPP scope;
- does not have the capability and authority to define, publish and set standards within the 3GPP scope, nationally or regionally;
- has committed itself to all or part of the 3GPP scope;
- has signed the Partnership Project Agreement.

Organizations may apply to become Market Representation Partners by writing to any of the existing Partners. Further guidance for MRP applicants can be found in annex E.

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# Article 8: Individual Membership

Membership in an Organizational Partner is a pre-requisite for Individual Membership of 3GPP. All entities registered as members of an Organizational Partner and eligible for participation in the technical work of that Organizational Partner, can become Individual Members of 3GPP if they are committed to support 3GPP and:

- to contribute technically or otherwise to one or more of the Technical Specification Groups within the 3GPP scope;
- to use the 3GPP results to the extent feasible.

An Individual Member has the right to participate in the work of 3GPP by attending meetings of the Technical Specification Groups and subtending groups.

Applications for Individual Membership of a Technical Specification Group shall be made in writing to the relevant Organizational Partner using the form given at annex C. Applications may also be made on-line using the template available at http://www.3gpp.org.

Individual Members act in 3GPP in their own right and carry the full responsibility for their contributions.

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# Article 9: Termination of Individual Membership

Individual Membership of 3GPP may be terminated by dissolution, abolition, resignation or expulsion from the related Organizational Partner.

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# Article 10: Observers and Guests

The status of Observer may be granted by the Organizational Partners to an entity which has the qualifications to become a future Partner.

An Observer may send a single representative to an Organizational Partners or PCG meeting. An Observer may also have representatives at TSG meetings. Representatives of Observers may receive documents and contribute documents for information, but shall not submit documents that propose changes to the specifications, reports, work item descriptions, work plan, or any other document under the control of the TSG. Observers shall not take part in decision making or hold any leadership positions.

Additional participation rights of an Observer shall be decided by the Organizational Partners on a case-by-case basis.

The status of Guest may be granted for a limited period, by the Organizational Partners to an entity which has the qualifications to become a future Individual Member. The limited period shall be decided by the Organizational Partners on a case-by-case basis.

A Guest may have representatives at TSG and subtending group meetings. Representatives may receive documents but shall not take part in decision making, participate in discussions, contribute documents, or hold any leadership positions.

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# SECTION C: STRUCTURE

# Article 11: Structure of 3GPP

3GPP shall consist of a Project Co-ordination Group (PCG) and Technical Specification Groups (TSGs). The Technical Specification Groups may establish Working Groups if required.

The Organizational Partners may decide to call a meeting of the full 3GPP membership if required.

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# SECTION D: PARTNERS' COLLECTIVE RESPONSIBILITIES

# Article 12: Organizational Partners' Collective Responsibilities

The Organizational Partners shall determine the general policy and strategy of 3GPP.

In addition the Organizational Partners shall perform the following tasks:

- approval and maintenance of the 3GPP scope;

- maintenance of the Partnership Project Description;
- taking decisions on the creation or cessation of Technical Specification Groups, and approving their scope and terms of reference;
- approval of Organizational Partner funding requirements;
- allocation of human and financial resources provided by the Organizational Partners to the Project Co-ordination Group;
- acting as a body of appeal on procedural matters referred to them;
- conduct compliance training at least annually for elected leadership, relevant Support Team personnel and interested parties on best practices to follow to
  - avoid issues with respect to antitrust/competition laws and regulations;
  - fulfil the leadership/support role with impartiality and in the interests of 3GPP.

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## Article 13: Collective responsibilities of all Partners

Organizational Partners and Market Representation Partners shall perform the following tasks:

- maintenance of the Partnership Project Agreement;
- approval of applications for 3GPP partnership;
- taking decisions relating to the dissolution of 3GPP.

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# SECTION E: PROJECT CO-ORDINATION GROUP (PCG)

## Article 14: PCG tasks

The PCG shall perform the following tasks:

- appointment of PCG Chair and Vice Chairs;
- allocation of human and financial resources provided by Organizational Partners to TSGs;
- allocation of voluntary human and financial resources provided by Market Representation Partners and Individual Members;
- management of the 3GPP Support Team;
- handling of appeals from Individual Members on procedural matters referred to them;
- propose and approve modifications to the Partnership Project Working Procedures;
- handling of appeals from Individual Members on technical matters referred to them;
- determination of the overall time frame and manage overall work progress;
- final adoption of new and stopped work items proposed by the TSGs within the agreed 3GPP scope and objectives;
- when a work item is outside the scope of the 3GPP, and where a common global solution is desired, recommend how to achieve a global solution;

- appointment or dismissal of TSG Chairs and Vice Chairs, as proposed by TSGs based on election results. (The proposed candidate shall be appointed unless there are extraordinary reasons that prevent such an appointment, e.g., severe company or geographical imbalance within 3GPP. In such cases the TSG shall be requested to elect an alternative candidate. The decision not to appoint a candidate shall be made by consensus.);
- authorizing requests from the TSGs for approval to liaise with external organizations, and maintain a list of approved requests;
- maintenance of the register of Individual Members eligible to participate in 3GPP;
- maintenance of the register of IPR declarations relevant to 3GPP, received by the Organizational Partners.

The PCG may decide to call a meeting of the full 3GPP membership if required.

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# Article 15: PCG participation

The following shall have a right to participate in the PCG:

- Typically, a maximum of five representatives of each Organizational Partner (not counting the Chair and Vice-Chairs);
- A maximum of three representatives of each Market Representation Partner. (MRPs are however urged to limit their participation to one representative wherever possible.);
- The Chairs and Vice Chairs of the TSGs as ex-officio members;
- A maximum of three ITU representatives;
- One representative of each Observer.

top

# Article 16: PCG appointment of Chair and Vice Chairs

The PCG shall appoint their Chair and Vice Chairs from amongst the Organizational Partner representatives.

The Chair and Vice Chairs shall be appointed for a one year term of office.

The Chair and Vice Chairs shall normally serve one term of office. If no other candidates are available, the Chair or Vice Chairs may be appointed for a further term.

Successive Chairs and Vice Chairs should not be from the same Organizational Partner, the same region or from the same group of companies, unless no other candidate is available.

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# Article 17: PCG Chair and Vice Chair Responsibilities

The PCG Chair is responsible for the overall management of the co-ordination work within 3GPP.

The Chair has the overall responsibility to ensure that the Partnership Project Agreement, Partnership Project Description and Partnership Project Working Procedures are followed.

The Chair may nominate officials to assist in the work.

The Chair may be assisted by the Support Team.

The Chair may delegate tasks to the Vice Chairs.

In performing their leadership role, the Chair and Vice Chairs shall maintain impartiality and act in the interests of 3GPP.

At the commencement of each meeting of the PCG, the group shall be reminded that:

(i) compliance with all applicable antitrust and competition laws is required; and

(ii) the leadership will conduct the meeting with impartiality and in the interests of 3GPP.

top

## Article 18: PCG meetings

A meeting of the PCG shall be held at least twice per year.

At least thirty days before the due date, a calling notice, draft agenda and supporting documents shall be issued.

top

## Article 19: PCG decision making

In any meeting of the PCG, the quorum required for decision making shall be 50% of the total number of Organizational Partners. Proxies shall not be permitted.

The PCG shall endeavour to reach consensus on all issues. The views and opinions of the Market Representation Partners and the Chairs and Vice Chairs of the TSGs shall be taken into account during the consensus building process. If consensus cannot be achieved, the PCG Chair can decide to take a vote. The vote may exceptionally be performed by a secret ballot if decided by the PCG.

Each Organizational Partner shall have one vote. A proposal shall be deemed to be approved if 71% of the votes cast are in favour. Abstentions or failure to submit a vote shall not be included in determining the number of votes cast.

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# SECTION F: TECHNICAL SPECIFICATION GROUPS

## Article 20: TSG tasks

The TSGs shall prepare, approve and maintain the 3GPP Technical Specifications and Technical Reports taking into account the market requirements provided by Market Representation Partners.

The TSGs shall also perform the following tasks:

- Propose to the PCG for appointment TSG Chair and Vice Chairs based on election results;
- Creation of TSG Working Groups and approval of their terms of reference;
- When a new Working Group is created, the appointment of TSG Working Group Convenor;
- Allocation of resources within the TSG;
- Allocation of voluntary human and financial resources provided by Market Representation Partners and Individual Members;
- Handling of appeals from Individual Members on technical matters;
- Preparation of a detailed time frame and management of detailed work progress;

- Management of work items;
- Technical Co-ordination;
- Proposal and approval of work items within the agreed scope and terms of reference of the TSG;
- Where a work item is outside the scope of the 3GPP, but a common global solution is desired, recommend an approach to the PCG;
- Assignment of work to Partners. (Specification development may be accomplished using various methods, including the assignment of work to Partners.);
- Maintenance of the list of Individual Members eligible to vote within the TSG (Voting Members).

top

# Article 21: TSG participation

The following shall have a right to participate in the TSGs:

- Representatives of members of participating Organizational Partners (i.e. Individual Members);
- Representatives of Organizational Partners;
- Representatives of Market Representation Partners;
- Representatives of Observers;
- Representatives of Guests.

top

# Article 22: TSG and WG election of Chair and Vice Chairs

## 22.1 TSG elections

Regular TSG elections shall be held every two years in the first semester of odd numbered years.

The TSG Chair and Vice Chairs shall be elected by the Technical Specification Group from amongst the Individual Member representatives. Each TSG shall elect a maximum of three Vice Chairs.

A candidate for election to a TSG Chair or Vice Chair position shall provide a letter of support from the Individual Member that they represent. The support letter from the Individual Member shall indicate that the candidate will avail or has availed themselves of 3GPP supplied antitrust and competition law training in order to comply with all applicable antitrust/competition laws and regulations while acting in the capacity of TSG Chair or Vice Chair.

Nominations may be made up to the point when an election takes place.

The Chair and the Vice Chairs shall be elected for a two year term of office. The Chair and Vice Chairs may offer themselves for election for a second consecutive term. The term “consecutive” is taken to mean terms one after the other without another person being elected to the position in the interim. Exceptionally, they may offer themselves for further consecutive terms, subject to the following:

- A two week deadline that expires at noon Central European Time on the Friday which falls between 20 and 14 days prior to the first day of the meeting at which elections are due to be held shall be established.
- A Chair is not permitted to stand for another consecutive term if another candidate is announced via the 3GPP web site or via the relevant 3GPP email reflector prior to this deadline.
- A Chair is not permitted to stand for another consecutive term until after this deadline.

- A Vice Chair is not permitted to stand for another consecutive term in a Vice Chair position for which there is a candidate announced via the 3GPP web site or via the relevant 3GPP email reflector prior to this deadline.

- A Vice Chair is not permitted to stand for another consecutive term until after this deadline. If, by the deadline, the number of candidatures is less than the number of Vice Chair positions, then any incumbent Vice Chair may put forward their candidature.

There is no restriction on a Vice Chair whose term of office is due to expire offering himself for the position of Chair; neither is there any restriction on a Chair whose term of office is due to expire offering himself as a Vice Chair. There is no restriction of a retiring Chair or Vice Chair of one TSG offering himself for election as either Chair or Vice Chair of any other TSG (or WG).

Should the office of Chair or Vice Chair of a TSG become vacant for reasons other than expiration of term of office, a special election shall be conducted to fill the unexpired term. This special election shall be conducted at a meeting of the TSG, and shall be announced in the agenda according to the provisions of article 32.

When such a special election is held to fill the office of Chair, and one or more of the Vice Chairs of the TSG intends to stand for election to that position, the announcement shall also indicate that there will be an election to fill the position of Vice Chair in the event that a Vice Chair be elected to the office of Chair. If at the special election the Vice Chair is elected to the office of Chair, that individual shall become Chair immediately, and, the position of Vice Chair thus being vacant, an election shall be held for the office of Vice Chair.

Similarly, if an incumbent Chair intends to stand for election to the position of Vice Chair, the same applies, with the necessary changes to the text above.

If a Chair or Vice Chair changes the Individual Member that they represent (e.g., job change, merger or acquisition) during their term of office, a new letter of support shall be provided. In order to provide a new letter of support, a Chair or Vice Chair may request a grace period allowing their term to be extended the lesser of 6 weeks or until the day before the next scheduled regular term (e.g., every 2 years) election. Although the term is extended, under the rules of article 22, the Chair or Vice Chair can only chair meetings when representing an Individual Member. This rule continues to apply during the grace period. If the change of company affiliation is due to a move to another company, then the decision for the Chair or Vice Chair to continue in office to the end of the present term shall be made by consensus of the TSG. If consensus cannot be achieved, a special election shall be held for the office. The incumbent Chair or Vice Chair is permitted to offer their candidacy in a special election even if they have held the position for 2 terms or more.

The term of office for a Chair or Vice Chair elected at a special election is a partial term lasting until the end of the current term. If a new Chair or Vice Chair is elected at a special election then the partial term of office does not count towards the two consecutive term limit. If the previous Chair or Vice Chair is re-elected at a special election then the entire term (of two parts) is considered as a single term and does count towards the two consecutive term limit.

Chairs and Vice Chairs should not be from the same region, Organizational Partner, or from the same group of companies, unless no other candidate is available.

Successive Chairs should not be from the same Organizational Partner, the same region or from the same group of companies, unless no other candidate is available. This does not apply to special elections or to regular elections for a second or subsequent consecutive term of office .

When a new TSG is established, the Organizational Partners shall appoint a convenor for the first two TSG meetings. The election for TSG Chair and Vice Chairs shall take place at the second TSG meeting. If the election takes place other than at the normal time for TSG elections (see above), the elected Chair and Vice Chairs shall serve until the next regular TSG election. This partial term of office does not count towards the two consecutive term limit. The provisions of this paragraph may be overridden by consensus of the PCG where a new TSG is formed by the merger of existing TSGs; under these circumstances, the PCG shall establish a set of ad hoc rules for the creation of the new TSG.

Following election by the TSG, the TSG Chair and Vice Chairs shall be appointed by the PCG on the proposal of the TSG.

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## 22.2 WG elections

The provisions concerning the election of WG Chairs and Vice Chairs shall be as for TSG Chairs and Vice Chairs as defined in 22.1 above, changing TSG to WG wherever TSG is mentioned, with the following differences.

Each WG shall elect a maximum of two Vice Chairs.

WG elections shall be held when the corresponding terms of office expire or when an existing Chair or Vice Chair resigns. WG elections need not be synchronized within the WG (i.e. elections for Chair and each Vice Chair may occur at different times), across different WGs of the same or other TSGs, nor with the regular TSG elections.

WG Chairs and Vice Chairs are always elected for a period of two years (and not, as is the case with special elections in TSGs, for the unexpired period of the present term of office). An exception to this is where the previous Chair or Vice Chair is re-elected in the special election. In this case the Chair or Vice Chair continues for the unexpired period of the present term of office.

Note: For this reason, elections for WG Chairs and Vice Chairs are likely to become spread over a period of time, rather than being grouped like the TSGs' regular elections.

When a new WG is established, the parent TSG is responsible for appointing a convenor for the first two meetings.

Following election by the WG, the Chair and Vice Chairs hold office immediately, without need of appointment by TSG or PCG.

If a WG does not meet physically with enough frequency to maintain an up to date voting list, the working group may elect to escalate the voting for officers to the parent TSG.

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# Article 23: TSG and WG Chair and Vice Chair responsibilities

The TSG Chair is responsible for the overall management of the technical work within the TSG and its Working Groups. The Chair has an overall responsibility to ensure that the activities of the TSG follow the Partnership Project Working Procedures.

The WG Chair is responsible for the overall management of the technical work within the WG and its sub-groups.

The Chair may nominate officials to assist in the work.

The Chair may delegate tasks to the Vice Chairs.

The Chair may be assisted by the Support Team.

The Chair shall form a Management Team, including the Vice Chairs and Support Team, in order to assist in discharging the Chair’s duties.

Recognizing the need to balance the requirement of rapid specification development with the limited resources of delegates, the Chair should encourage a minimum number of meetings, especially parallel meetings, and maximize the use of electronic means to advance the work.

In performing their leadership role, the Chair and Vice Chairs shall maintain impartiality and act in the interests of 3GPP.

At the commencement of each meeting of a TSG or WG, the group shall be reminded that:

(i) compliance with all applicable antitrust and competition laws is required;

(ii) timely submissions of work items in advance of TSG or WG meetings are important to allow for full and fair consideration of such matters; and

(iii) the leadership will conduct the meeting with impartiality and in the interests of 3GPP.

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# Article 24: TSG and WG Chair and Vice Chair dismissal

A secret ballot shall be taken for the proposal to dismiss a TSG or WG Chair or Vice Chair because of a failure to effectively perform their duties, if requested by 30% of the TSG or WG membership list. 71% of the votes cast are required to recommend dismissal.

The PCG shall dismiss a Chair or Vice Chair on the proposal of the TSG.

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# Article 25: TSG and WG decision making

TSGs and WGs shall endeavour to reach consensus on all issues, including decisions on Technical Specifications and Technical Reports. Informal methods of reaching consensus are encouraged (e.g., a show of hands). If consensus cannot be achieved, the Chair can decide to take a vote. The vote may exceptionally be performed by a secret ballot if decided by the TSG or WG. A vote may be conducted during a TSG or WG meeting or by correspondence.

A proposal shall be deemed to be approved if 71% of the votes cast are in favour. Abstentions or failure to submit a vote shall not be included in determining the number of votes cast.

It is the responsibility of the Chair to ensure that questions to be voted upon are phrased in a positive yes/no manner, with 71% required to approve the question. Questions should not be phrased as the TSG shall not do something. Examples of appropriate questions are; Shall the TSG approve the Specification and send it to the SDOs? Shall the liaison be approved? Shall the new WI be approved? Shall the existing WI be stopped? If the issue is to choose option A or B, the question should be split into two questions, with the Chair selecting the order. First, shall the TSG take option A as the way forward? If this question fails the second question is, shall the TSG take option B as the way forward?

Contributions on which decisions will be based should be made available in good time before each meeting. TSGs may establish informal guidelines for dealing with late contributions.

If a WG does not meet physically with enough frequency to maintain an up to date voting list, the working group may elect to escalate the voting to the parent TSG.

Working Agreements may be used to establish tentative agreements in cases where consensus cannot be obtained. The working agreement process is described in annex G.

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# Article 26: TSG and WG voting during a meeting

The following procedures apply for voting during a TSG or WG meeting:

- before voting, a clear definition of the issues shall be provided by the Chair;
- Voting Members shall only be entitled to one vote;
- if a Voting Member has more than one representative present, only one representative may vote;
- each Voting Member may only cast the vote once;
- each Voting Member may carry proxy votes for up to five other Voting Members. All proxy votes shall be accompanied by a letter of authority from the authorising Voting Member. Proxies will not be taken into account when determining the quorum;
- the quorum required for voting during a TSG or WG meeting shall be 30% of the total number of Voting Member companies on the TSG or WG voting list;
- the result of the vote shall be recorded in the meeting report.

For the determination of the quorum, see annex H.

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# Article 27: TSG or WG voting by correspondence

The following procedures apply for voting by correspondence:

- before voting, a clear definition of the issues shall be provided by the Chair and disseminated to all on the TSG or WG membership list;
- Voting Members shall only be entitled to one vote;
- each Voting Member may only cast the vote once within the voting period;
- the voting period shall be 30 days;
- there are no quorum requirements;
- The result of the vote should be disseminated to the TSG or WG.

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# Article 28: TSG or WG voting for the election of TSG or WG Chair and Vice Chair

In the case where there is more than one candidate for TSG or WG Chair or Vice Chair, a secret ballot shall be used. For interpreting the result of the secret ballot the following procedure shall apply:

When, in the first ballot, no candidate has obtained 71% of the votes cast, a second ballot shall be held. In the second ballot, in cases where there are only two candidates, the candidate obtaining the higher number of votes is elected. In cases where there are more than two candidates, if none of them has obtained 71% of the votes, a third and final ballot shall be held among the two candidates who have obtained the highest number of votes in the second ballot. The candidate obtaining the higher number of votes in the third ballot is then elected.

The TSG or WG Chair shall be responsible for the voting process and shall ensure that confidentiality is maintained.

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# Article 29: TSG or WG appeal process

An Individual Member of 3GPP who opposes a Chair's ruling on a vote taken within a TSG or WG may submit their case to the PCG for decision. In such cases the Individual Member shall also inform the relevant TSG or WG Chair.

When a TSG or WG Chair has made a ruling, their decision shall be taken as the basis for future operations, unless or until overturned by the PCG.

If an Individual Member in a TSG or WG believes that a Chair or Vice Chair of any such group is acting without impartiality and not in the interests of 3GPP, such Individual Member may object to such actions within the relevant group, and may request that such objection be recorded in the minutes of the applicable group meeting and it shall be so recorded. The objecting Individual Member may ultimately take their objection to the PCG for consideration. In such cases the Individual Member shall also inform the relevant TSG or WG Chair.

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# Article 30: TSG and WG meetings

TSGs and WGs shall meet as necessary to complete their work within the prescribed timeframe. TSGs should endeavour to hold their meetings at the same time and place to assist in the overall co-ordination of the work.

Meeting locations should reflect the geographical diversity of the TSG and WG delegates.

Further information on meetings is given in annex F.

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# Article 30A: TSG and WG participation

IMs wishing to progress work on topics in 3GPP are expected to participate physically in the meetings.

If a 3GPP IM is materially interested in a specific topic but is unable to participate in a meeting by sending a delegate, the IM is urged to engage the support of other IMs whose delegates will be present at the meeting to present its views. If this is not possible for any reason, the IM may advise the Chair of the situation and may provide documents supporting their position. The Chair may facilitate the introduction of these documents during the meeting and the record of the meeting can include the discussion and outcome. Note that physical participation in meetings is considered the norm and the option to engage the Chair is intended for exceptional situations. The Chair has the right to decline the request.

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# Article 31: TSG and WG meeting invitation

The invitation to a TSG or WG meeting and the necessary logistical information should be disseminated as soon as practically possible, taking into account the need to obtain travel documentation. It shall be disseminated at least 28 days before the meeting to all on the TSG or WG membership list.

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# Article 32: TSG and WG meeting agenda

The draft agenda for a TSG or WG meeting shall be disseminated by the responsible Chair to all on the TSG or WG membership list at least 21 days before a meeting. The draft agenda should indicate subject matters where voting may be required. The draft agenda shall indicate elections to be held (including known candidates). The draft agenda shall indicate the deadlines (dates and times) for registration and meeting document submission to the TSG/WG meeting. Other deadlines may also be indicated (whenever required).

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# Article 33: TSG and WG meeting registration

Delegates and officials must register before participating in any 3GPP meeting. Each delegate or official who represents an Individual Member shall declare the precise name of that Individual Member. A delegate or official may only register to represent one Individual Member.

The deadline for registration for all delegates and officials is one week in advance of the start of the meeting. Registrations after this deadline will still be processed, but timely receipt of meeting related information is not guaranteed for late registrants.

To aid in communication, delegates or officials at co-located meetings may briefly visit a meeting they have not registered for. However, any extensive involvement such as presenting a contribution or formally objecting requires prior registration to the meeting.

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# Article 34: TSG and WG meeting document and file naming

Documents for a TSG or WG meeting shall follow a consistent numbering system as shown in the following example:

**xminnzzzz**

This numbering system has six logical elements:

1) **x**: a single letter corresponding to the TSG;

   where x : **R** (Radio Access Network)

   **N** (Core Network) [TSG closed March 2005]

   **S** (Service and System Aspects)

   **T** (Terminals) [TSG closed March 2005]

   **G** (GSM/EDGE Radio Access Network)

   **C** (Core network and Terminals)

2) **m** A single character corresponding to the Working Group identity (typically 1, 2, 3, etc) or, in the case of the TSG itself, the letter "**P**".

3) **i**: Normally the hyphen character "-". May take on other values depending on the nature of the meeting at which the document is presented, eg the identity of a subgroup.

4) **nn**: two digits to indicate the year, i.e. 99, 00, 01, etc;

5) **zzzz**: unique number of the document

No provision is made for the use of revision numbers. Documents which are a revision of a previous version should indicate the document number of that previous version.

The filename of documents shall be the document number. Documents may be compressed to .Zip files (and thus bear a file extension ".zip"). For example, document **S1-060357** will be contained in file **S1-060357.zip**.

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# Article 35: TSG and WG Voting Membership List

## 35.1 Voting list

Each TSG and WG shall maintain a list of Individual Members eligible to vote in that group.

The voting list shall be used to establish quorum and for determining those eligible to take part in a vote.

NOTE 1: The term "membership list" has no particular significance in the context of TSG and WG meetings. The term "attendance list" is used for a list of individuals who attend a given meeting representing an Individual Member or other entity entitled to participate in meetings – see annex F.

For the determination of the quorum, see annex H.

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## 35.2 On creation of new TSG or WG

When a new TSG or WG is formed an Individual Member is added to the voting list at the first meeting at which it is represented, and may vote at the second meeting where it is represented.

Exceptionally, if inadequate notice (less than the period of time given in article 31) had been given for the first meeting of the new group, an Individual Member shall be added to the voting list on its delegate's attending the second meeting (the election meeting) and vote at that meeting even if it had not been represented at the group's first meeting.

Only an Individual Member that had been represented at the group's first meeting may provide a proxy for the second meeting.

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## 35.3 Established TSGs and WGs

To qualify for the voting list it is necessary for at least one delegate of an Individual Member to attend at least two meetings of the group concerned, without being removed according to the provisions of article 35.4..

An Individual Member having been represented at at least two ordinary meetings of the group has the right to cast a vote by proxy (see article 26). Thus an Individual Member may not cast a vote by proxy during a meeting at which it is not represented unless it had already been represented at two or more qualifying meetings of the group.

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## 35.4 Removal from and reinstatement to voting list

An Individual Member which is not represented at three consecutive meetings of the TSG or WG shall be removed from the voting list.

The right to vote is reinstated at the second meeting which a delegate of the Individual Member attends without missing the number of consecutive meetings mentioned in the previous paragraph (but see article 35.3 for eligibility to cast a proxy vote).

EXAMPLE 1: If Individual Member Z is represented at meeting K and K+3 (and is thus eligible to vote) but is not represented at meetings K+4, K+5 and K+6, it is removed from the voting list.

EXAMPLE 2: If Individual Member X, not previously having been represented at a meeting of the group, is represented at meetings N and N+3, it may cast a vote at meeting N+3.

NOTE: Individual Member X might choose to cast a vote by proxy at meeting N+3, even though its delegate is physically present. This is sometimes useful for coordinating company positions where one large company has several Individual Memberships, possibly via several different Organizational Partners.

EXAMPLE 3: If Individual Member Y, not previously having been represented at a meeting of the group, is represented at meeting N only, it may not cast a vote by proxy at meeting N+2.

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## 35.5 Meetings other than ordinary meetings

Any group that wants to call an electronic meeting (audio, video, document distribution by posting or e-mail, etc) may do so, although this works best with smaller groups. Therefore, all electronic meetings are allowed but only ordinary meetings (see annex F) count towards attendance. However, if a meeting is designated as face-to-face, provision of bridge and speakerphone capabilities for those requesting it would be at the discretion of the host. Those participating by speakerphone are not to be counted toward quorum or attendance, and are not allowed to vote.

For the determination of the quorum, see annex H.

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## Article 36: TSG Sub Working Groups

A Working Group may establish a Sub Working Group (SWG) with defined Terms of Reference. The Working Group shall appoint a SWG Chair. The SWG shall work by consensus. The meeting notice requirements for a SWG meeting are the same as for TSGs and WGs.

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# SECTION G: WORK PROGRAMME AND TECHNICAL CO-ORDINATION

## Article 37: Work Programme

The 3GPP Work Programme shall consist of Work Items defined by the TSGs.

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## Article 38: Work Items

A 3GPP Work Item is a specification task defined in terms of the following principal parameters:

- title;
- intended output (i.e. Technical Specifications or Technical Reports);
- impact on other Technical Specifications and Technical Reports;
- technical scope, including the field of application of the intended output;
- impact on other 3GPP Work Items;
- the schedule of tasks to be performed;
- the identities of the supporting Individual Members;
- the identity of the Work Item Rapporteurs.

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## Article 39: Work Item creation

Each proposed new Work Item shall be supported by at least four Individual Members, and their names shall be recorded in the Work Item definition prepared for the TSG approval. One or more persons shall be named as Rapporteur for the proposed Work Item, and the Rapporteur shall act as the prime contact point on technical matters and for information on progress throughout the drafting phases. The supporting Individual Members are expected to contribute to and progress the new work item throughout the drafting phases.

In addition to the above, TSGs shall approve new Work Items, giving all essential parameters. The proposal shall be entered into the 3GPP work programme, clearly marked as a new entry, for which a unique reference identity shall be allocated.

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# Article 40: Work Item adoption by PCG

The 3GPP work programme shall be made available to all Individual Members. A new Work Item shall remain flagged as "new" until the end of the month following the month during which the 3GPP work item was entered into the 3GPP work programme. A new Work Item shall be adopted by the PCG unless a substantial objection is received from an Individual Member or Partner during this period. At the end of the period, the "new" flag shall be removed (even if there is an objection) and it is the responsibility of any objecting Individual Member or Partner to discuss their objections with the TSG Chair. If it is not possible to resolve the objection, it is the responsibility of the Individual Member or Partner to raise the issue with the PCG.

The TSGs shall ensure that the 3GPP Work Item details are maintained at regular intervals.

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# Article 41: Work Item stopping

Prior to completion of the intended 3GPP output, the responsible TSG may conclude that a Work Item is no longer required. Any Work Item shall automatically be considered by a TSG for stopping, if no progress has been achieved in a given period of time, typically six months, e.g. due to a lack of contribution. In such cases, the Work Item shall be flagged as "stopped" in the Work Programme. The proposal to stop a Work Item shall be fully justified.

The Work Programme shall be updated accordingly, and shall show the Work Item as "stopped" until the end of the month following the month during which the Work Item was initially flagged.

The Work Item will be stopped by the PCG unless substantial objection is received from an Individual Member during this period. It is the responsibility of any objecting Individual Member to discuss their objections with the TSG Chair. If it is not possible to resolve the objection, it is the responsibility of the Individual Member to raise the issue with the PCG.

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# Article 42: Technical co-ordination

The PCG shall be responsible for determining the overall time frame and for managing the overall work progress. The System Aspects TSG shall have a particular responsibility for the technical co-ordination of work being undertaken within 3GPP, and for overall system architecture and system integrity. Problems encountered in performing this technical co-ordination role shall be reported immediately to the PCG.

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# SECTION H: DELIVERABLES

# Article 43: Deliverable types

3GPP shall prepare, approve and maintain documents known as Technical Specifications and Technical Reports. Such documents shall be drawn up by the TSGs and shall, following approval at that level, be submitted to the participating Organizational Partners to be submitted to their respective standardization processes.

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# Article 44: Approval process

Approval of Technical Specifications and Technical reports by a TSG shall normally be by consensus.

Where consensus cannot be achieved in the TSG a vote may be taken.

When Technical Specifications and Technical Reports become sufficiently stable, they shall be put under change control of the relevant TSG. The further elaboration of these Technical Specifications and Technical Reports shall be achieved by change requests to be approved by the TSG.

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# Article 45: Drafting rules

The Technical Specifications and Technical Reports drafted by the TSGs shall follow the 3GPP drafting rules, using document processing facilities, format, languages and notations agreed by the Organizational Partners, and on a medium suited for electronic document handling and publishing.

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# Article 46: Copyright and ownership

The Organizational Partners will have joint ownership (including copyright) of the Technical Specifications and Technical Reports produced by 3GPP.

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# Article 47: Conversion by Organizational Partners

Organizational Partners shall use their best endeavours to convert the Technical Specifications and Technical Reports approved by the Partnership Project into national/regional deliverables in a timely manner through their normal processes.

The Organizational Partners are urged not to change the technical parts of the Technical Specifications and Technical Reports; they may add non-technical parts required by their own deliverable schemes and they may add descriptions of options selected.

Organizational Partners should ensure that all unresolved comments raised during their public enquiry and approval phases are delivered to the appropriate TSG.

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# SECTION I: REPORTING

# Article 48: Chair’s reporting obligations

A report shall be prepared by the Chair following all PCG and TSG meetings.

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# Article 49: Changes to structure and officials

The Chair of each TSG shall inform the PCG of all organizational changes concerning Working Groups and their officials. An up to date record of the 3GPP structure shall be maintained.

top

# Article 50: Calendar of meetings

The PCG and TSGs shall maintain an up to date calendar of the dates and venues for future meetings.

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# SECTION J: EXTERNAL RELATIONS

# Article 51: Relationship with the ITU

3GPP results should be submitted to the ITU as appropriate.

For working groups, the following handling of communications toward ITU shall apply:

1 Working groups shall send ITU submissions which are destined to become part of ITU deliverables to their parent TSG for review.

2 Working group communications towards the ITU which are NOT destined to become part of an ITU deliverable must be reviewed by the TSG Chair and the appropriate ITU sector convener (if one exists for the given ITU sector). The working group's TSG Chair and ITU sector convener will determine if such a communication should be sent to the parent TSG for review. If for some reason either the TSG Chair or ITU sector convener is not available, then it is sufficient for the remaining person to review the document and determine if it should be escalated to the TSG or not.

3 If the working group communication does not require TSG review, then it shall be conveyed to the ITU from the WG using one of the mechanisms described below.

For TSGs, the following handling of communications toward ITU shall apply:

1 TSGs shall send ITU submissions which are destined to become part of ITU deliverables to the PCG for review.

2 TSGs communications towards the ITU which are deemed sensitive by the TSG shall be sent to the PCG for review.

3 If the TSG does not judge the communication as sensitive, then it shall be conveyed to the ITU from the WG using one of the mechanisms described below.

To convey a communications towards the ITU, one of the following mechanisms shall be used based upon determination of the sending body (a body may determine a default mechanism).

a) The communication shall be sent from the OPs as a deliverable from their organizations (applicable to PCG reviewed communications only)

b) The communication shall be made by Individual Members who are also members of the ITU. In such a circumstance, the appropriate ITU sector convener will coordinate and handle the administrative matters for the submission. 3GPP Technical Specifications and Technical Reports may be taken as the technical content of such contributions (applicable to PCG reviewed communications or TSG reviewed communications).

c) The communication shall be sent directly from the 3GPP liaison coordinator to the appropriate ITU receiver in the ITU (applicable to TSG reviewed communications or WG reviewed communications).

Representatives of ITU-D, ITU-R and ITU-T are invited to participate in the Project Coordination Group for the efficient coordination and exchange of information.

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## Article 52: Relations with other groups

TSGs and WGs are encouraged to liaise directly with the relevant technical bodies within the 3GPP and Partners as appropriate.

A liaison statement shall clearly communicate what is expected from the receiver, i.e., which parts are for information, which questions are expected to be clarified and by whom (especially if there are multiple receivers), and also when an answer is needed, e.g., when is the next meeting of the group sending the liaison statement.

A TSG or any subtending Working Group may send individual liaisons to any external organization (other than ITU) without PCG approval, except if the statement is considered sensitive by the TSG Chair, in which case PCG clearance is needed.

It is not necessary to have all external liaisons copied to the PCG and/or TSG SA. The liaison originating TSG should decide, at its own discretion, which should be copied. External liaisons that may have management implications such as schedules, organization, process, procedures, and policy shall be copied to the PCG, or approved by the PCG if sensitive.

Relations with the ITU are described in article 51.

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# SECTION K: MISCELLANEOUS

## Article 53: Resources

The resources for the operation of 3GPP shall be managed by the Organizational Partners. The resources are allocated to the TSGs by the PCG.

top

## Article 54: Support Team

The Partners shall provide logistical support to, and assist in the operation of, 3GPP. The support shall be in the form of a Support Team which shall operate under the overall management of the PCG and the day to day management of TSGs.

top

## Article 55: Intellectual Property Rights (IPR) Policy

Individual Members shall be bound by the IPR Policy of their respective Organizational Partner.

Individual Members should declare at the earliest opportunity, any IPRs which they believe to be essential, or potentially essential, to any work ongoing within 3GPP. Declarations should be made by Individual Members to their respective Organizational Partners.

Organizational Partners should encourage their respective members to grant licences on fair, reasonable terms and conditions and on a non-discriminatory basis.

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## Article 56: Working language

The working language for 3GPP shall be English.

Meetings of the PCG and TSGs shall be conducted in English.

3GPP Technical Specifications and Technical Reports shall be prepared in English (as defined by the Shorter Oxford English Dictionary).

top

## Article 57: Duration

3GPP shall be task oriented and on completion of the tasks the future of 3GPP shall be re-considered. The continuation of 3GPP shall therefore be confirmed by the Organizational Partners on an annual basis.

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## Article 58: Review of activities

An evaluation of the activities of 3GPP should be made by the Organizational Partners at regular intervals.

top

## Article 59: Dissolution, winding up

In the event of a voluntary dissolution of 3GPP, the Partners shall determine the terms of liquidation by consensus. All issues shall be documented and distributed at least 30 days prior to decisions being made.

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## Article 59A: Exhaustion of appeal procedures

In connection with any claim or dispute of an Individual Member arising from or relating to any activity of any 3GPP meeting or action, including in connection with a TSG or WG meeting, such Individual Member shall, prior to commencing any such legal proceeding against 3GPP, its leadership, support staff, or one or more Organizational Partners in a court, an arbitral panel or other adjudicatory body, exhaust all appeal procedures provided in the 3GPP Working Procedures. Exhaustion of appeal procedures shall be diligently expedited by both the appealing party and the appeal body.

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## Article 60: Amendments to 3GPP Working Procedures

These Partnership Project Working Procedures may only be amended by decision taken by the PCG.

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# Annex A: Definitions

| | |
|---|---|
| Consensus: | General agreement, characterized by the absence of sustained opposition to substantial issues by any important part of the concerned interest and by a process that involves seeking to take into account the views of all parties concerned and to reconcile any conflicting arguments. (Note: consensus need not imply unanimity). |
| Conversion: | The transformation of a 3GPP output document into an Organizational Partners deliverable following the Organizational Partners' recognized processes. |
| Delegate: | An individual taking part in a TSG/WG meeting physically or by electronic means. |
| Drafting Rules: | A document approved by the Organizational Partners providing rules for the drafting of 3GPP Technical Specifications and Technical Reports. |
| Election: | The voting process used to identify an individual from a number of individuals. |
| Guest: | An entity fulfilling the criteria to become a future Individual Member, which has been granted temporary participation rights in the 3GPP |
| Individual Member: | A member of an Organizational Partner having participation rights within that Organizational Partner and which has registered to take part in 3GPP. |
| ITU Representative | Representatives of ITU-D, ITU-R and ITU-T invited to participate in the Project Coordination Group for the efficient coordination and exchange of information. |
| Leadership: | A Chair, Vice-Chair, or Convenor of an OP/PCG/TSG/WG/SWG/Ad-Hoc or any other 3GPP meeting. |
| Market Representation Partner: | A Partner invited by the Organizational Partners to participate in 3GPP to offer advice and to bring into 3GPP a consensus view of market requirements. |
| Observer: | An Organization fulfilling the criteria to become a future Partner which has been granted temporary participation rights in 3GPP. |
| Organizational Partner: | A recognized Standards Organization which has been accepted as a Partner in 3GPP. |
| Partner: | An Organizational Partner or a Market Representation Partner of 3GPP. |
| Partnership Project Agreement: | The document signed by 3GPP Partners defining their rights and obligations. |
| Partnership Project Description: | A document which describes the overall structure and operation of 3GPP. |
| Represent: | Attend on behalf of.<br>A person who attends a meeting on behalf of an Individual Member represents that Individual Member. The person is not necessarily employed by that Individual Member, but may be, for example, employed by a subsidiary company in the same group as the represented Individual Member; or the person may be an independent consultant under contract to the Individual Member. "Representation" sometimes influences the eligibility to vote – see article 35 and annexes A and F. |
| Sub Working Group | A subordinate body of a Working Group. |
| Support Team: | A number of persons dedicated to support 3GPP. |
| Technical Report: | A 3GPP output document containing mainly informative elements approved by a Technical Specification Group. |
| Technical Specification: | A 3GPP output document containing normative provisions approved by a Technical Specification Group. |
| Voting Member | An Individual Member who has voting rights within a TSG/WG. |
| Work Item: | The documented record of a specific technical activity of 3GPP. |
| Work Programme: | The documented record of the all technical activities of 3GPP. |
| Working Group: | A subordinate body of a Technical Specification Group. |

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# Annex B: Abbreviations

| | |
|---|---|
| 3GPP | Third Generation Partnership Project |
| ARIB | Association of Radio Industries and Businesses |
| ATIS | Alliance for Telecommunications Industry Solutions (successor to T1) |
| CCSA | China Communications and Standards Association (successor to CWTS) |
| CDMA | Code Division Multiple Access |
| CWTS | China Wireless Telecommunications Standards Group (superseded by CCSA) |
| ETSI | European Telecommunications Standards Institute |
| FDD | Frequency Division Duplex |
| GSM | Global System for Mobile Communication |
| IM | Individual Member |
| IMT-2000 | International Mobile Telecommunication |
| ITU | International Telecommunication Union |
| MRP | Market Representation Partner |
| PCG | Project Co-ordination Group |
| SWG | Sub Working Group |
| T1 | Standards Committee T1 (superseded by ATIS) |
| TDD | Time Division Duplex |
| TSDSI | Telecommunications Standards Development Society, India |
| TSG | Technical Specification Group |
| TTA | Telecommunications Technology Association |
| TTC | Telecommunication Technology Committee |
| UIM | User Identity Module |
| UTRA | Universal Terrestrial Radio Access |
| UTRAN | Universal Terrestrial Radio Access Network |
| WG | Working Group |

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# Annex C: Individual member application form

**APPLICATION FORM**
for INDIVIDUAL MEMBERSHIP
of the THIRD GENERATION PARTNERSHIP PROJECT
Please complete this form and return it to your Organizational Partner

COMPANY NAME .....

Please indicate below which ORGANIZATIONAL PARTNER you are a member of

| | |
|---|---|
| ARIB | |
| CCSA | |
| ETSI | |
| ATIS | |
| TSDSI | |
| TTA | |
| TTC | |

Please indicate below which Technical Specification Groups you wish to participate in:

| | |
|---|---|
| Radio Access Network | |
| | |
| | |
| Core Network and Terminals | |
| Service and System Aspects | |
| GSM EDGE Radio Access Network (GERAN) | |

Upon your approval as an Individual Member of the Third Generation Partnership Project you agree that you will be bound by the Working Procedures of the Third Generation Partnership Project then in effect and as they may be amended from time to time.

| | |
|---|---|
| Signed by (Authorized Representative) (See Note 1) | |
| Print name | |
| Position | |
| Date | |
| Telephone | |
| Fax | |
| Email | |
| Company Website URL | |

| | |
|---|---|
| Contact person's family name (See Note 2) | |
| Contact person's given name | |
| Job title | |
| Mailing address | |
| Telephone | |
| Fax | |

| | |
|---|---|
| Email | |

Note 1: Is either the official contact person or voting contact of a company.

Note 2: People attending meetings and who can also have signing authority.

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# Annex D: (Void)

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# Annex E: Guidance for MRP applicants

## E.1 Introduction

The conditions for the acceptance of Market Representation Partners (MRPs) in 3GPP are given in article 7 of these Working Procedures. This annex provides additional guidance to MRP Applicants.

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## E.2 Guidance

During the application process, the Organizational Partners will need to be assured that an Applicant:

(a) Has a field of interest directly or indirectly related to the work being undertaken by 3GPP;

(b) Has attained a demonstrable level of recognition within this field of interest;

(c) Has an understanding of the market requirements relevant to 3GPP;

(d) Is willing to actively contribute to the work of 3GPP and has sufficient resources for this purpose;

(e) Fully supports the goals and objectives of 3GPP and does not take part in activities that conflict with these goals and objectives.

In processing an application, the Organizational Partners will peruse openly available documentation published by an Applicant, including material posted on its Website, in order to confirm that the points listed above have been satisfied.

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# Annex F: Guidance on meeting organization

## F.1 Meeting classification

TSG and WG Meetings are classified either:

- ordinary; or
- ad hoc.

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## F.2 Ordinary meetings

Ordinary meetings are ones where the regular business of the TSG or WG is conducted. Such meetings are normally chaired by the Group's Chair or, if unavailable, a Vice Chair. Ordinary meeting should be announced at least six months prior to the opening day of the meeting.

TSG and WG ordinary meetings shall follow an incrementing number sequence. If an additional ordinary meeting is required between two ordinary meetings, the sequence may be preserved, even though this means renumbering subsequent meetings, or the additional meeting may be numbered using the 'bis' suffix as a numbering scheme.

Attendance at an ordinary meeting counts towards an Individual Member's eligibility to cast a vote in the Group (see articles 26 and 27). The Support Team shall record the participation in an ordinary meeting (each person and organization represented) and the attendance list shall be included in the meeting report.

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## F.3 Ad hoc meetings

An ad hoc meeting of a WG or a TSG is one called to address one or more particular topics. The ad hoc meeting shall be called by decision of the WG (or its parent TSG) or TSG concerned; the decision to hold any subsequent ad hoc meetings on the same topic may be made by the ad hoc meeting participants themselves without reference to the parent WG or TSG, although the parent WG or TSG shall review any ad hoc activity at every Ordinary meeting and determine to either continue or to close the ad hoc activity, even if the previous ad hoc meeting suggested a further meeting. The scope of each subsequent ad hoc meeting shall be indicated by the Chair at least 21 days before the meeting. The ad hoc meeting shall not expand or change the scope originally determined by the parent group. An ad hoc meeting is allowed to make decisions only within its pre-defined remit, and any such decisions shall be ratified by the parent WG or TSG unless, in the case of a WG, a decision was previously explicitly delegated by the WG to the ad hoc meeting.

An ad hoc meeting may be chaired as described for an ordinary meeting above, or, with the agreement of the WG or TSG concerned, by a Work Item rapporteur, or other appropriate person. Although open to all 3GPP Individual Members, ad hoc meetings may attract only a subset of Individual Member representatives who would normally participate in ordinary meetings.

Ad hoc meetings shall not be considered when calculating voting rights. That is, attendance at (or absence from) an ad hoc meeting shall not influence voting rights, which are determined solely by attendance at "ordinary" meetings.

No voting shall occur at ad hoc meetings.

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# F.4 Attendance register

## F.4.1 Face to face meetings

A delegate is deemed to have attended a given meeting if the individual confirms their participation by signing the attendance list made available by the group's secretary during the meeting. If a delegate does not sign the attendance sheet during the meeting, the secretary shall assume that the individual did not attend.

A delegate, having registered and begun to participate in a meeting, is not allowed to change their represented organization during the course of that meeting. An individual delegate is not allowed to simultaneously represent two or more Individual Members at a meeting.

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## F.4.2 Electronic meetings

Electronic meetings such as audio / video conferences, email exchanges considered as meetings, etc, are encouraged where appropriate. For such events, the Secretary will establish the attendance list on the basis of those actually participating in the meeting (those dialling in to the conference bridge, those issuing and responding to emails, etc.) Nevertheless, advance registration is strongly encouraged.

Fully electronic meetings are to be considered as "ad hoc" as defined above.

Participation by Individual Member in fully electronic meetings, or electronic participation in a face to face meeting (eg by phoning in) is not considered for the accrual or loss of voting rights.

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# Annex G: Working agreements

"Working agreements" are tentative decisions reached by 3GPP groups in order to make progress on matters where consensus (as defined in annex A) cannot be reached. It is intended to be used in situations where there is a clear majority in favour of one approach, but a small minority has sustained opposition to that approach.

The working agreement process has the following steps:

- Consensus cannot be reached on an issue. A substantial majority of individual members prefer a given approach, but there is sustained opposition by a small minority of individual members, preventing consensus.
- The Chair declares a working agreement. The working agreement is documented in the meeting report
- The approach agreed to by the majority and documented in the working agreement can continue unimpeded.
- The working agreement is entered into the 3GPP working agreements page on the 3GPP web site. The window for challenging the working agreement is now open.
- Working agreements may be challenged, resulting in a formal vote. This potential vote would be held at the next meeting of the WG or parent TSG (whichever comes first). If the next meeting is less than 14 days after the establishment of the working agreement, then that meeting is skipped in determining the next meeting. The meeting for potential voting is documented on the 3GPP working agreements page of the 3GPP web site (http://www.3gpp.org/TSG-Working-Agreements).
- The challenge cut-off date is established. This is 7 days before the start of the meeting for potential voting. The cut-off date is documented on the 3GPP working agreements page of the 3GPP web site.
- Organizations wishing to challenge the working agreement may do so until the challenge window closes. A challenge may be made by informing the Chair of the group which will do the voting. Any received challenge is documented on 3GPP working agreements page of the 3GPP web site.
- The group which will be voting is informed of the intention to have a working agreement challenge vote and the specific voting question.
- If no challenge is received by the challenge cut-off date, then the working agreement is confirmed. The confirmation of the working agreement is documented on the 3GPP working agreements page of the 3GPP web site. The issue is closed.
- If a challenge is received, then a formal vote on the working agreement will occur at the designated meeting. If the draft agenda for the designated meeting has already been issued, then it will be updated to include the potential for voting on the working agreement. Voting is as described in articles 25, 26 and 32 of the working procedures with the exception that the requirement for quorum is waived.
- If the challenge fails (at least 71% in favour of the working agreement), then the working agreement is confirmed. The confirmation of the working agreement is documented on the 3GPP working agreements page of the 3GPP web site. The issue is closed.
- If the challenge succeeds (less than 71% in favour of the working agreement), then the working agreement fails. All changes which were made based on the working agreement shall be reversed and the group must continue to search for consensus. The overturning of the working agreement is documented on the 3GPP working agreements page of the 3GPP web site.
- Organizations may withdraw a challenge at any time in the process. If the last challenge is withdrawn after the challenge cut-off, then the working agreement is confirmed. The confirmation of the working agreement is documented on the 3GPP working agreements page of the 3GPP web site. The issue is closed.

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# Annex H: Calculation of quorum in TSGs and WGs

Where calculation of a quorum is required in the context of a vote conducted in a TSG or a WG, the quorum shall be deemed to have been met if:

$(B - P) / V >= Q$

Where:

B is the number of ballot papers issued;

P is the number of proxy votes exercised (i.e. the number of ballot papers issued to delegates bearing authorization to cast votes by proxy);

V is the number of Individual Members having the right to vote at the meeting (including those with only the right to vote “in person” and not by proxy);

Q is the required quorum value given in article 26.

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# Annex I: Special procedures for exceptional situations restricting travel

3GPP working procedures are designed around the concept of periodic face to face meetings. This is not always possible. This annex implements modifications to the working procedures intended to allow 3GPP to function in the absence of face to face meetings. The PCG has the responsibility of activating and deactivating this annex.

The following changes in the working procedures are in effect when this annex is activated:

## Article 14: PCG tasks

The following item shall be added to the list of PCG tasks:

- *maintenance of the voting and voting rights process integrity, to include disciplinary action if required.*

## Article 22: TSG and WG election of Chair and Vice Chairs

The following paragraph is removed from section 22.2

*If a WG does not meet physically with enough frequency to maintain an up to date voting list, the working group may elect to escalate the voting for officers to the parent TSG.*

## Article 26: TSG and WG voting during a meeting

The following additions to article 26 are in effect:

*If voting occurs in the context of an Electronic Meeting, then:*

- *Proxies are not allowed.*
- *Quorum does not apply.*
- *The voting period shall be a minimum of 18 consecutive hours excluding the period 12:00 UTC Friday to 11:59 UTC Monday which excludes Saturday and Sunday in every time zone. The use of 18:00 UTC to 12:00 UTC the next day is recommended for the voting period.*
- *The voting period shall commence no earlier than the start of the Electronic meeting and complete before the closure of the meeting. Voting for elections may exceptionally extend past the scheduled end of the meeting if additional rounds are required to complete the election of all open positions. Such elections are considered to be part of the meeting in which the elections started.*
- *The starting and closing times of the vote shall be clearly announced and disseminated to all on the principal TSG or WG membership mail exploder lists.*
- *The list of Voting Members (IMs that are eligible to vote) is as defined in article 35. Delegates vote on behalf of the IM under which they have registered, and only delegates checked in to the meeting may vote.*
- *If, in accordance with Article 25, the TSG or WG decides that a secret ballot is required, voting shall preserve the secrecy of the votes cast.*
- *A secure voting tool provided by the MCC shall be used for elections, and is also encouraged for other matters where voting is required.*

# Article 28: TSG or WG voting for the election of TSG or WG Chair and Vice Chair

The following new paragraph is added to the end of article 28:

*If an election is held during an electronic meeting, the voting shall use the voting procedures described in Article 26 as amended by this Annex.*

# Article 30: TSG and WG meetings

The following new paragraph is added after the 2nd paragraph of this article:

*Electronic meetings are encouraged where appropriate.*

# Article 30A: TSG and WG participation

The text in article 30A shall be replaced with:

*IMs wishing to progress work on topics in 3GPP are expected to participate in both face to face meetings and electronic meetings.*

*If a 3GPP IM is materially interested in a specific topic but is unable to participate in a meeting by sending a delegate, the IM is urged to engage the support of other IMs whose delegates will be present at the meeting to present its views. If this is not possible for any reason, the IM may advise the Chair of the situation and may provide documents supporting their position. The Chair may facilitate the introduction of these documents during the meeting and the record of the meeting can include the discussion and outcome. The option to engage the Chair is intended for exceptional situations. The Chair has the right to decline the request.*

# Article 32: TSG and WG meeting agenda

The following paragraph is added:

*The draft agenda shall indicate the start and end dates and times of the meeting. The draft agenda shall indicate if the meeting counts toward maintenance of voting rights.*

# Article 35: TSG and WG Voting Membership List

## 35.3 Established TSGs and WGs

The text in section 35.3 shall be replaced with:

*To qualify for the voting list it is necessary for at least one delegate of an Individual Member to fulfill the voting rights establishment provisions of article 35.4 for the group concerned, without being removed according to the provisions of article 35.4.*

*An individual member having attained voting rights according to clause 35.4 has the right to cast a vote by proxy (see article 26). Thus, an Individual Member may not cast a vote by proxy during a meeting at which it is not represented unless it had already attained voting rights as described in clause 35.4.*

## 35.4 Removal from and instatement to voting list

The word *reinstatement* in the title of section 35.4 shall be replaced by *instatement*

The text in section 35.4 shall be replaced with:

*An Individual Member shall be removed from the voting list when either of the following happens:*

1. *The Individual Member is not represented at three consecutive face to face ordinary meetings of the group (TSG or WG),*
2. *The Individual Member is not represented in two consecutive ordinary meetings of the group (TSG or WG) of which at least one is electronic*

*The right to vote shall be instated or reinstated for an Individual Member at either of the following events:*

1. *the second face to face ordinary meeting which a delegate of the Individual Member attends without missing the number of consecutive face to face ordinary meetings mentioned in the previous paragraph,*
2. *the third consecutive ordinary meeting which a delegate of the Individual Member attends*

*Note: See article 35.3 for eligibility to cast a proxy vote.*

*EXAMPLE 1:* *If Individual Member Z is represented at face to face ordinary meeting K and K+3 (and is thus eligible to vote) but is not represented at face to face ordinary meetings K+4, K+5 and K+6, it is removed from the voting list.*

*EXAMPLE 2:* *If Individual Member X, not previously having been represented at an face to face ordinary meeting of the group, is represented at face to face ordinary meetings N and N+3, it may cast a vote at face to face ordinary meeting N+3.*

*NOTE:* *Individual Member X might choose to cast a vote by proxy at face to face ordinary meeting N+3, even though its delegate is physically present. This is sometimes useful for coordinating company positions where one large company has several Individual Memberships, possibly via several different Organizational Partners.*

*EXAMPLE 3:* *If Individual Member Y, not previously having been represented at a meeting of the group, is represented at ordinary meeting N only, it may not cast a vote by proxy at ordinary meeting N+2.*

*EXAMPLE 4:* *If Individual Member A is represented at electronic ordinary meetings N, N+1, and N+2 (and is thus eligible to vote) but is not represented at electronic ordinary meetings N+3 and N+4, it is removed from the voting list.*

*EXAMPLE 5:* *If Individual Member B, not previously having been represented at an ordinary meetings of the group, is represented at electronic ordinary meetings N, N+1, and N+2, it may cast a vote at electronic ordinary meeting N+2.*

## 35.5 (Void)

The contents of this section shall be struck and the heading replaced with VOID.

The following subclause is added to Article 35:

## *35.6 OP Voting Rights Hardship Exemption*

*For an IM belonging to an OP that has a voting rights hardship exemption for a given meeting, then missing the meeting is not counted in the voting rights algorithm. (In other words, for that IM, it is treated as though the meeting did not occur). If an IM covered by a voting rights hardship exemption for voting rights does attend the meeting, then it is counted as normal attendance.*

*If an IM covered by voting rights hardship exemption misses a meeting, there will be a permanent record (e.g., in the relevant meeting report) to note the list of IMs who have the voting rights hardship exemption for that meeting, and the voting rights list will also indicate the voting rights hardship exemption for the relevant meeting.*

*Voting rights hardship exemptions are granted on a per OP, per meeting basis.*

# Annex A: Definitions

The following 4 definitions are added:

| | |
|---|---|
| *Ad hoc Meeting* | *A meeting called to address one or more particular topics that is not an ordinary meeting (see F.3)* |
| *Electronic meeting:* | *A electronic meeting is one where all the participants connect to the meeting using electronic means such as audio/video conference, email, etc.* |
| *Face to face meeting:* | *A face to face meeting, also referred to as a physical meeting, is one held at a designated physical location where participants are invited to attend in person.* |
| *Ordinary Meeting* | *A meeting where the ordinary business of a group is conducted (see F.2).* |

# Annex F: Guidance on meeting organization

The title of Annex F shall be changed to Guidance on TSG and WG meeting Organization

## F.2 Ordinary meetings

The contents of clause F.2 shall be replaced with the following:

*Ordinary meetings are ones where the regular business of the TSG or WG is conducted. Such meetings are normally chaired by the Group's Chair or, if unavailable, a Vice Chair. Ordinary meetings should be announced at least six months prior to the opening day of the meeting. An ordinary meeting may be held as a face to face meeting or as an electronic meeting.*

*TSG and WG ordinary meetings shall follow an incrementing number sequence. If an additional ordinary meeting is required between two ordinary meetings, the sequence may be preserved, even though this means renumbering subsequent meetings, or the additional meeting may be numbered using the 'bis' suffix as a numbering scheme. Ordinary meetings that are held electronically shall be designated with an 'e' suffix.*

*Attendance at an ordinary meeting counts towards an Individual Member's eligibility to cast a vote in the Group (see articles 26 and 27). The Support Team shall record the participation in an ordinary meeting (each person and organization represented) and the attendance list shall be included in the meeting report.*

*If a meeting is designated as face to face, provisions to support remote participation (e.g. by using additional audio/video capabilities) would be at the discretion of the host and leadership. In a meeting designated as face to face, those participating remotely are not to be counted toward quorum or attendance, and are not allowed to vote.*

*Following each ordinary meeting, the Support Team shall publish a list of IMs that have gained or lost voting rights at that meeting.*

## F.3 Ad hoc meetings

The contents of clause F.3 shall be replaced with the following:

*An ad hoc meeting of a WG or a TSG is one called to address one or more particular topics. An ad hoc meeting may be held as a face to face or as an electronic meeting. The ad hoc meeting shall be called by decision of the WG (or its parent TSG) or TSG concerned; the decision to hold any subsequent ad hoc meetings on the same topic may be made by the ad hoc meeting participants themselves without reference to the parent WG or TSG, although the parent WG or TSG shall review any ad hoc activity at every Ordinary meeting and determine to either continue or to close the ad hoc activity, even if the previous ad hoc meeting suggested a further meeting. The scope of each subsequent ad hoc meeting shall be indicated by the Chair at least 21 days before the meeting. The ad hoc meeting shall not expand or change the scope originally determined by the parent group. An ad hoc meeting is allowed to make decisions only within its pre-defined remit, and any such decisions shall be ratified by the parent WG or TSG unless, in the case of a WG, a decision was previously explicitly delegated by the WG to the ad hoc meeting.*

*An ad hoc meeting may be chaired as described for an ordinary meeting above, or, with the agreement of the WG or TSG concerned, by a Work Item rapporteur, or other appropriate person. Although open to all 3GPP Individual Members, ad hoc meetings may attract only a subset of Individual Member representatives who would normally participate in ordinary meetings.*

*Ad hoc meetings shall not be considered when calculating voting rights. That is, attendance at (or absence from) an ad hoc meeting shall not influence voting rights, which are determined solely by attendance at "ordinary" meetings.*

*No voting shall occur at ad hoc meetings.*

## F.4 Attendance Register

The contents of clause F.4 (and subclauses) shall be replaced with the following:

*A delegate is deemed to have attended a given meeting if the individual confirms their participation by checking in. If a delegate does not check in during the meeting, the secretary shall assume that the individual did not attend. Checking in must be performed between the start and end of the meeting. In addition, the check in process shall clearly inform the delegate that 'Checking in carries the responsibility for participating in relevant parts of the meeting'.*

*A delegate, having registered and checked in to a meeting, is not allowed to change their represented organization during the course of that meeting. An individual delegate is not allowed to simultaneously represent two or more Individual Members at a meeting.*

### F.4.1 (void)

### F.4.2 (void)

# Annex G: Working agreements

The following changes to Annex G are in effect:

*Challenge votes may be conducted at Electronic meetings provided they are Ordinary meetings.*

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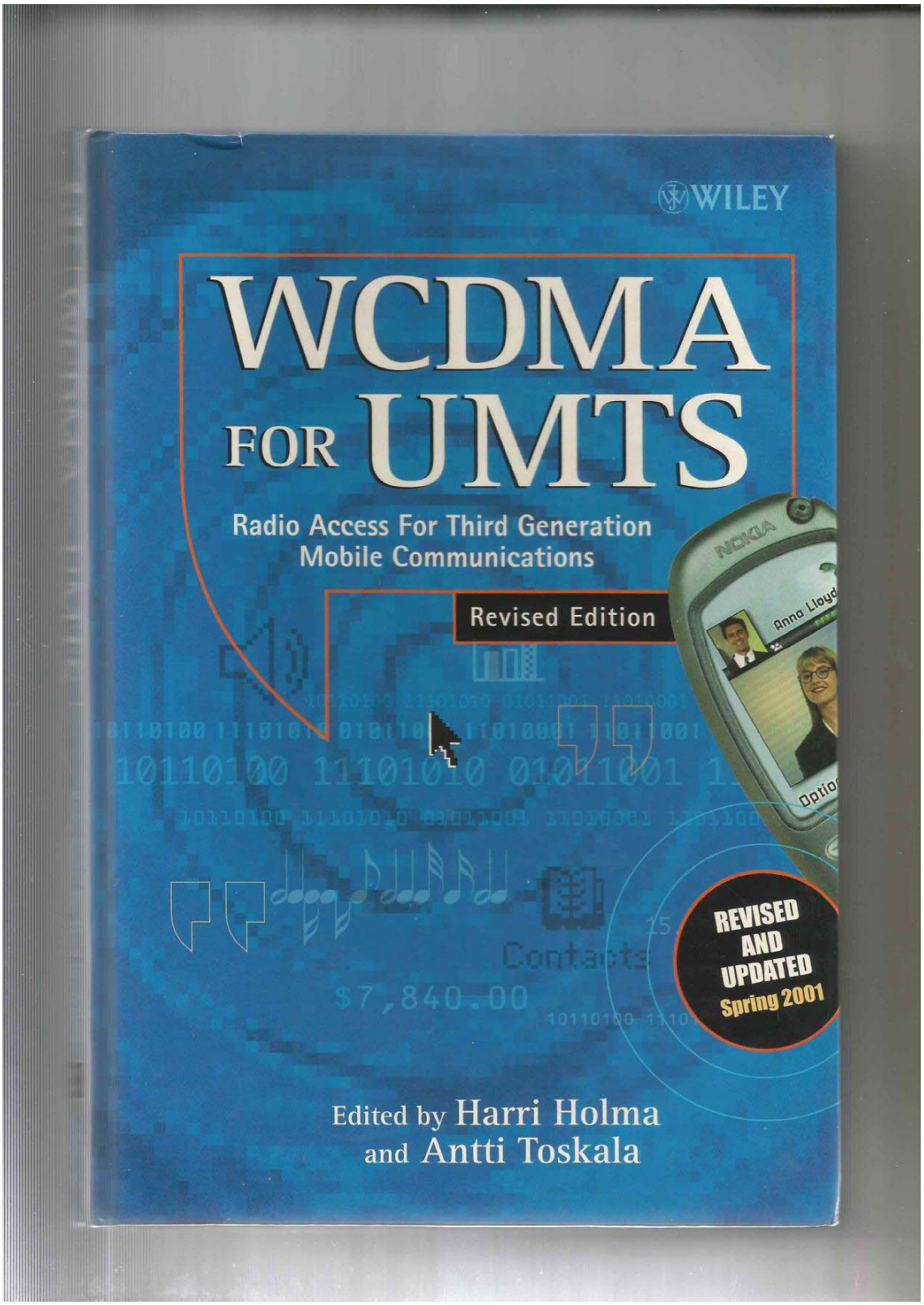
# Annex J: Change history

| Date | PCG # | PCG Doc. | CR | Rev | Subject/Comment |
|---|---|---|---|---|---|
| 2002-04-25 | 6 | | | | |
| 2005-03-01 | 13 | | | | Changes agreed at PCG meeting incorporated. [No formal change control system yet in place] |
| 2006-04-24 | 16 | PCG16_07 | 2 | | ETSI proposal: Article 10<br>Clarify the rights of observers and guests |
| | | | 3 | | ETSI proposal: Article 15<br>To allow leeway in the number of delegates representing each OP at PCG<br>(To reflect the decision already taken by PCG#14 on PCG participation) |
| | | | 9 | | ETSI proposal: Article 34<br>To cater for current TSG structure and to reflect common practice of Tdoc numbering |
| | | | 1 | 1 | Article 3<br>Reflect decision on regional options<br>(To incorporate PCG#7 decision) |
| | | | 4 | 1 | Article 22<br>Clarification and codification of the rights to stand for elected positions in TSGs and WGs |
| | | | 8 | | Article 30 & annex F<br>Inclusion of an annex giving guidance on meeting organization |
| 2006-10-27 | 17 | PCG17_15 r1 | 10 | | Article 35<br>Clarification of voting rights |
| 2009-05-18 | 22 | PCG22_18 | 11 | 5 | Changes resulting from the OP ad hoc group on improvements report and conclusions of OP#20.<br>Articles affected:<br>22<br>23<br>31<br>35<br>41<br>52<br>Annex D<br>plus sundry spelling corrections. |
| | | PCG22_19 | 12 | 2 | Rules on eligibility to cast votes at TSG and WG level. |
| | | PCG22_20 | 13 | | Bring statement of purpose of 3GPP up to date |
| | | PCG22_23 | 14 | | Adding Working Agreements to working procedures |
| | | PCG22_30 r3 | 15 | 3 | Change of ITU liaison process<br><br>Note: PCG meeting #22 approved contribution PCG22_30r1 but this was subsequently revised to r3 after the meeting with the apparent approval of the PCG. |
| | | | | | Decision PCG22/11: clause 22.1 changed wording from "in the March time frame in" to "in the first semester of". |
| 2009-08-12 | | | | | Editorial correction to implementation of CR15r3. (article 52). |
| 2010-04-23 | 24 | PCG24_11 | 16 | | TSG vs WG election |
| | | PCG24_12 | 17 | | Quorum |
| | | PCG24_13 | 18 | | Communication with ITU |
| | | PCG24_25 | 19 | | Attendance register for meetings |
| 2012-10-24 | | PCG29_17 | 20 | | Update to 3GPP Working Procedures article 22 |
| 2014-07-22 | 33 | PCG33_10 | 21 | | Anti-trust / competition law requirements<br>articles 12, 17, 22.1, 23, 29, 59A, annex C |
| 2014-12-31 | 34 | PCG34_14 | 22 | | Anti-trust recommendations v1.1. |
| | | | | | Addition of TSDSI to list of OPs in annexes B and C.<br><br>Minor formatting and spelling corrections, consistent capitalization. |

| | | | | | |
|---|---|---|---|---|---|
| 2016-11-15 | 35 | PCG37_14 | 23 | | Article 22.1<br>Modification to clarify obligation on elected officials regarding antitrust/competition law training. |
| 2019-08-22 | 42 | (none) | 24 | | Article 55<br>Correction of text to reflect actual practice.<br><br>Note: Decision taken by email in response to Action PCG42/7. |
| 2019-08-23 | 42 | PCG42_18 | 25 | | Article 22.2<br>Adds text allowing WGs which meet infrequently to escalate elections of their officials to the parent TSG.<br><br>Article 25<br>Adds text allowing WGs which meet infrequently to escalate technical votes to the parent TSG.<br><br>Article 30A (new)<br>Introduces procedures for situations where an IM is unable to send a delegate in person to a meeting but nevertheless wishes to contribute to the proceedings.<br><br>Secretary's note 1:<br>Annex B<br>Added abbreviation 'IM', though this was not included in PCG42_18.<br><br>Secretary's note 2:<br>Corrected the CR numbers in the previous two change history entries. |
| 2020-02-07 | 43 | PCG43_14 | | | Annex G: Removal of the statement that voting on working agreements was to be a standard element of every meeting agenda. Addition of a reference to article 32. Removal of the requirement for a quorum during voting on working agreements. |
| 2020-05-15 | 44 | | | | Addition of "crisis annex" |
| 2020-09-30 | 45 | PCG45_11 | | | Update to 3GPP Working Procedures Annex I ("crisis annex") |
| 2021-04-29 | 46 | PCG46_20 | | | Decision PCG46/09:<br>Gender Neutrality Changes<br><br>Annex I<br>Change minimum voting window from 24 to 18 hours |
| 2022-03-07 | 48 | PCG48_12 | | | Voting Rights pCR to Annex I |
| 2022-03-07 | 48 | PCG48_13 | | | Hardship Exemption pCR to Annex I |
| 2022-09-01 | 49 | - | | | Working Procedures P-CR for Registration |

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# Appendix 6


WILEY
WCDMA
FOR UMTS
Radio Access For Third Generation
Mobile Communications
Revised Edition
NOKIA
Anna Lloyd
REVISED
AND
UPDATED
Spring 2001
Edited by Harri Holma
and Antti Toskala

# WCDMA FOR UMTS

Radio Access For Third Generation Mobile Communications

Revised edition

Edited by
**Harri Holma and Antti Toskala**
*Both of Nokia, Finland*

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in which at least two trees are planted for each one used for paper production.

### 4.5.3 *cdma2000*

The cdma2000 air interface proposal to ITU is the result of work in TR45.5 on the evolution of IS-95 towards the third generation. The cdma2000 proposal is based partly on IS-95 principles with respect to synchronous network operation, common pilot channels, and so on, but it is a wideband version with three times the bandwidth of IS-95. The ITU proposal contains further bandwidth options as well as the multi-carrier option for downlink. The cdma2000 proposal has a high degree of commonality with the Global CDMA 1 ITU proposal from TTA, Korea.

The cdma2000 multi-carrier option is covered in more detail in Chapter 13, as being currently standardised by 3GPP2.

### 4.5.4 *TR46.1*

The WIMS W-CDMA was not based on work derived from an existing second generation technology but was a new third generation technology proposal with no direct link to any second generation standardisation. It was based on the constant processing gain principle with a high number of multicodes in use, thus showing some fundamental differences but also a level of commonality with WCDMA technology in other forums.

### 4.5.5 *WP-CDMA*

WP-CDMA (Wideband Packet CDMA) resulted from the convergence between W-CDMA N/A of T1P1 and WIMS W-CDMA of TR46.1 in the US. The main features of the WIMS W-CDMA proposal were merged with the principles of W-CDMA N/A. The merged proposal was submitted to the ITU-R IMT-2000 process towards the end of 1998, and to the 3GPP process at the beginning of 1999. Its the most characteristic feature, compared with the other WCDMA-based proposals, was a common packet mode channel operation for the uplink direction, but there were also a few smaller differences.

## 4.6 Creation of 3GPP

As similar technologies were being standardised in several regions around the world, it became evident that achieving identical specifications to ensure equipment compatibility globally would be very difficult with work going on in parallel. Also, having to discuss similar issues in several places was naturally a waste of resources for the participating companies. Therefore initiatives were made to create a single forum for WCDMA standardisation for a common WCDMA specification.

The standardisation organisations involved in the creation of the 3rd Generation Partnership Project (3GPP) [9] were ARIB (Japan), ETSI (Europe), TTA (Korea), TTC (Japan) and T1P1 (USA) as shown in Figure 4.2. The partners agreed on joint efforts for the standardisation of UTRA, now standing for Universal Terrestrial Radio Access, as distinct from UTRA (UMTS Terrestrial Radio Access) from ETSI, also submitted to 3GPP. Companies such as manufacturers and operators are members of 3GPP through the respective standardisation organisation to which they belong.

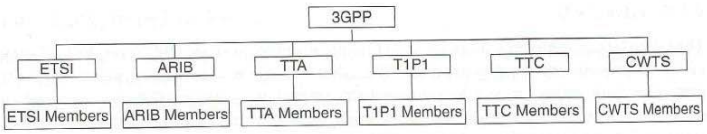



**Figure 4.2.** 3GPP organisational partners

Later during 1999, CWTS (the China Wireless Telecommunication Standard Group) also joined 3GPP and contributed technology from TD/SCDMA, a TDD-based CDMA third generation technology already submitted to ITU-R earlier.

3GPP also includes market representation partners: GSM Association, UMTS Forum, Global Mobile Suppliers Association, IPv6 Forum and Universal Wireless Communications Consortium (UWCC). In [9] there are up-to-date links to all participating organisations.

The work was initiated formally at the end of 1998 and the detailed technical work was started in early 1999, with the aim of having the first version of the common specification, called Release-99, ready by the end of 1999.

Within 3GPP, four different technical specification groups (TSG) were set up as follows:

- Radio Access Network TSG
- Core Network TSG
- Service and System Aspects TSG
- Terminals TSG

Within these groups the one most relevant to the WCDMA technology is the Radio Access Network TSG (RAN TSG), which has been divided into four different working groups as illustrated in Figure 4.3.

The RAN TSG will produce Release-99 of the UTRA air interface specification. The work done within the 3GPP RAN TSG working groups has been the basis of the technical description of the UTRA air interface covered in this book. Without such a global initiative, this book would have been forced to focus on a single regional specification, though with many similarities to those of other regions. Thus the references throughout this book are to the specification volumes from 3GPP.

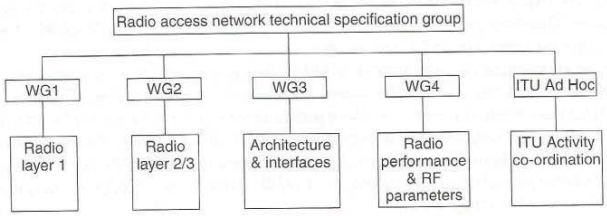



**Figure 4.3.** 3GPP RAN TSG working groups

During the first half of 1999 the inputs from the various participating organisations were merged in a single standard, leaving the rest of the year to finalise the detailed parameters for the first full release, Release-99, of UTRA from 3GPP. The member organisations have undertaken individually to produce standard publications based on the 3GPP specification. Thus, for example, the Release-99 UMTS specifications from ETSI are identical to the Release-99 specifications produced by 3GPP. The latest specifications can be obtained from 3GPP [9].

During 2000, further work on GSM evolution was moved from ETSI and other forums to 3GPP, including work on GPRS and EDGE. A new TSG, TSG GERAN was set up for this purpose.

## 4.7 Creation of 3GPP2

Work done in TR45.5 and TTA was merged to form 3GPP2, focused on the development of cdma2000 Direct-Sequence (DS) and Multi-Carrier (MC) mode for the cdma2000 third generation component. This activity has been running in parallel with the 3GPP project, with participation from ARIB, TTC and CWTS as member organisations. Recently the main concentration has been on the MC mode work, due to decisions resulting from the global harmonisation efforts.

## 4.8 Harmonisation Phase

During the spring of 1999 several operators and manufacturers held series of meetings to seek further harmonisation and convergence between the CDMA-based third generation solutions, WCDMA and cdma2000. For the 3GPP framework the ETSI, ARIB, TTA and T1P1 concepts had already been merged to a single specification, while cdma2000 was still on its own in TR45.5. As a result of several meetings and telephone conferences, the manufacturers and operators agreed to adopt a harmonised global third generation CDMA standard consisting of three modes: Multi-Carrier (MC), Direct Spread (DS) and Time Division Duplex (TDD). The MC mode was based on the cdma2000 multi-carrier option, the DS mode on WCDMA (UTRA FDD), and the TDD mode on UTRA TDD. The agreement was to phase in a modular approach in which both core networks could be used with all air interface alternatives, as described in Figure 1.4 in Chapter 1.

The main technical impacts of these harmonisation activities were the change of UTRA FDD and TDD mode chip rate from 4.096 Mcps to 3.84 Mcps and the inclusion of a common pilot for UTRA FDD. The work in 3GPP2 focused on the MC mode, and the DS mode from cdma2000 was abandoned. The result is that globally there is only one Direct Spread (DS) wideband CDMA standard, WCDMA.

## 4.9 IMT2000 Process in ITU

In the ITU, recommendations have been developed for third generation mobile communications systems, the ITU terminology being called IMT-2000 [10], formerly FPLMTS. In the ITU-R, ITU-R TG8/1 has worked on the radio-dependent aspects, while the radio-independent aspects have been covered in ITU-T SG11.

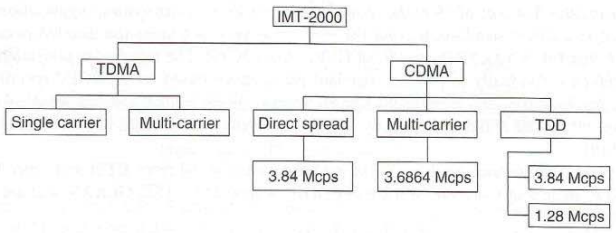



**Figure 4.4.** ITU-R IMT-2000 grouping

In the radio aspects, ITU-R TG8/1 received a number of different proposals during the IMT-2000 candidate submission process. In the second phase of the process, evaluation results were received from the proponent organisations as well as from the other evaluation groups that studied the technologies. During the first half of 1999 recommendation IMT.RKEY was created which describes the IMT-2000 multimode concept.

The ITU-R IMT-2000 process was finalised at the end of 1999, when the detailed specification (IMT-RSCP) was created and the radio interface specifications were approved by ITU-R [11]. The detailed implementation of IMT-2000 will continue in the regional standards bodies. The ITU-R process has been an important external motivation and timing source for IMT-2000 activities in regional standards bodies. The requirements set by ITU for an IMT-2000 technology have been reflected in the requirements in the regional standards bodies, for example in ETSI UMTS 21.01 [5], in order for the ETSI submission to fulfil the IMT-2000 requirements. The ITU-R interaction between regional standardisation bodies in the IMT-2000 process is reflected in Figure 4.5.

The ITU-R IMT-2000 grouping, with TDMA- and CDMA-based groups, is illustrated in Figure 4.4. The UTRA FDD (WCDMA) and cdma2000 are part of the CDMA interface, as CDMA Direct Spread and CDMA Multi-Carrier respectively. UWC-136 and DECT are part of the TDMA-based interface in the concept, as TDMA Single Carrier and TDMA Multi-Carrier respectively. The TDD part in CDMA consists of UTRA TDD from 3GPP and TD-SCDMA from CWTS. For the FDD part in the CDMA interface, harmonisation has been completed, and the harmonisation process is expected to continue for the CDMA TDD mode within 3GPP during 2000 and 2001.

## 4.10 Beyond 3GPP Release-99

Upon completion of the Release-99 specifications, work will concentrate on specifying new features as well as making the necessary corrections to Release-99. Typically such corrections arise as implementation proceeds and test systems are updated to include the latest changes in the specifications. As experience in various forums has shown, a major step forward in system capabilities with many new features requires a phasing-in period for the specifications. Fortunately, the main functions have been verified in the various test systems in operation since 1995, but only the actual implementation will reveal any errors and inconsistencies in the fine detail of the specifications.

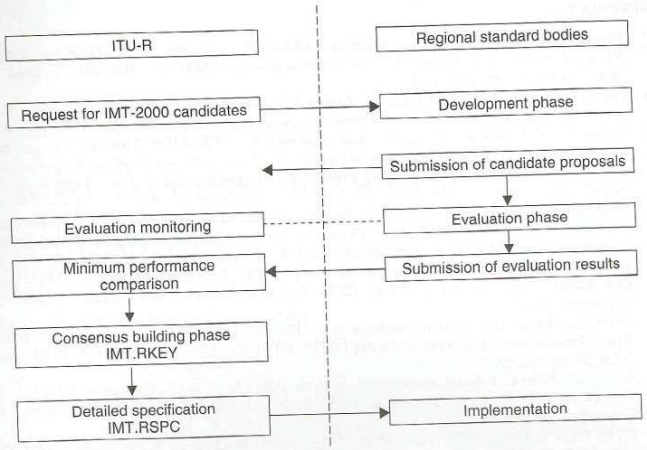



**Figure 4.5.** Relationship of ITU-R to the regional standards bodies

In 3GPP the next version of the specifications was originally considered as Release 2000, but since that the Release naming was adjusted so that next release is called Release 4 due to the 03/2001. Release 4 will contain only minor adjustment with respect to the Release'99. Bigger items are foreseen for inclusions in Release 5, including reaching for the data rates even up to the 10 Mbps in the downlink direction. Release 5 is due for the end of 2001. Release'99 specifications have a version number starting with 3 while Release 4 and 5 specifications have version number starting logically with 4 and 5 respectively.

During coming years, part of the process is to specify the extensions for connecting UTRA FDD to IS-41 based core networks. Work will be carried out on cdma2000 to allow connection to GSM-based core networks. This development will offer operators some degree of flexibility in selecting their third generation technology, assuming they are not aiming to launch such a service immediately, since Release-99 does not yet contain these options.

On the TDD side, further alignment is expected between the TDD mode in UTRA and the TDD mode from CWTS (China). This process is expected to continue after Release-99 is completed in 3GPP. 3GPP Release-4 is also planned to cover the lower chip rate (1.28 Mcps) TDD.

Other interesting developments are expected in the area of using IP based technology in UTRA. First step is going to be the IP based transport option in Release 4 and further releases are likely to see IP technology shaping the internal architecture of the UTRA Network (UTRAN). Also some of the protocols developed by the Internet Engineering Task Force (IETF) [12], such as robust IP header compression suitable for cellular transmission, are foreseen to be adopted as part the UTRA Rel'4 specifications.

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[2] Nikula, E., Toskala, A., Dahlman, E., Girard, L., and Klein, A., 'FRAMES Multiple Access for UMTS and IMT-2000', *IEEE Personal Communications Magazine*, April 1998, pp. 16–24.

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[5] Universal Mobile Telecommunications System (UMTS), Requirements for the UMTS Terrestrial Radio Access System (UTRA), ETSI Technical Report, UMTS 21.01 version 3.0.1, November 1997.

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[7] Universal Mobile Telecommunications System (UMTS), UMTS Terrestrial Radio Access System (UTRA) Concept Evaluation, ETSI Technical Report, UMTS 30.06 version 3.0.0, December 1997.

[8] ETSI Press Release, SMG Tdoc 40/98, 'Agreement Reached on Radio Interface for Third Generation Mobile System, UMTS', Paris, France, January 1998.

[9] http://www.3GPP.org

[10] http://www.itu.int/imt/

[11] ITU Press Release, ITU/99–22, 'IMT-2000 Radio Interface Specifications Approved in ITU Meeting in Helsinki', 5 November 1999.

[12] http://www.ietf.org

# Appendix 7

# MCC Activity Report

Source

Adrian Scrase

# Contents

- Departures and Arrivals
- Resource Allocation
- Workload
- 3GPP Membership
- 3G Ultimate Project
- Summary and Outlook

# Departures and Arrivals

Adrian Zoicas retired from ETSI as of February 2015

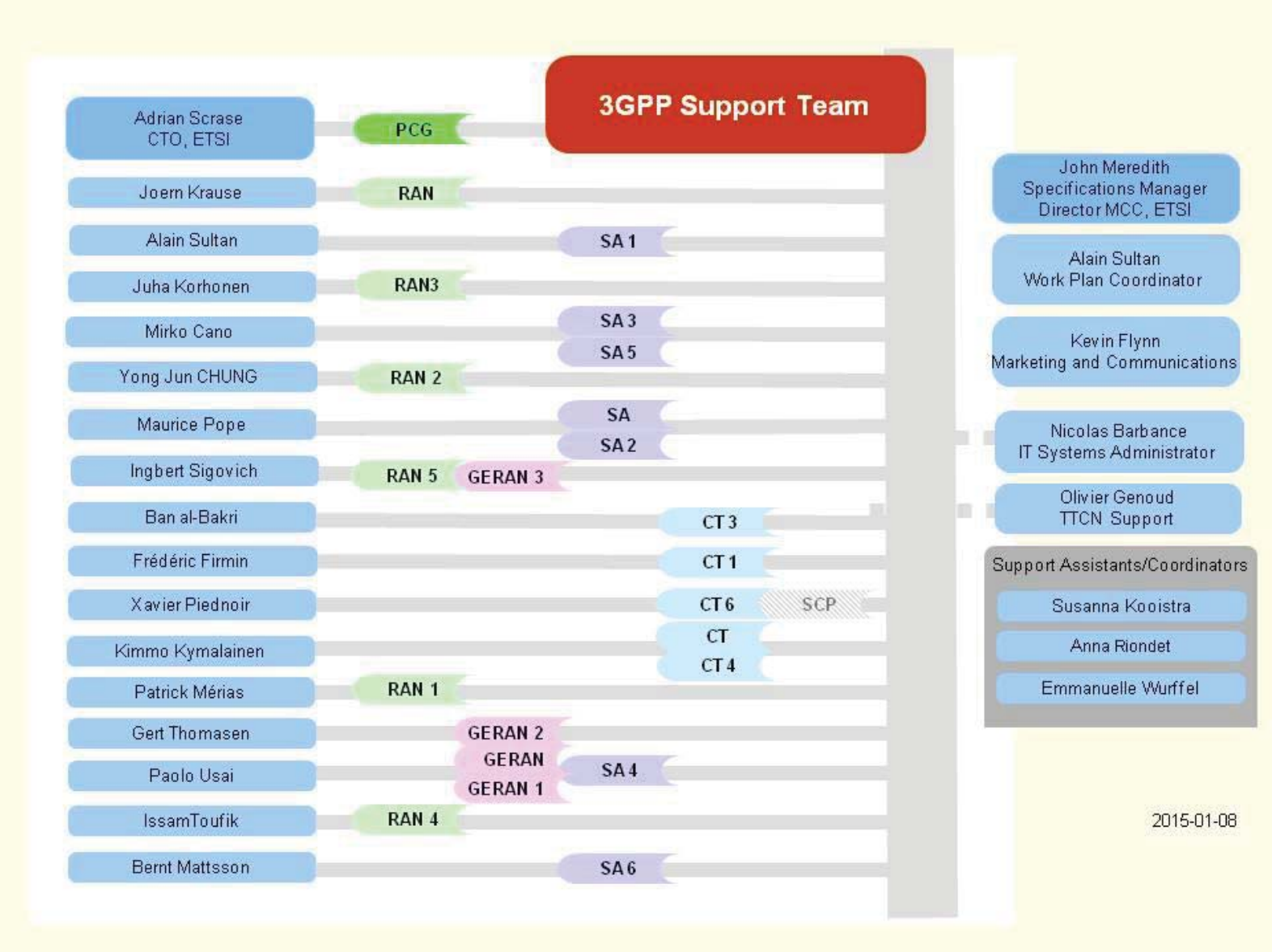


He has been temporarily replaced by Ban Al Bakri who will support CT3 until end April 2015



A more permanent solution for CT3 support is being pursued

# Current Resource Allocation



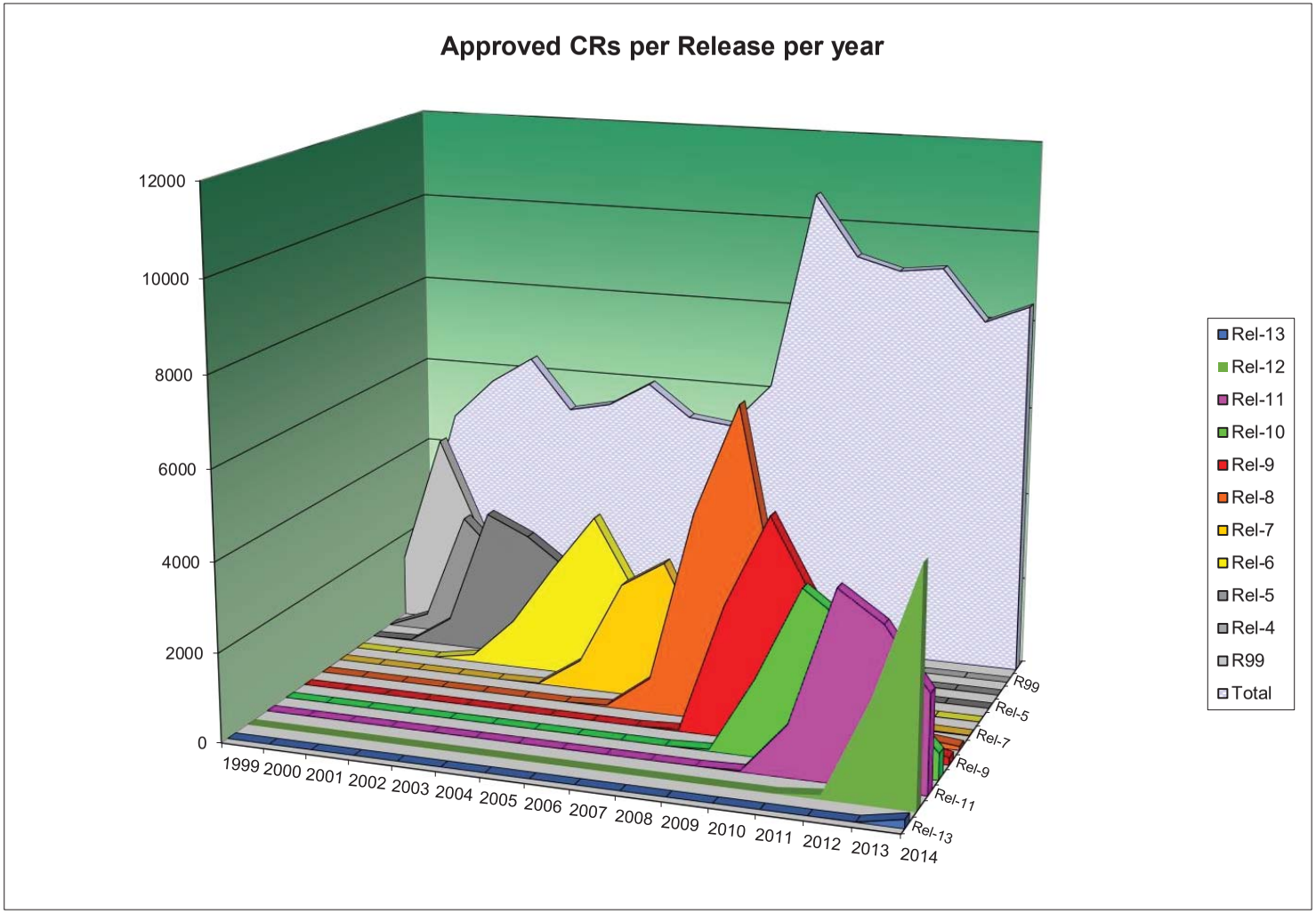
# Workload

## Approved CRs per Release per Year

| Release | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R99 | 1408 | 4398 | 2266 | 1004 | 581 | 512 | 111 | 42 | 23 | 5 | 5 | 1 | 0 | | | | **10356** |
| Rel-4 | | 376 | 2828 | 1900 | 690 | 257 | 122 | 63 | 48 | 22 | 20 | 13 | 11 | 8 | 7 | 2 | **6367** |
| Rel-5 | | 27 | 644 | 3274 | 2842 | 2162 | 1357 | 509 | 94 | 25 | 22 | 7 | 7 | 5 | 3 | 2 | **10980** |
| Rel-6 | | | | 172 | 1088 | 2458 | 3721 | 2074 | 1078 | 212 | 74 | 19 | 17 | 10 | 4 | 4 | **10931** |
| Rel-7 | | | | | 1 | 20 | 663 | 2529 | 3132 | 1262 | 492 | 176 | 91 | 43 | 25 | 15 | **8449** |
| Rel-8 | | | | | | | | 49 | 777 | 4609 | 7073 | 2347 | 706 | 347 | 184 | 91 | **16183** |
| Rel-9 | | | | | | | | | | 49 | 2918 | 4991 | 3252 | 1366 | 376 | 165 | **13117** |
| Rel-10 | | | | | | | | | | | 47 | 1722 | 3800 | 3103 | 1636 | 584 | **10892** |
| Rel-11 | | | | | | | | | | | | 32 | 1152 | 4178 | 3525 | 2186 | **11073** |
| Rel-12 | | | | | | | | | | | | | 6 | 102 | 2254 | 5181 | **7543** |
| Rel-13 | | | | | | | | | | | | | | | 8 | 200 | **208** |
| Total | **1408** | **4801** | **5738** | **6350** | **5202** | **5409** | **5974** | **5266** | **5152** | **6184** | **10651** | **9308** | **9042** | **9162** | **8022** | **8430** | 106099 |

# Workload

## Approved CRs per Release per Year

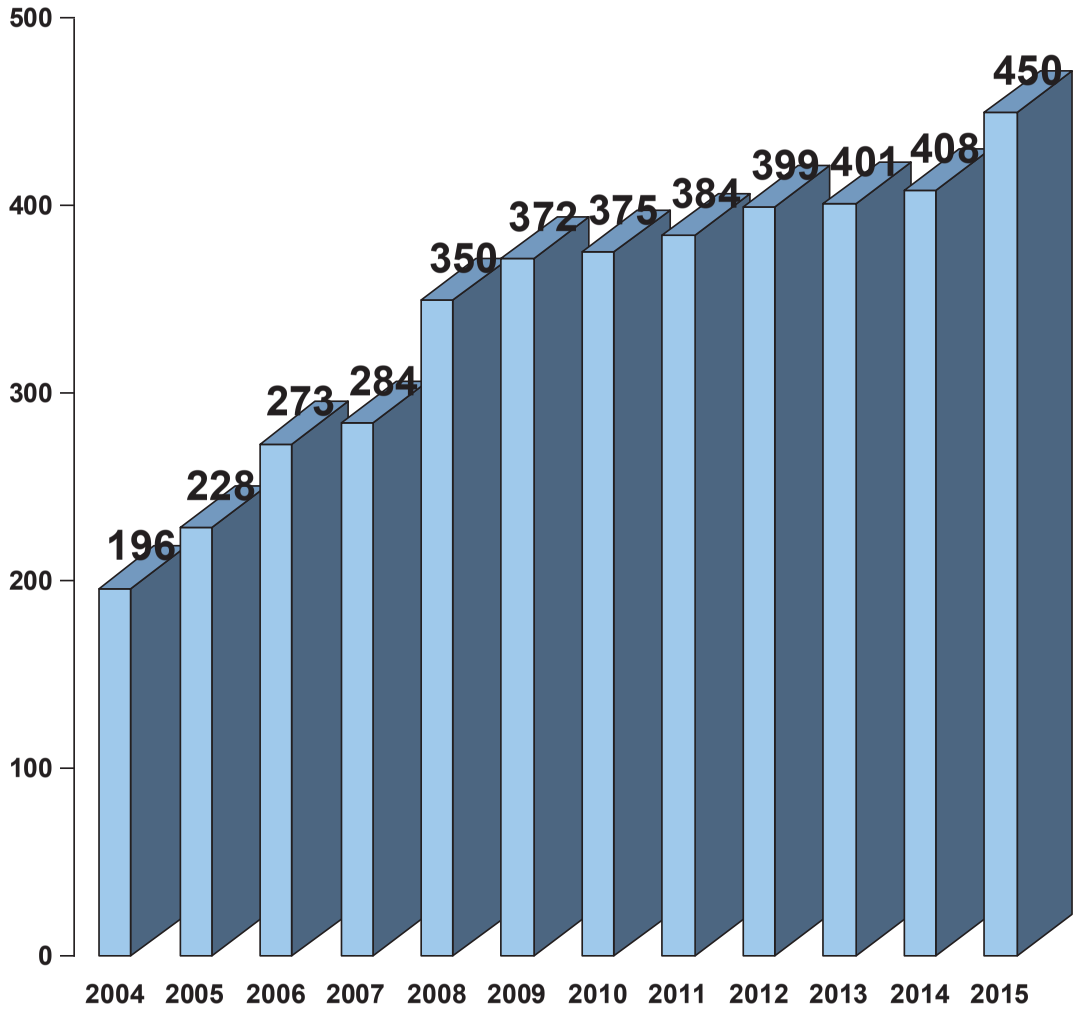


# 3GPP Membership

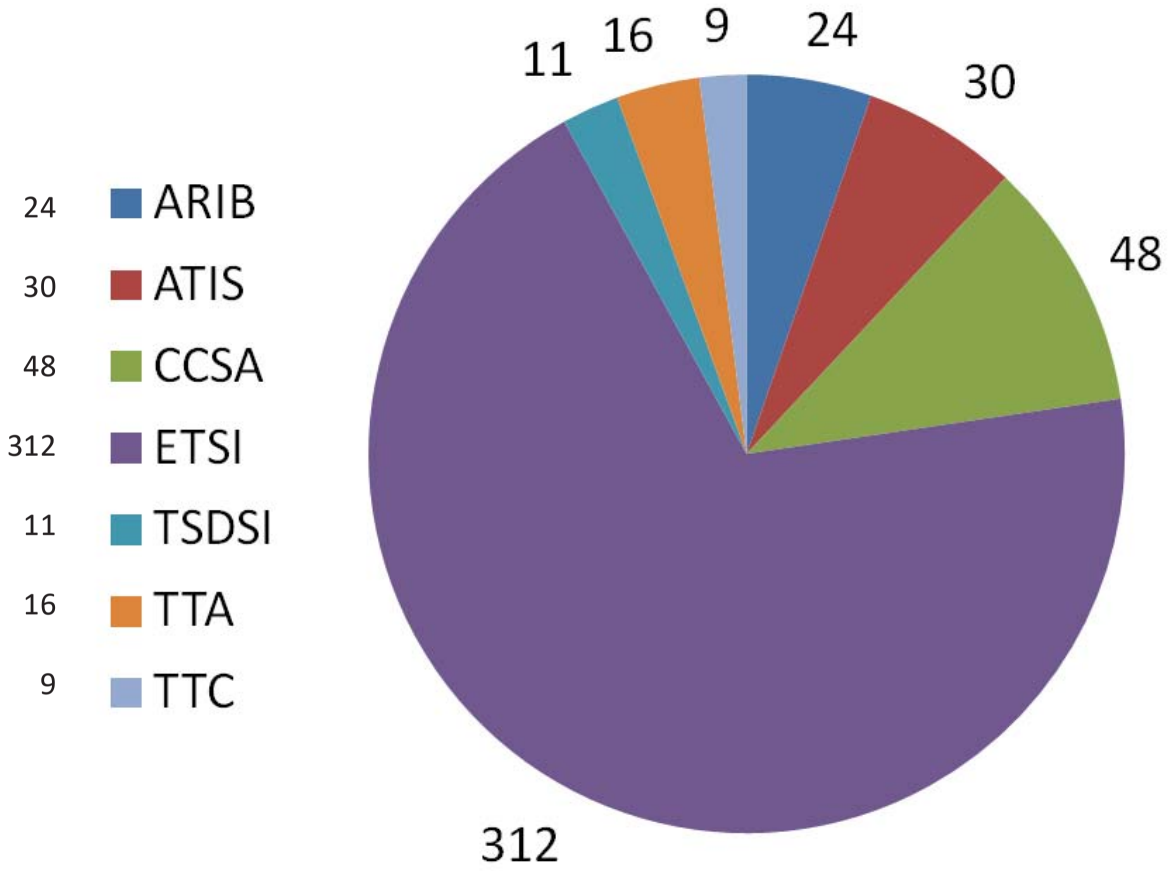
3GPP Membership has peaked in 2015 with *450* Individual Members. In addition, there are 23 companies having Guest Status, which are potential IMs

Number of Individual Members in 3GPP

3GPP Individual Members come from 41 Countries worldwide



# Individual Members in 3GPP

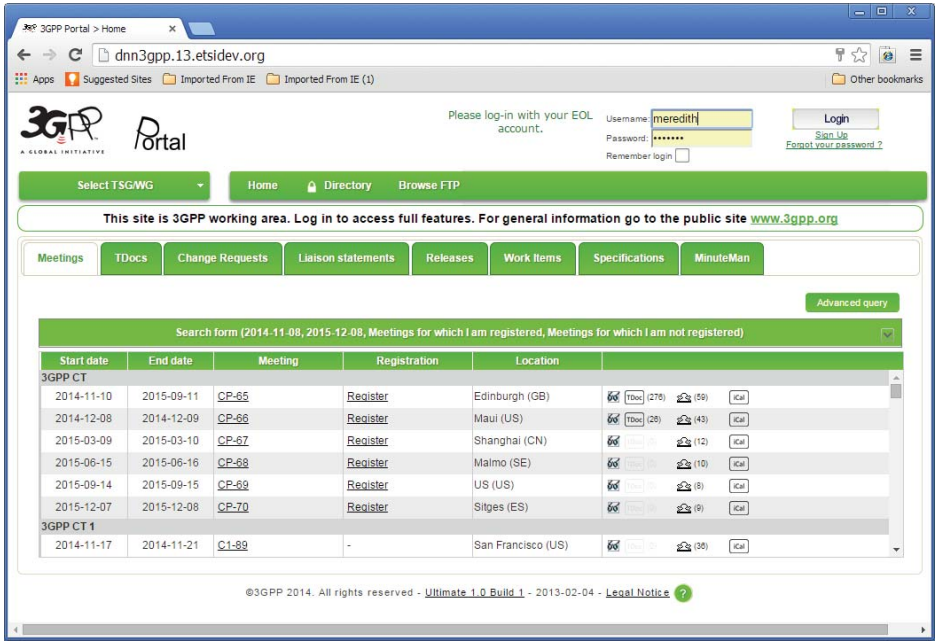


# 3GPP Ultimate Project (3GU)

Data import from the old databases to the 3GPP Ultimate portal occurred in early January 2015. The 3GU database is now the master source for specs and releases. Over the coming months, 3GU will be the prime source of progressively more data. At present, the 3GPP web site http://www.3gpp.org and the 3GU portal http://portal.3gpp.org both offer information on meetings, specifications, tdocs, CRs, etc, and both should be aligned.

Several WGs (e.g., RAN1, SA1, SA6, CT3, CT4, CT6) plus CT plenary have used 3GU for TDoc number allocation, and though some bugs have been reported, the feedback from MCC secretaries and delegates alike has been generally very positive. We expect all groups to be using 3GU by 2015 Q3,

*" Our experience of using 3GU tool for allocating and uploading the tdocs has been very impressive. Even dozens of tdocs were uploaded all together in just few seconds. This has saved many hours of our effort that in the past was needed for uploading tdocs via the old ADN! So this is really a big improvement in efficiency. "*



# Summary and Outlook

The number of IMs within 3GPP continues to grow and the advent of 5G work is likely to add to that increase. This will change the dynamics within the project over time.

The workload within 3GPP is relatively constant although there is a slight increase in the number of physical meetings.

Discussions on the organizational structure within 3GPP continue (*cf* RAN/GERAN) and this will be monitored to ensure that support resources are always commensurate with the project structure.

Improvements in 3GPP tooling are well underway and the effectiveness of these tools will become more apparent towards the end of 2015.

# Appendix 8

# The 3G IP Multimedia Subsystem (IMS)

## Merging the Internet and the Cellular Worlds

Gonzalo Camarillo and Miguel A. García-Martín

Both of
*Ericsson, Finland*



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# Chapter 2

# The History of the IMS Standardization

In Chapter 1 we mentioned that the IMS uses Internet protocols. When the IMS needs a protocol to perform a particular task (e.g., to establish a multimedia session), the standardization bodies standardizing the IMS take the Internet protocol intended for that task and specify its use in the IMS. Still, no matter how simple this may sound the process of choosing protocols to be used in the IMS can sometimes get tricky. Sometimes, the Internet protocol that is chosen lacks some essential functionality, or does not even exist at all. When this happens the IMS standardization bodies contact the standardization body developing Internet protocols to work together on a solution. We will cover this collaboration in Section 2.5. Nevertheless, before jumping into that we will introduce in Section 2.1 all the standardization bodies involved in IMS development. We need to know who is who and which functions of the IMS each of them performs.

## 2.1 Relations between IMS-related Standardization Bodies

The ITU (International Telecommunication Union) IMT-2000 (International Mobile Telecommunications-2000) is the global standard for 3G (third generation) networks. IMT-2000 is the result of the collaboration between different standards bodies and aims at providing access to telecommunication services using radio links, which include satellite and terrestrial networks.

We will focus on two of the standard bodies involved in IMT-2000: 3GPP (Third Generation Partnership Project) and 3GPP2 (Third Generation Partnership Project 2). Still, they are not the only ones working within IMT-2000. Other bodies, such as the ITU-R (ITU-Radiocommunication Sector), for instance, are also involved in IMT-2000 but on different areas than the IMS.

Both 3GPP and 3GPP2 have standardized their own IMS (IP Multimedia Subsystem). The 3GPP IMS and the 3GPP2 IMS are fairly similar, but, nevertheless, have a few differences (Appendix A lists the most important differences).

An important similarity between the 3GPP IMS and the 3GPP2 IMS is that both use Internet protocols, which have been traditionally standardized by the IETF (Internet Engineering Task Force). Consequently, both 3GPP and 3GPP2 collaborate with the IETF in developing protocols that fulfill their requirements. The following sections introduce the IETF, 3GPP, and 3GPP2 and provide a brief history of the IETF-3GPP/3GPP2 collaboration.

In addition to the standard bodies we have just mentioned, OMA (Open Mobile Alliance [144]) will play an important role in developing IMS services in the near future. While 3GPP and 3GPP have standardized (or are standardizing) a few IMS services, such as basic video calls or conferencing, from now on OMA will focus on service standardization for the IMS (of course, other standard bodies and third parties besides OMA may also develop services for the IMS).

## 2.2 Internet Engineering Task Force (IETF)

The Internet Engineering Task Force (IETF) is a loosely self-organized collection of network designers, operators, vendors, and research institutions that work together to develop the architecture, protocols, and operation of the public Internet. The IETF is body that is open to any interested individual. The IETF is not a corporation and, therefore, does not have a board of directors, members, nor dues.

The IETF is the standardization body that has developed most of the protocols that are currently used on the Internet. The IETF does not standardize networks, architectures combining different protocols, the internal behaviour of nodes, nor APIs (Application Programming Interface). The IETF is the protocol factory for IP-related protocols.

### 2.2.1 Structure of IETF

Work in the IETF is organized in working groups. Each working group is chartered to perform specific tasks, such as the delivery of a precise set of documents. Each working group has from one to three chairs, who take care that the working group completes its chartered tasks in time. Working groups have a temporary lifetime; so, once they have delivered their documents, either they are rechartered or they cease to exist. Figure 2.1 shows a few, but not all, of the working groups in the IETF; there are more than 100 active working groups in the IETF. The complete up-to-date list of active working groups is available at:

`http://www.ietf.org/html.charters/wg-dir.html`

Working groups get an acronym name that identifies the chartered task. For instance, SIPPING is the acronym of "Session Initiation Protocol Investigation", SIMPLE is the acronym of "SIP for Instant Messaging and Presence Leveraging Extensions" or AAA for "Authentication, Authorization and Accounting".

A collection of working groups form an Area Directorate. There are currently eight areas, as illustrated in Figure 2.1.

Each area has one or two area directors who, together with the IETF chairman, form the IESG (Internet Engineering Steering Group). The IESG is the technical

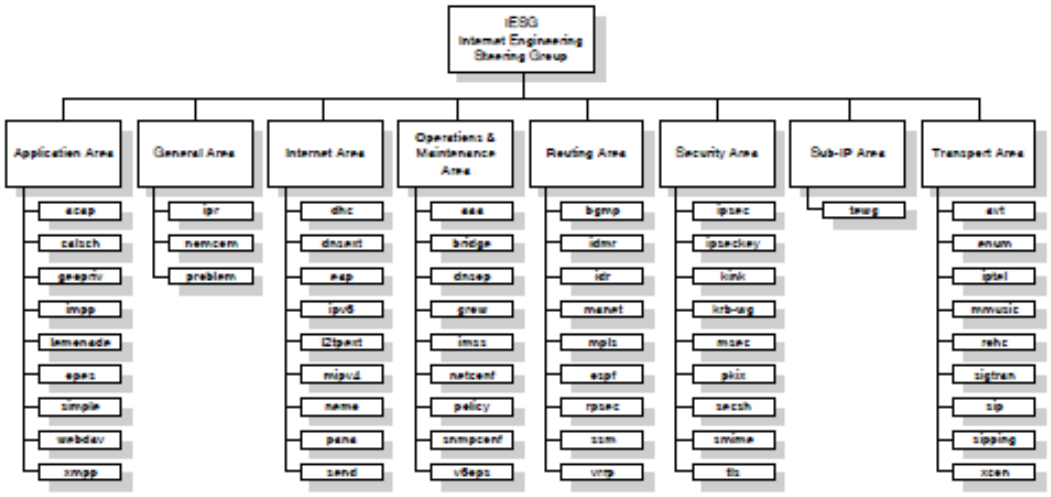



Figure 2.1: The structure of the IETF

management team of the IETF. They decide on which areas the IETF should work and review all the specifications that are produced.

The following web pages contain the complete list of the working groups of all areas and the charter of the SIPPING working group respectively.

```
http://www.ietf.org/html.charters/wg-dir.html
http://www.ietf.org/html.charters/sipping-charter.html
```

The IAB (Internet Architecture Board) is the body that provides technical leadership and handles appeals. Its web page is:

```
http://www.iab.org/
```

### 2.2.2 Working Group Operations

The technical work in the IETF is done within the working groups. Working groups do not have any kind of membership; they are formed by a number of volunteers that work as individuals. That is, they do not represent their companies when working for the IETF.

Most of the technical discussions within a working group take place in its mailing list. Even the decisions made at face-to-face meetings (held three times a year) have to be confirmed in the mailing list.

The technical documents used within the working groups are called Internet-Drafts. There are two types of them: individual submissions and working group items. Individual submissions are technical proposals submitted by an individual or individuals. If the working group decides that an individual submission is a good starting point to work on a particular topic, it becomes a working group item.

Individual submissions and working group items can be distinguished by the name of the file where they are stored. Individual submissions start with:

```
draft-author's_name
```

while working group items start with:

```
draft-ietf-name_of_the_working_group
```

A list of all the Internet-Drafts can be found at:

```
http://www.ietf.org/internet-drafts/
```

When a working group feels that a working group item is ready for publication as an RFC the working group chairs send it to the IESG. The IESG may provide feedback to the working group (e.g., ask that working group to change something in the draft) and, eventually, decides whether or not a new RFC is published.

Although most of the Internet-Drafts that the IESG receives come from working groups an individual may also submit an Internet-Draft to the IESG. This usually happens with topics that are not large enough to grant the creation of a working group, but which, nevertheless, are of interest to the Internet community.

It is important to note that Internet-Drafts, even if they are working group items, represent work in progress and should only be referenced as such. Internet-Drafts are temporary documents that expire and cease to exist six months after they are issued. They can change at any time without taking into consideration backward compatibility issues with existing implementations. Only when a particular Internet-Draft becomes an RFC can it be considered a stable specification.

### 2.2.3 Types of RFCs

The technical documents produced by the IETF are called RFCs (Request For Comments). According to the contents of the document there are three main types of RFCs:

- Standards-track RFCs.
- Non-standards-track RFCs.
- BCP (Best Current Practise) RFCs.

Standards-track RFCs typically define protocols and extensions to protocols. According to the maturity of the protocol there are three levels of standards-track RFCs: proposed standard, draft standard, and Internet standard. Standards-track specifications are supposed to advance from proposed to draft and, finally, to Internet standard as they get more and more mature. An important requirement in this process is that a particular specification is implemented by several people to show that different independently built implementations that follow the same specification can successfully interoperate.

Nevertheless, in practise only a few RFCs reach the draft standard level and even fewer become Internet standards. At present, the specifications of many protocols that are used massively on the Internet are proposed standards.

There are three types of non-standards-track RFCs: experimental, informational, and historical (which are called *historic* RFCs). Experimental RFCs specify protocols with a very limited use, while informational RFCs provide information for the Internet community about some topic, such as a requirements document or a process. When a standards-track RFC becomes obsolete, it becomes a historic RFC.

BCP RFCs record the best current practise known to the community to perform a particular task. They may deal with protocol issues or with administrative issues.

Figure 2.2 shows the relations between all the RFC types. A list of all the RFCs published so far and their status can be fetched from:

`http://www.ietf.org/iesg/1rfc_index.txt`

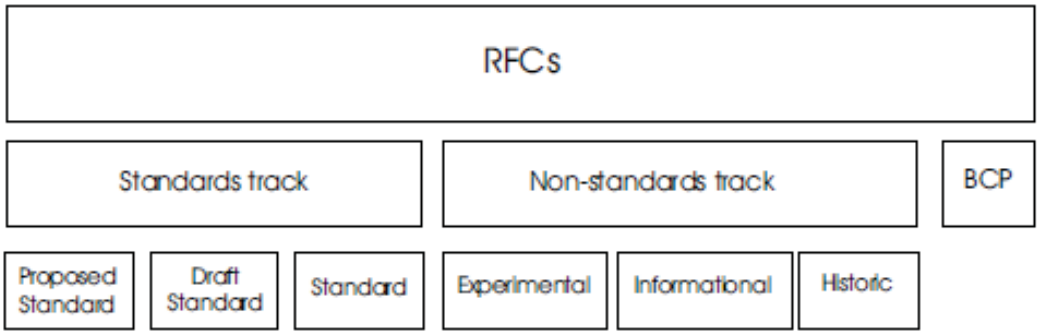



Figure 2.2: RFC types

RFCs can be downloaded from the following web page by just introducing the RFC number:

`http://www.ietf.org/rfc.html`

Additionally, the RFC Editor offers a web page that allows us to search for RFCs by title, number, author and keywords:

`http://www.rfc-editor.org/rfcsearch.html`

## 2.3 Third Generation Partnership Project (3GPP)

The Third Generation Partnership Project (3GPP) was born in 1998 as a collaboration agreement between a number of regional telecommunication standard bodies, known as *organizational partners*. The current 3GPP organizational partners are:

1. ARIB (Association of Radio Industries and Business) in Japan,

   `http://www.arib.or.jp/english/`

2. CCSA (China Communications Standards Associations) in China,

   `http://www.ccsa.org.cn/english/`

3. ETSI (European Telecommunications Standards Institute) in Europe,

   `http://www.etsi.org/`

4. Committee T1 in the United States of America,

   `http://www.t1.org/`

5. TTA (Telecommunications Technology Association) of Korea

   `http://www.tta.or.kr/English/`

6. TTC (Telecommunication Technology Committee) in Japan,

   `http://www.ttc.or.jp/e/`

3GPP was originally chartered to develop globally applicable Technical Specifications and Technical Reports for a third-generation mobile system based on GSM. The scope has been reinforced to include maintenance and development of GSM specifications including the supported and evolved radio networks, technologies, and packet access technologies.

Besides the organizational partners, *market representation partners* provide the partnership with market requirements. Market representation partners include, among others, the UMTS Forum, 3G Americas, the GSM Association, the Global mobile Suppliers Association, the TD-SCDMA Forum, and the IPv6 Forum.

3GPP maintains an up-to-date web site at:

`http://www.3gpp.org/`

### 2.3.1 3GPP Structure

3GPP is organized in a Project Co-ordination Group (PCG) and Technical Specification Groups (TSGs), as illustrated in Figure 2.3. The PCG is responsible for the overall management of 3GPP, time plans, allocation of work, etc. The technical work is produced in the TSGs. At the moment there are five TSGs, responsible for the Core Network (CN), System and Services Aspects (SA), GSM EDGE Radio Access Network (GERAN), Radio Access Network (RAN), and Terminals (T). Each of the TSGs is further divided into Working Groups. Each of the Working Groups is allocated particular tasks. For instance, CN WG1 is responsible for all the detailed design of the usage of SIP and SDP in the IMS, CN WG3 for interworking aspects and CN4 for all the detailed design of the usage of Diameter. SA WG1 is responsible for the requirements, SA2 for the architecture, SA WG3 for the security aspects, SA WG4 for the codecs, and SA WG5 for the operation and maintenance of the network.

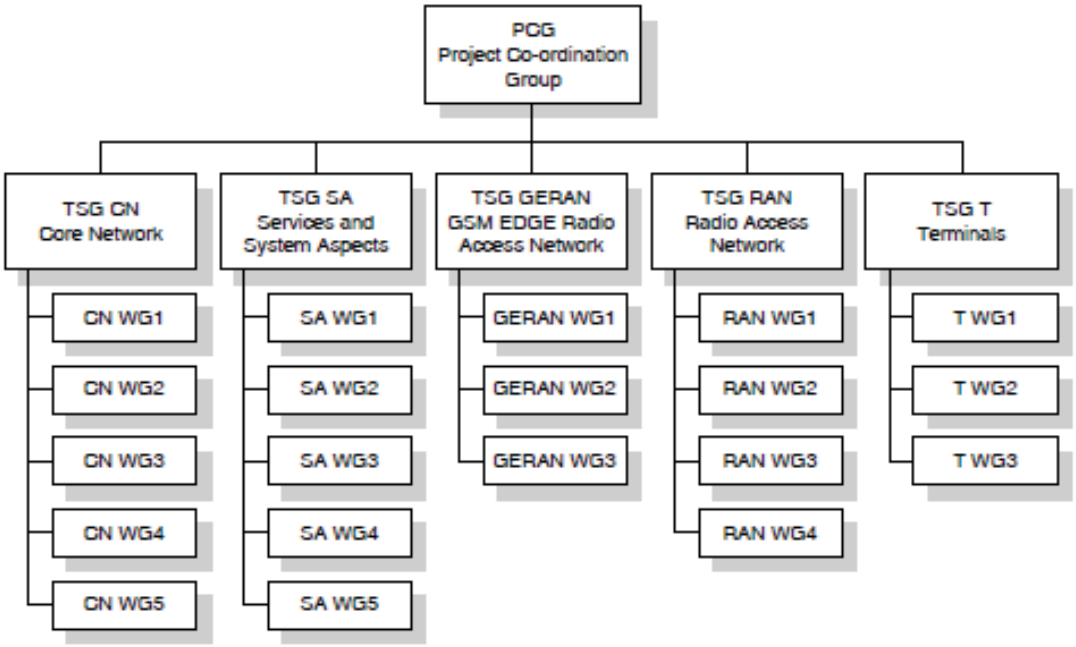



Figure 2.3: The structure of 3GPP

### 2.3.2 3GPP Deliverables

3GPP working groups do not produce standards. Instead, they produce Technical Specifications (TS) and Technical Reports (TR) that are approved by the TSGs. Once approved they are submitted to the organizational partners to be submitted to their respective standardization processes. The final part of the process is in the organizational partners' hands when they approve the TSs or TRs as part of their standards procedures. As a result, there is a set of globally developed standards that are ready to be used in a particular region.

3GPP TSs and TRs are numbered according to the sequence of four or five digits that follow the pattern "xx.yyy". The first two digits "xx" identify the series number, and the last two or three digits "yy" or "yyy" identify a particular specification within a series. For instance, 3GPP TS 23.228 [21] describes the architectural aspects of the IMS.

3GPP groups its specifications in what is called a *Release*. 3GPP Release 5 contains the first version of the IMS. 3GPP Release 6 contains enhancements to the IMS. The reader must note that the IMS is just a fraction of the 3GPP deliverables in a particular Release, as there are other non-IMS specifications included in a 3GPP Release. 3GPP TSs and TRs include a version number that follows the pattern "x.y.z", where "x" represents the 3GPP Release where the specification is published, "y" is the version number, and "z" is a sub-version number. So, 3GPP TS 23.228 version 5.8.0 means version 8.0 of the Release 5 version of TS 23.228.

3GPP TSs and TRs are publicly available at the 3GPP web site at either of the following URIs:

`http://www.3gpp.org/specs/specs.htm`

`http://www.3gpp.org/ftp/Specs/archive/`

## 2.4 Third Generation Partnership Project 2 (3GPP2)

If 3GPP was born to evolve GSM specifications into a third-generation cellular system, the Third Generation Partnership Project 2 (3GPP2) was born to evolve North American and Asian cellular networks based on ANSI/TIA/EIA-41 standards and CDMA2000© radio access into a third-generation system. 3GPP2 like 3GPP is a partnership project whose members are also known as *organizational partners*. The current list of organizational partners include ARIB (Japan), CCSA (China), TIA (Telecommunications Industry Association) (North America), TTA (Korea), and TTC (Japan). Probably, the reader has noticed that most of them are also organizational partners of 3GPP.

Like 3GPP, 3GPP2 gets market requirements and advice from *market representation partners*. At the moment the list includes the IPv6 Forum and the CDMA Development Group.

### 2.4.1 3GPP2 Structure

The 3GPP2 structure mimics the structure of 3GPP, as illustrated in Figure 2.4. A Steering Committee (SC) is responsible for the overall standardization process and the planning. The technical work is done in Technical Specification Groups (TSGs). TSG-A is focused on the Access Network Interface, TSG-C on CDMA2000© technology, TSG-S on Service and System Aspects, and TSG-X in Intersystems Operations. TGS-X was born as a merger between the former TSG-N (Core Networks) and TSG-P (Packet Data) TSGs. The structure of TSN-X is not completely defined yet.

### 2.4.2 3GPP2 Deliverables

Like 3GPP, 3GPP2 does not produce standards but, instead, Technical Specifications (TSs) and Technical reports (TRs). The documents are created by the TSGs and approved by the SC. Then, they are submitted to the organizational partners to be submitted to their respective standardization processes.

3GPP2 TSs and TRs are numbered with a sequence of letters and digits that follows the scheme "A.Bxxxx-yyy-R" where "A" is a letter that represents the name of the TSG that delivers the document, "B" can be an "R" letter to indicate a TR or a requirements document, but it can also be an "S" letter to indicate a TS. "xxxx" is a sequential number allocated to the document. An optional "yyy" sequence of digits can further identify the chapter within a specification series. The "R" letter identifies the revision. The version number follows the specification and indicates a major and

# Appendix 9

# 3GPP MEMBERSHIP

2024-02-19 Version 1.1

New Query

**Selected categories:**

- **Individual Members (all partners)**

Choose csv separator : , export to csv file

## INDIVIDUAL MEMBERS

| Organization | Country | Partner |
|---|---|---|
| **3in**<br>**(Industrial Internet Innovation Center (Shanghai) Co.,Ltd.)** | CHINA | CCSA |
| **450connect GmbH**<br>**(450connect GmbH)** | GERMANY | ETSI |
| **A.S.T.R.I.D. SA/NV**<br>**(A.S.T.R.I.D. SA)** | BELGIUM | ETSI |
| **ABP, NRTA**<br>**(Academy of Broadcasting Planning, NRTA)** | CHINA | CCSA |
| **ABS**<br>**(Academy of Broadcasting Science)** | CHINA | CCSA |
| **AccelerComm Ltd**<br>**(AccelerComm Ltd)** | UNITED KINGDOM | ETSI |
| **Acer Incorporated**<br>**(Acer Incorporated)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **adare GmbH**<br>**(adare GmbH)** | GERMANY | ETSI |
| **Airbus**<br>**(Airbus DS SLC)** | FRANCE | ETSI |
| **albis-elcon system GermanyGmbH**<br>**(albis-elcon system Germany GmbH)** | GERMANY | ETSI |
| **Alibaba (China) Group., Ltd.**<br>**(Alibaba (China) Group., Ltd.)** | CHINA | CCSA |
| **Allot Ltd**<br>**(Allot Ltd)** | ISRAEL | ETSI |
| **Altan Redes S.A.P.I. de C.V.**<br>**(Altan Redes S.A.P.I. de C.V.)** | MEXICO | ETSI |
| **Amazon Web Services**<br>**(Amazon Web Services EMEA SARL)** | LUXEMBOURG | ETSI |
| **Amdocs Software Systems Ltd**<br>**(Amdocs Software Systems Limited)** | IRELAND | ETSI |
| **Analog Devices, Inc.**<br>**(Analog Devices, Inc.)** | UNITED STATES | ATIS |
| **Anemone Technology**<br>**(Anemone Technology)** | DENMARK | ETSI |
| **Anritsu Corporation**<br>**(ANRITSU CORPORATION)** | JAPAN | ARIB |
| **Anritsu EMEA Ltd**<br>**(Anritsu EMEA Ltd)** | UNITED KINGDOM | ETSI |
| **Anterix**<br>**(Anterix)** | UNITED STATES | ATIS |
| **Apple**<br>**(Apple Purchase Operation management)** | CHINA | CCSA |
| **Apple (Guizhou)**<br>**(Apple Technology Services (Guizhou) Ltd.)** | CHINA | CCSA |

| | | |
|---|---|---|
| **Apple (UK) Limited**<br>**(Apple (UK) Limited)** | UNITED KINGDOM | ETSI |
| **Apple (Ulanqab)**<br>**(Apple Technology Services (Ulanqab) Ltd)** | CHINA | CCSA |
| **Apple AB Denmark**<br>**(Apple AB, filial AF Apple Aktiebolag, Sverige)** | DENMARK | ETSI |
| **Apple Benelux B.V.**<br>**(Apple Benelux B.V.)** | NETHERLANDS | ETSI |
| **Apple Benelux B.V. - Belgium**<br>**(Apple Benelux B.V. - Belgium Branch)** | BELGIUM | ETSI |
| **Apple Computer Trading Co. Ltd**<br>**(Apple Computer Trading (Shanghai) Co., Ltd.)** | CHINA | CCSA |
| **Apple Distribution Intl Ltd**<br>**(Apple Distribution International Limited)** | IRELAND | ETSI |
| **Apple France**<br>**(Apple France)** | FRANCE | ETSI |
| **Apple GmbH**<br>**(Apple GmbH)** | GERMANY | ETSI |
| **Apple Inc**<br>**(Apple Inc)** | UNITED STATES | ATIS |
| **Apple R&D**<br>**(Apple R&D)** | CHINA | CCSA |
| **Apple Solutions**<br>**(Apple Solutions Consulting Services (Beijing) Company Limited)** | CHINA | CCSA |
| **Apple Switzerland AG**<br>**(Apple Switzerland AG)** | SWITZERLAND | ETSI |
| **Apple Trading**<br>**(Apple Trading (Shanghai) Company Limited)** | CHINA | CCSA |
| **AQSACOM S.A.S.**<br>**(AQSACOM S.A.S.)** | FRANCE | ETSI |
| **Arriver Software AB**<br>**(Arriver Software AB)** | SWEDEN | ETSI |
| **ARTICLE19**<br>**(ARTICLE19)** | UNITED KINGDOM | ETSI |
| **ASELSAN**<br>**(ASELSAN Inc.)** | TÜRKIYE | ETSI |
| **AsiaInfo**<br>**(AsiaInfo Technologies (China), Inc.)** | CHINA | CCSA |
| **AsiaInfo Technologies Inc**<br>**(AsiaInfo Technologies Inc)** | CHINA | ETSI |
| **ASR**<br>**(ASR Microelectronics Co., Ltd.)** | CHINA | CCSA |
| **ASTRI**<br>**(Hong Kong Applied Science & Technology Research Institute)** | HONG KONG | ETSI |
| **Astrome Technologies Pvt Lt**<br>**(Astrome Technologies Pvt Lt)** | INDIA | TSDSI |
| **ASUSTEK COMPUTER (SHANGHAI)**<br>**(ASUSTEK COMPUTER (SHANGHAI) CO. LTD.)** | CHINA | CCSA |
| **AT&T**<br>**(AT&T)** | UNITED STATES | ATIS |
| **AT&T GNS Belgium SPRL**<br>**(AT&T Global Network Services Belgium SPRL)** | BELGIUM | ETSI |
| **AT&T Labs, Inc**<br>**(AT&T Labs, Inc)** | UNITED STATES | ATIS |
| **AT&T Services, Inc.**<br>**(AT&T Services, Inc.)** | UNITED STATES | ATIS |
| **ATEME**<br>**(ATEME SA)** | FRANCE | ETSI |
| **Avanti**<br>**(Avanti Communications Ltd)** | UNITED KINGDOM | ETSI |
| **BAE Systems AI Ltd**<br>**(BAE Systems Applied Intelligence Limited)** | UNITED KINGDOM | ETSI |
| **Baicells Technologies Co. Ltd**<br>**(Baicells Technologies Co. Ltd)** | CHINA | CCSA |
| **BBC** | UNITED KINGDOM | ETSI |

| | | |
|---|---|---|
| **(BRITISH BROADCASTING CORPORATION)** | | |
| **B-Com**<br>**(B-Com)** | FRANCE | ETSI |
| **BDBOS**<br>**(Federal Agency for Public Safety Digital Radio)** | GERMANY | ETSI |
| **BeammWave AB**<br>**(BeammWave AB)** | SWEDEN | ETSI |
| **Beijing Lenovo Software Ltd.**<br>**(Beijing Lenovo Software Ltd.)** | CHINA | CCSA |
| **BEIJING SAMSUNG TELECOM R&D**<br>**(BEIJING SAMSUNG TELECOM R&D CENTER)** | CHINA | CCSA |
| **Beijing Xiaomi Electronics**<br>**(Beijing Xiaomi Electronics)** | CHINA | CCSA |
| **Beijing Xiaomi Mobile Software**<br>**(Beijing Xiaomi Mobile Software Co., Ltd)** | CHINA | CCSA |
| **Beijing Xiaomi Mobile Software**<br>**(Beijing Xiaomi Mobile Software Co., Ltd.)** | CHINA | ETSI |
| **Beijing Xiaomi Software Tech**<br>**(Beijing Xiaomi Software Technology)** | CHINA | CCSA |
| **Bell Mobility**<br>**(Bell Mobility)** | CANADA | ETSI |
| **BfV**<br>**(Bundesamt für Verfassungsschutz)** | GERMANY | ETSI |
| **Bharti Airtel Limited**<br>**(Bharti Airtel Limited)** | INDIA | TSDSI |
| **BIFNC**<br>**(BRICS Institute of Future Network)** | CHINA | CCSA |
| **BIPT**<br>**(BIPT - Belgian Institute for Postal services & Telecommunications)** | BELGIUM | ETSI |
| **Bittium Wireless Ltd.**<br>**(Bittium Wireless Ltd.)** | FINLAND | ETSI |
| **BJTU**<br>**(Beijing Jiaotong University)** | CHINA | CCSA |
| **BKA**<br>**(Bundeskriminalamt)** | GERMANY | ETSI |
| **Bluetest AB**<br>**(Bluetest AB)** | SWEDEN | ETSI |
| **BMF**<br>**(Austrian Federal Ministry of Finance)** | AUSTRIA | ETSI |
| **BMWK**<br>**(Bundesministerium für Wirtschaft und Klimaschutz)** | GERMANY | ETSI |
| **BOCRA**<br>**(Botswana Communications Regulatory Authority)** | BOTSWANA | ETSI |
| **BOUYGUES Telecom**<br>**(BOUYGUES Telecom)** | FRANCE | ETSI |
| **Broadcom (EU)**<br>**(Broadcom Europe Ltd)** | UNITED KINGDOM | ETSI |
| **BSI (DE)**<br>**(Bundesamt für Sicherheit in der Informationstechnik)** | GERMANY | ETSI |
| **BSNL**<br>**(Bharat Sanchar Nigam Limited)** | INDIA | TSDSI |
| **BT plc**<br>**(British Telecommunications plc)** | UNITED KINGDOM | ETSI |
| **BTL Inc.**<br>**(BTL Inc.)** | CHINA | ETSI |
| **BTPDI**<br>**(Beijing Telecom Planning & Designing Institute Co.,LTD.)** | CHINA | CCSA |
| **BUPT**<br>**(Beijing University of Posts and Telecommunications)** | CHINA | CCSA |
| **Bureau Veritas ADT**<br>**(Bureau Veritas Consumer Products Services (Hong Kong) Limited, Taoyuan Branch)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **Bytedance**<br>**(Bytedance (Nanjing) Technology Research and Development Co., Ltd.)** | CHINA | CCSA |
| **C Spire Wireless**<br>**(C Spire Wireless)** | UNITED STATES | ATIS |

| | | |
|---|---|---|
| **CableLabs**<br>**(CableLabs)** | UNITED STATES | ETSI |
| **Cadence Design Systems Inc.**<br>**(Cadence Design Systems Inc.)** | UNITED STATES | ETSI |
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| **CAMBRIDGE CONSULTANTS LTD**<br>**(CAMBRIDGE CONSULTANTS LTD)** | UNITED KINGDOM | ETSI |
| **CANON Research Centre France**<br>**(CANON Research Centre France SAS)** | FRANCE | ETSI |
| **Casa Systems Inc.**<br>**(Casa Systems Inc.)** | UNITED STATES | ETSI |
| **Catapult**<br>**(Satellite Applications Catapult Ltd)** | UNITED KINGDOM | ETSI |
| **CATT**<br>**(China Academy of Telecommunications Technology (CATT))** | CHINA | ETSI |
| **CATT**<br>**(China Academy of Telecommunication Technology - (Datang Telecom Technology and Industry Group))** | CHINA | CCSA |
| **CBN**<br>**(China Broadcasting Network Group Corporation Ltd.)** | CHINA | CCSA |
| **CCU**<br>**(National Chung Cheng University)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **C-DAC**<br>**(Centre for Development of Advanced Computing)** | INDIA | TSDSI |
| **C-DOT**<br>**(C-DOT)** | INDIA | TSDSI |
| **CEA**<br>**(Commissariat à l'Energie Atomique et aux Energies Alternatives)** | FRANCE | ETSI |
| **Cellnex**<br>**(Cellnex Telecom)** | SPAIN | ETSI |
| **CENC**<br>**(CETC Network & Communications Group Co., Ltd.)** | CHINA | CCSA |
| **CEPRI**<br>**(China Electric Power Research Institute)** | CHINA | CCSA |
| **Ceragon Networks AS**<br>**(Ceragon Networks AS)** | NORWAY | ETSI |
| **CERTH**<br>**(CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS)** | GREECE | ETSI |
| **cetecom advanced GmbH**<br>**(cetecom advanced GmbH)** | GERMANY | ETSI |
| **CEWiT**<br>**(Centre of Excellence in Wireless Technology (CEWiT))** | INDIA | TSDSI |
| **CGL**<br>**(CHAZAH GROUP LTD)** | UGANDA | ETSI |
| **Charter Communications, Inc**<br>**(Charter Communications, Inc)** | UNITED STATES | ATIS |
| **Chengdu OPPO Telecommunication**<br>**(Chengdu OPPO Mobile Telecommunications Corp., ltd.)** | CHINA | CCSA |
| **CHENGDU TD TECH LTD.**<br>**(CHENGDU TD TECH LTD.)** | CHINA | CCSA |
| **China Broadnet**<br>**(China Broadnet Mobile Communications Co., Ltd.)** | CHINA | CCSA |
| **China Mobile (Hangzhou) Inf.**<br>**(China Mobile (Hangzhou) Information Technology Co., Ltd.)** | CHINA | CCSA |
| **China Mobile (Suzhou) Software**<br>**(China Mobile (Suzhou) Software Technology Co., Ltd.)** | CHINA | CCSA |
| **China Mobile Com. Corporation**<br>**(China Mobile Communications Corporation (CMCC))** | CHINA | CCSA |
| **China Mobile E-Commerce Co.**<br>**(China Mobile E-Commerce Co.)** | CHINA | CCSA |
| **China Mobile Group Device Co.** | CHINA | CCSA |

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| **(China Mobile Group Device Co., Ltd)** | | |
| **China Mobile International Ltd**<br>**(China Mobile International Limited)** | CHINA | CCSA |
| **China Mobile M2M Company Ltd.**<br>**(China Mobile M2M Company Ltd.)** | CHINA | CCSA |
| **China Southern Power Grid Co.**<br>**(China Southern Power Grid Co., Ltd.)** | CHINA | CCSA |
| **China Telecom Corporation Ltd.**<br>**(China Telecom Corporation Ltd.)** | CHINA | CCSA |
| **China Telecommunications**<br>**(China Telecommunications Corporation)** | CHINA | ETSI |
| **China Telecomunication Corp.**<br>**(China Telecomunication Corporation)** | CHINA | CCSA |
| **China Unicom**<br>**(China Unicom)** | CHINA | CCSA |
| **Chinatelecom Cloud**<br>**(China Telecom Cloud Technology Co., Ltd)** | CHINA | CCSA |
| **Chongqing University**<br>**(Chongqing University)** | CHINA | CCSA |
| **Chosun University**<br>**(Chosun University)** | KOREA (REPUBLIC OF) | TTA |
| **CHTTL**<br>**(Chunghwa Telecommunication Laboratories, Chunghwa Telecommunication Co.)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **CICT**<br>**(China Information Communication Technologies Group)** | CHINA | ETSI |
| **CICT**<br>**(China Information Communication Technologies Group Corporation)** | CHINA | CCSA |
| **CICT Mobile**<br>**(CICT Mobile Communication Technology Co., Ltd.)** | CHINA | CCSA |
| **CICTCI**<br>**(CICT Connected and Intelligent Technologies Co., Ltd)** | CHINA | CCSA |
| **CIS**<br>**(Center for Internet Security)** | UNITED STATES | ETSI |
| **CISA ECD**<br>**(Cybersecurity and Infrastructure Security Agency (CISA) ECD)** | UNITED STATES | ATIS |
| **Cisco Systems**<br>**(Cisco Systems)** | UNITED STATES | ATIS |
| **Cisco Systems Belgium**<br>**(Cisco Systems Belgium)** | BELGIUM | ETSI |
| **Cisco Systems France**<br>**(Cisco Systems France)** | FRANCE | ETSI |
| **CITC**<br>**(CHINA INFORMATION TECHNOLOGY DESIGNING&CONSULTING INSTITUTE CO.,LTD.)** | CHINA | CCSA |
| **CKH IOD UK LIMITED**<br>**(CKH IOD UK LIMITED)** | UNITED KINGDOM | ETSI |
| **CMDI**<br>**(China Mobile Group Design Institute Co., Ltd)** | CHINA | CCSA |
| **CNC**<br>**(CLAP-N-CLANK)** | JAPAN | ETSI |
| **CNES**<br>**(CNES - Centre National d'Etudes Spatiales)** | FRANCE | ETSI |
| **Cobham SatCom A/S**<br>**(Thrane & Thrane A/S)** | DENMARK | ETSI |
| **Cognyte**<br>**(Cognyte Technologies Israel Ltd.)** | ISRAEL | ETSI |
| **Cohere Technologies**<br>**(Cohere Technologies)** | UNITED STATES | ATIS |
| **Comba**<br>**(Comba Network Systems Company Limited)** | CHINA | CCSA |
| **Comcast**<br>**(Comcast)** | UNITED STATES | ATIS |
| **Comprion GmbH**<br>**(Comprion GmbH)** | GERMANY | ETSI |
| **Comtech Telecommunications Cor**<br>**(Comtech Telecommunications Corp)** | UNITED STATES | ATIS |

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| **Consort Digital**<br>**(Consort Digital Private Limited)** | INDIA | ETSI |
| **Continental Automotive**<br>**(Continental Automotive Technologies GmbH)** | GERMANY | ETSI |
| **Convida Wireless**<br>**(Convida Wireless, LLC)** | UNITED STATES | ETSI |
| **Cosmian**<br>**(Cosmian Tech SAS)** | FRANCE | ETSI |
| **COSMOTE S.A.**<br>**(COSMOTE MOBILE TELECOMMUNICATIONS S.A.)** | GREECE | ETSI |
| **CQUPT**<br>**(Chongqing University of Posts and Telecommunications)** | CHINA | CCSA |
| **Crosscall**<br>**(Crosscall)** | FRANCE | ETSI |
| **CSA**<br>**(Cyber Security Agency of Singapore)** | SINGAPORE | ETSI |
| **CSCN**<br>**(CHINA SATELLITE NETWORK GROUP CO., LTD.)** | CHINA | CCSA |
| **CSIRO**<br>**(Commonwealth Scientific and Industrial Research Organisation)** | AUSTRALIA | ETSI |
| **cstconsultancy**<br>**(CyberSecurity & Technology Consultancy LTD)** | UNITED KINGDOM | ETSI |
| **CTSI**<br>**(China Telecom System Integration Co., Ltd)** | CHINA | CCSA |
| **CTTC**<br>**(Centre tecnologic de Telecomunicacions de Catalunya)** | SPAIN | ETSI |
| **CU Digital Technology**<br>**(China Unicom Digital Technology Co., Ltd.)** | CHINA | CCSA |
| **CUC**<br>**(Communication University of China)** | CHINA | CCSA |
| **CUG**<br>**(China Unicom Global Limited)** | CHINA | CCSA |
| **Cybercore**<br>**(Beijinig Cybercore Technology Co., Ltd.)** | CHINA | CCSA |
| **Cygnusemi**<br>**(Cygnusemi)** | CHINA | CCSA |
| **Czech Telecommunication Office**<br>**(Czech Telecommunication Office)** | CZECH REPUBLIC | ETSI |
| **DAC-UPC**<br>**(Departamento de Arquitectura de Computadores de la Universidad Politecnica de Cataluna (DAC-UPC))** | SPAIN | ETSI |
| **DanKook University**<br>**(DanKook University)** | KOREA (REPUBLIC OF) | TTA |
| **DARS TELECOM S.L.**<br>**(DARS TELECOM S.L.)** | SPAIN | ETSI |
| **Datang Linktester Technology**<br>**(Datang Linktester Technology Co., Ltd.)** | CHINA | CCSA |
| **Datang Mobile Com. Equipment**<br>**(Datang Mobile Communications Equipment Co., Ltd)** | CHINA | CCSA |
| **DEKRA**<br>**(DEKRA testing and Certification, S.A.U.)** | SPAIN | ETSI |
| **Dell Technologies**<br>**(Dell Technologies)** | UNITED STATES | ATIS |
| **DENSO CORPORATION**<br>**(DENSO CORPORATION)** | JAPAN | ARIB |
| **Department of Telecom**<br>**(Department of Telecommunications)** | INDIA | TSDSI |
| **Dept of Home Affairs**<br>**(Department of Home Affairs)** | AUSTRALIA | ETSI |
| **Deutsche Telekom AG**<br>**(Deutsche Telekom AG)** | GERMANY | ETSI |
| **DIGG**<br>**(Agency for Digital Government)** | SWEDEN | ETSI |
| **DISA**<br>**(Defense Information Systems Agency)** | UNITED STATES | ATIS |
| **Dish Network** | UNITED STATES | ATIS |

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| **(Dish Network)** | | |
| **DLR**<br>**(Deutsches Zentrum für Luft- und Raumfahrt e.V.)** | GERMANY | ETSI |
| **DOCOMO Beijing Labs**<br>**(DOCOMO Beijing Communications Laboratories Co., Ltd)** | CHINA | CCSA |
| **DOCOMO Communications Lab.**<br>**(DOCOMO Communications Laboratories Europe GmbH)** | GERMANY | ETSI |
| **Dolby France SAS**<br>**(Dolby France SAS)** | FRANCE | ETSI |
| **Dolby Germany GmbH**<br>**(Dolby Germany GmbH)** | GERMANY | ETSI |
| **Dolby Sweden AB**<br>**(Dolby Sweden AB)** | SWEDEN | ETSI |
| **Douyin**<br>**(Beijing Douyin Information Service Co., Ltd.)** | CHINA | CCSA |
| **DP**<br>**(DigitalPlatforms SpA)** | ITALY | ETSI |
| **DSIT**<br>**(Department for Science, Innovation and Technology)** | UNITED KINGDOM | ETSI |
| **DTCY**<br>**(Deloitte Tohmatsu Cyber LLC)** | JAPAN | TTC |
| **DTS Licensing Limited**<br>**(DTS Licensing Limited)** | IRELAND | ETSI |
| **EBU**<br>**(EBU - European Broadcasting Union)** | SWITZERLAND | ETSI |
| **ECTL**<br>**(Enhanced Communications & Technologies Pvt Ltd)** | INDIA | TSDSI |
| **EDF Recherche et Développement**<br>**(EDF)** | FRANCE | ETSI |
| **EFORT**<br>**(Etudes et Formations en Telecommunication)** | FRANCE | ETSI |
| **Elbit Systems**<br>**(Elbit Systems C4I and Cyber Ltd)** | ISRAEL | ETSI |
| **Element Materials Technology**<br>**(Element Materials Technology Warwick Ltd)** | UNITED KINGDOM | ETSI |
| **Elena**<br>**(Elena Geo Systems Pvt Ltd)** | INDIA | TSDSI |
| **Embotech AG**<br>**(Embotech AG)** | SWITZERLAND | ETSI |
| **EMITE**<br>**(EMITE Ingenieria S.L.)** | SPAIN | ETSI |
| **ENENSYS**<br>**(ENENSYS Technologies SA)** | FRANCE | ETSI |
| **Ericsson España S.A.**<br>**(Ericsson España S.A.)** | SPAIN | ETSI |
| **Ericsson France S.A.S**<br>**(Ericsson France S.A.S)** | FRANCE | ETSI |
| **Ericsson GmbH, Eurolab**<br>**(Ericsson GmbH, Eurolab - Unternehmensbereich Forschung und Entwicklung)** | GERMANY | ETSI |
| **Ericsson Hungary Ltd**<br>**(Ericsson Hungary Ltd)** | HUNGARY | ETSI |
| **Ericsson Inc.**<br>**(Ericsson Incorporated)** | UNITED STATES | ATIS |
| **Ericsson India Private Limited**<br>**(Ericsson India Private Limited)** | INDIA | TSDSI |
| **Ericsson Japan K.K.**<br>**(Ericsson Japan K.K.)** | JAPAN | ARIB |
| **Ericsson Limited**<br>**(Ericsson Limited)** | UNITED KINGDOM | ETSI |
| **Ericsson LM**<br>**(Ericsson Telefonaktiebolaget LM)** | SWEDEN | ETSI |
| **Ericsson Telecomunicazioni SpA**<br>**(Ericsson Telecomunicazioni SpA)** | ITALY | ETSI |
| **Ericsson-LG Co., LTD**<br>**(Ericsson-LG Co., LTD)** | KOREA (REPUBLIC OF) | TTA |

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| **Erillisverkot**<br>**(Suomen Erillisverkot Oy)** | FINLAND | ETSI |
| **ERNET India**<br>**(ERNET India)** | INDIA | TSDSI |
| **ESA**<br>**(ESA - European Space Agency)** | NETHERLANDS | ETSI |
| **E-SPACE**<br>**(E-SPACE SAS)** | FRANCE | ETSI |
| **ESSEN INNOVATION**<br>**(ESSEN INNOVATION COMPANY LIMITED)** | CHINA | CCSA |
| **E-surfing Digital**<br>**(E-surfing Digital Life Technology Co., Ltd)** | CHINA | CCSA |
| **Esurfing IoT**<br>**(Esurfing IoT Tech Co., Ltd)** | CHINA | CCSA |
| **ETELM**<br>**(Electronique Telematique ETELM)** | FRANCE | ETSI |
| **Etherstack Wireless Limited**<br>**(Etherstack Wireless Limited)** | UNITED KINGDOM | ETSI |
| **ETRI**<br>**(Electronics & Telecommunications Research Institute)** | KOREA (REPUBLIC OF) | TTA |
| **ETS-Lindgren Europe**<br>**(ETS-Lindgren Europe)** | FINLAND | ETSI |
| **EURECOM**<br>**(EURECOM)** | FRANCE | ETSI |
| **Eurofins KCTL**<br>**(Eurofins KCTL Co. Ltd)** | KOREA (REPUBLIC OF) | ETSI |
| **European Commission**<br>**(EC - European Commission)** | BELGIUM | ETSI |
| **European Patent Organisation**<br>**(European Patent Organisation)** | GERMANY | ETSI |
| **EUTC**<br>**(European Utilities Telecom Council (EUTC))** | BELGIUM | ETSI |
| **Eutelsat Group**<br>**(Eutelsat S.A.)** | FRANCE | ETSI |
| **EVE Compliancy Solutions**<br>**(EVE Compliancy Solutions)** | NETHERLANDS | ETSI |
| **Everactive**<br>**(Everactive)** | UNITED STATES | ATIS |
| **F5**<br>**(F5, Inc.)** | UNITED STATES | ETSI |
| **Fabasoft AG**<br>**(Fabasoft AG)** | AUSTRIA | ETSI |
| **Facebook Japan G.K.**<br>**(Facebook Japan G.K.)** | JAPAN | ARIB |
| **Fastweb S.p.A.**<br>**(Fastweb S.p.A.)** | ITALY | ETSI |
| **FAU**<br>**(Friedrich-Alexander-Universität Erlangen-Nürnberg)** | GERMANY | ETSI |
| **FBK**<br>**(Fondazione Bruno Kessler)** | ITALY | ETSI |
| **FCC**<br>**(Federal Communications Commission)** | UNITED STATES | ATIS |
| **Fiberhome Technologies Group**<br>**(Fiberhome Technologies Group)** | CHINA | CCSA |
| **FirstNet**<br>**(FirstNet)** | UNITED STATES | ATIS |
| **FORCE Technology**<br>**(FORCE Technology)** | DENMARK | ETSI |
| **Ford**<br>**(Ford Motor Company)** | UNITED STATES | ETSI |
| **Fraunhofer FOKUS**<br>**(Fraunhofer Institute for Open Communication Systems FOKUS)** | GERMANY | ETSI |
| **Fraunhofer HHI**<br>**(Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute)** | GERMANY | ETSI |
| **Fraunhofer IIS** | GERMANY | ETSI |

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| **(Fraunhofer Institut für Integrierte Schaltungen IIS)** | | |
| **Frequentis AG**<br>**(Frequentis AG)** | AUSTRIA | ETSI |
| **Fujitsu Limited**<br>**(Fujitsu Limited)** | JAPAN | ETSI |
| **Fujitsu Limited.**<br>**(Fujitsu Limited.)** | JAPAN | TTC |
| **Fujitsu Limited..**<br>**(Fujitsu Limited..)** | JAPAN | ARIB |
| **Futurewei**<br>**(Futurewei Technologies Inc.)** | UNITED STATES | ETSI |
| **Futurewei Technologies**<br>**(Futurewei Technologies)** | UNITED STATES | ATIS |
| **G+D MS**<br>**(Giesecke+Devrient Mobile Security Germany GmbH)** | GERMANY | ETSI |
| **Gatehouse Satcom A/S**<br>**(Gatehouse Satcom A/S )** | DENMARK | ETSI |
| **GDCNI**<br>**(Guangdong Communications and Networks Institute)** | CHINA | CCSA |
| **GE Network Technologies, LLC**<br>**(GE Network Technologies, LLC)** | UNITED STATES | ATIS |
| **GEESPACE**<br>**(ZHE JIANG GEESPACE TECHNOLOGY CO., LTD.)** | CHINA | CCSA |
| **Gigaset Communications GmbH**<br>**(Gigaset Communications GmbH)** | GERMANY | ETSI |
| **Gilat**<br>**(Gilat Satellite Networks Ltd)** | ISRAEL | ETSI |
| **GLOBALSTAR Inc.**<br>**(GLOBALSTAR Inc.)** | UNITED STATES | ETSI |
| **GM - ATCI**<br>**(General Motors - ATCI)** | ISRAEL | ETSI |
| **Google Inc.**<br>**(Google Inc.)** | UNITED STATES | ATIS |
| **Group 2000**<br>**(Group 2000 Nederland B.V.)** | NETHERLANDS | ETSI |
| **GTRC**<br>**(Georgia Tech Research Corporation)** | UNITED STATES | ETSI |
| **GUANGDONG GENIUS TECHNOLOGY CO**<br>**(GUANGDONG GENIUS TECHNOLOGY CO., LTD. )** | CHINA | CCSA |
| **Guangdong OPPO Mobile Telecom.**<br>**(Guangdong OPPO Mobile Telecommunications Corp., Ltd)** | CHINA | CCSA |
| **GW**<br>**(Greenerwave)** | FRANCE | ETSI |
| **HA/ST**<br>**(HARTING Stiftung & Co. KG)** | GERMANY | ETSI |
| **Hangzhou Douku**<br>**(Hangzhou Douku Software Technologies Co., Ltd.)** | CHINA | CCSA |
| **Hangzhou Mengyuxiang**<br>**(Hangzhou Mengyuxiang Network Technology Corp., Ltd.)** | CHINA | CCSA |
| **Harman GmbH**<br>**(Harman Becker Automotive Systems GmbH)** | GERMANY | ETSI |
| **HEAD acoustics GmbH**<br>**(HEAD acoustics GmbH)** | GERMANY | ETSI |
| **Hewlett-Packard Enterprise**<br>**(Hewlett-Packard Enterprise)** | FRANCE | ETSI |
| **HiSilicon Technologies Co. Ltd**<br>**(HiSilicon Technologies Co.Ltd)** | CHINA | CCSA |
| **HISPASAT SA**<br>**(HISPASAT SA)** | SPAIN | ETSI |
| **HOME OFFICE**<br>**(HOME OFFICE)** | UNITED KINGDOM | ETSI |
| **Honda Motor Co., Ltd**<br>**(Honda Motor Co., Ltd)** | JAPAN | ARIB |
| **Honor**<br>**(Honor Device Co., Ltd)** | CHINA | ETSI |

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| **Honor**<br>**(Honor Device Co., Ltd.)** | CHINA | CCSA |
| **Huawei Device Co., Ltd**<br>**(Huawei Device Co., Ltd)** | CHINA | CCSA |
| **HUAWEI TECH. GmbH**<br>**(HUAWEI TECHNOLOGIES Duesseldorf GmbH)** | GERMANY | ETSI |
| **Huawei Tech.(UK) Co.. Ltd**<br>**(Huawei Technologies (UK) Co., Ltd.)** | UNITED KINGDOM | ETSI |
| **Huawei Technologies (Korea)**<br>**(Huawei Technologies (Korea))** | KOREA (REPUBLIC OF) | TTA |
| **HUAWEI TECHNOLOGIES Co. Ltd.**<br>**(Huawei Technologies Co. Ltd.)** | CHINA | ETSI |
| **HuaWei Technologies Co., Ltd**<br>**(HuaWei Technologies Co., Ltd)** | CHINA | CCSA |
| **Huawei Technologies France**<br>**(Huawei Technologies France)** | FRANCE | ETSI |
| **Huawei Technologies Japan K.K.**<br>**(Huawei Technologies Japan K.K.)** | JAPAN | TTC |
| **HUAWEI Technologies Japan K.K.**<br>**(HUAWEI Technologies Japan K.K.)** | JAPAN | ARIB |
| **Huawei Technologies R&D UK**<br>**(Huawei Technologies Research & Development (UK) Limited)** | UNITED KINGDOM | ETSI |
| **Huawei Technologies Sweden AB**<br>**(Huawei Technologies Sweden AB)** | SWEDEN | ETSI |
| **Huawei Telecommunication India**<br>**(Huawei Telecommunication (India) Co. Pvt. Ltd.)** | INDIA | TSDSI |
| **HUGHES Network Systems Ltd**<br>**(HUGHES Network Systems Ltd)** | UNITED KINGDOM | ETSI |
| **Husqvarna AB**<br>**(Husqvarna AB (publ))** | SWEDEN | ETSI |
| **Hytera Communications Corp.**<br>**(Hytera Communications Corporation Limited)** | CHINA | CCSA |
| **Hyundai Motor Company**<br>**(Hyundai Motor Company)** | KOREA (REPUBLIC OF) | TTA |
| **IBM Europe**<br>**(IBM Europe)** | GERMANY | ETSI |
| **ICS**<br>**(Institute for Communication Systems - University of Surrey)** | UNITED KINGDOM | ETSI |
| **IDEMIA**<br>**(IDEMIA)** | FRANCE | ETSI |
| **IDRBT**<br>**(Institute for Development and Research in Banking Technology)** | INDIA | TSDSI |
| **III**<br>**(Institute for Information Industry)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **IIIT Bangalore**<br>**(International Institute of Information Technology - Bangalore)** | INDIA | TSDSI |
| **IIIT Naya Raipur**<br>**(International Institute of Information Technology, Naya Raipur)** | INDIA | TSDSI |
| **IISc, Bangalore**<br>**(Indian Institute of Science, Bangalor)** | INDIA | TSDSI |
| **IIT Bhilai**<br>**(Indian Institute of Technology Bhilai)** | INDIA | TSDSI |
| **IIT Bombay**<br>**(Indian Institute of Technology Bombay)** | INDIA | TSDSI |
| **IIT Delhi**<br>**(Indian Institute of Technology Delhi)** | INDIA | TSDSI |
| **IIT Gandhinagar**<br>**(Indian Institute of Technology Gandhinagar)** | INDIA | TSDSI |
| **IIT JODHPUR**<br>**(Indian Institute of Technology Jodhpur)** | INDIA | TSDSI |
| **IIT Kanpur**<br>**(Indidan Institute of Technology Kanpur)** | INDIA | TSDSI |
| **IIT Mandi**<br>**(Indian Institute of Technology Mandi)** | INDIA | TSDSI |
| **IIT Patna** | INDIA | TSDSI |

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| **(Indian Institute of Technology Patna)** | | |
| **IIT, Kharagpur**<br>**(IIT, Kharagpur)** | INDIA | TSDSI |
| **IMDA**<br>**(Infocomm Media Development Authority)** | SINGAPORE | ETSI |
| **IMU**<br>**(Istanbul Medipol University)** | TÜRKIYE | ETSI |
| **Indian Institute of Tech (H)**<br>**(Indian Institute of Technology Hyderabad)** | INDIA | TSDSI |
| **Indian Institute of Tech (M)**<br>**(Indian Institute of Technology Madras)** | INDIA | TSDSI |
| **INFINEON TECHNOLOGIES**<br>**(Infineon Technologies)** | GERMANY | ETSI |
| **Inmarsat**<br>**(Inmarsat)** | UNITED KINGDOM | ETSI |
| **Institut Mines-Telecom**<br>**(Institut Mines-Telecom)** | FRANCE | ETSI |
| **Institute VEDECOM**<br>**(Institute VEDECOM)** | FRANCE | ETSI |
| **Intel**<br>**(Intel)** | UNITED STATES | ATIS |
| **Intel Belgium SA/NV**<br>**(Intel Belgium SA/NV)** | BELGIUM | ETSI |
| **Intel China Ltd.**<br>**(Intel China Ltd.)** | CHINA | CCSA |
| **Intel Corporation (UK) Ltd**<br>**(Intel Corporation (UK) Ltd)** | UNITED KINGDOM | ETSI |
| **Intel Corporation Italia SpA**<br>**(Intel Corporation Italia SpA)** | ITALY | ETSI |
| **Intel Corporation SAS**<br>**(Intel Corporation SAS)** | FRANCE | ETSI |
| **Intel Deutschland GmbH**<br>**(Intel Deutschland GmbH)** | GERMANY | ETSI |
| **Intel Ireland**<br>**(Intel Ireland Ltd)** | IRELAND | ETSI |
| **Intel K.K.**<br>**(Intel K.K.)** | JAPAN | ARIB |
| **Intel Sweden AB**<br>**(Intel Sweden AB)** | SWEDEN | ETSI |
| **Intel Technology India Pvt Ltd**<br>**(Intel Technology India Pvt. Ltd.)** | INDIA | TSDSI |
| **Intel Technology Poland SP Zoo**<br>**(Intel Technology Poland SP Zoo)** | POLAND | ETSI |
| **Intelsat**<br>**(Intelsat)** | UNITED STATES | ATIS |
| **InterDigital Belgium. LLC**<br>**(InterDigital Belgium, LLC)** | BELGIUM | ETSI |
| **InterDigital Canada**<br>**(InterDigital Canada)** | CANADA | ATIS |
| **InterDigital Communications**<br>**(InterDigital Communications Corporation)** | UNITED STATES | ATIS |
| **InterDigital Finland Oy**<br>**(InterDigital Finland Oy)** | FINLAND | ETSI |
| **InterDigital France R&D, SAS**<br>**(InterDigital France R&D, SAS)** | FRANCE | ETSI |
| **InterDigital New York**<br>**(InterDigital New York)** | UNITED STATES | ATIS |
| **InterDigital Pennsylvania**<br>**(InterDigital Pennsylvania)** | UNITED STATES | ATIS |
| **InterDigital, Europe, Ltd.**<br>**(InterDigital, Europe, Ltd.)** | UNITED KINGDOM | ETSI |
| **InterDigital, Inc.**<br>**(InterDigital, Inc.)** | UNITED STATES | ETSI |
| **Intersec**<br>**(Intersec SA)** | FRANCE | ETSI |

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| **Intertek**<br>**(Intertek)** | UNITED KINGDOM | ETSI |
| **IPCom GmbH & Co.KG**<br>**(IPCom GmbH & Co.KG)** | GERMANY | ETSI |
| **IPLOOK**<br>**(IPLOOK Networks Co., Ltd.)** | CHINA | CCSA |
| **iQoo**<br>**(iQoo Software Technology (Shanghai) Co., Ltd.)** | CHINA | CCSA |
| **Iridium Satellite LLC**<br>**(Iridium Satellite LLC)** | UNITED STATES | ATIS |
| **IRT Saint Exupery**<br>**(Institut de recherche technologique Saint Exupery)** | FRANCE | ETSI |
| **ISED**<br>**(Innovation, Science and Economic Development Canada)** | CANADA | ETSI |
| **ISRO**<br>**(Indian Space Research Organisation)** | INDIA | TSDSI |
| **ISSDU**<br>**(Information Security Service Digital United Inc.)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **ITL**<br>**(Innovative Technology Lab Co., Ltd)** | KOREA (REPUBLIC OF) | TTA |
| **ITOCHU Techno-Solutions Corp**<br>**(ITOCHU Techno-Solutions Corporation)** | JAPAN | TTC |
| **ITRI**<br>**(Industrial Technology Research Institute)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **ITRON SAS**<br>**(ITRON SAS)** | FRANCE | ETSI |
| **Ittiam System Pvt Ltd**<br>**(Ittiam System Pvt Ltd)** | INDIA | TSDSI |
| **Japan Radio Co., Ltd**<br>**(Japan Radio Co., Ltd)** | JAPAN | ARIB |
| **Jetflow**<br>**(Jetflow Technologies Co., Ltd)** | CHINA | CCSA |
| **Jio**<br>**(Jio Estonia OÜ)** | ESTONIA | ETSI |
| **JMA Wireless**<br>**(JMA Wireless)** | UNITED STATES | ATIS |
| **John Deere GmbH & Co. KG**<br>**(John Deere GmbH & Co. KG)** | GERMANY | ETSI |
| **Johns Hopkins University APL**<br>**(Johns Hopkins University Applied Physics Laboratory)** | UNITED STATES | ATIS |
| **JSI GmbH**<br>**(JSI GmbH)** | GERMANY | ETSI |
| **Juniper Networks**<br>**(Juniper Networks)** | UNITED STATES | ETSI |
| **Kapsch TrafficCom AG**<br>**(Kapsch TrafficCom AG)** | AUSTRIA | ETSI |
| **KDDI Corporation**<br>**(KDDI Corporation)** | JAPAN | TTC |
| **KDDI Corporation**<br>**(KDDI Corporation)** | JAPAN | ARIB |
| **Kepler**<br>**(Kepler Communications GmbH)** | GERMANY | ETSI |
| **Keysight Technologies UK Ltd**<br>**(Keysight Technologies UK Ltd)** | UNITED KINGDOM | ETSI |
| **KIPO**<br>**(Korean Intellectual Property Office)** | KOREA (REPUBLIC OF) | TTA |
| **Kontron Transportation France**<br>**(Kontron Transportation France S.A.S)** | FRANCE | ETSI |
| **Korea Testing Laboratory**<br>**(Korea Testing Laboratory)** | KOREA (REPUBLIC OF) | TTA |
| **KPN N.V.**<br>**(Koninklijke KPN N.V.)** | NETHERLANDS | ETSI |
| **KRRI**<br>**(Korea Railroad Research Institute)** | KOREA (REPUBLIC OF) | TTA |
| **KT Corp.** | KOREA (REPUBLIC OF) | TTA |

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| **(KT Corporation)** | | |
| **Kymeta Corporation**<br>**(Kymeta Corporation)** | UNITED STATES | ETSI |
| **Kyocera Corporation**<br>**(Kyocera Corporation)** | JAPAN | ARIB |
| **Kyonggi University**<br>**(Kyonggi University)** | KOREA (REPUBLIC OF) | TTA |
| **Kyoto University**<br>**(Kyoto University)** | JAPAN | ETSI |
| **L.M. Ericsson Limited**<br>**(L.M. Ericsson Limited)** | IRELAND | ETSI |
| **L3Harris Technologies**<br>**(L3Harris Technologies)** | UNITED STATES | ATIS |
| **Langbo**<br>**(Shanghai Langbo Communication Technology Co., Ltd.)** | CHINA | CCSA |
| **Lansus**<br>**(Lansus Technologies Inc.)** | CHINA | CCSA |
| **LEGRAND FRANCE**<br>**(LEGRAND FRANCE ISERE)** | FRANCE | ETSI |
| **Lekha Wireless Solutions**<br>**(Lekha Wireless Solutions Pvt Ltd)** | INDIA | TSDSI |
| **Lenovo (Beijing) Ltd**<br>**(Lenovo (Beijing) Ltd)** | CHINA | CCSA |
| **Lenovo Future Communications**<br>**(Lenovo Future Communications Technology (Chongqing) Co., Ltd.)** | CHINA | CCSA |
| **Lenovo Information Technology**<br>**(Lenovo (Beijing) Information Technology Co., Ltd.)** | CHINA | CCSA |
| **Leonardo SpA**<br>**(Leonardo SpA)** | ITALY | ETSI |
| **LG Electronics Deutschland**<br>**(LG Electronics Deutschland GmbH)** | GERMANY | ETSI |
| **LG Electronics Finland**<br>**(LG Electronics Finland Lab Oy)** | FINLAND | ETSI |
| **LG Electronics France**<br>**(LG Electronics France)** | FRANCE | ETSI |
| **LG Electronics Inc.**<br>**(LG Electronics Inc.)** | KOREA (REPUBLIC OF) | TTA |
| **LG Electronics Polska**<br>**(LG Electronics Polska Sp. z.o.o.)** | POLAND | ETSI |
| **LG Electronics UK**<br>**(LG Electronics UK Ltd)** | UNITED KINGDOM | ETSI |
| **LG Uplus**<br>**(LG Uplus)** | KOREA (REPUBLIC OF) | TTA |
| **Ligado Networks**<br>**(Ligado Networks)** | UNITED STATES | ETSI |
| **LKA Niedersachsen**<br>**(Landeskriminalamt Niedersachsen)** | GERMANY | ETSI |
| **Locaila**<br>**(Locaila)** | UNITED STATES | ATIS |
| **Lockheed Martin**<br>**(Lockheed Martin)** | UNITED STATES | ATIS |
| **Lynk Global**<br>**(Lynk Global)** | UNITED STATES | ATIS |
| **Magister Solutions Ltd**<br>**(Magister Solutions Ltd)** | FINLAND | ETSI |
| **Maketh Secure Limited**<br>**(Maketh Secure Limited)** | UNITED KINGDOM | ETSI |
| **MATRIXX Software**<br>**(MATRIXX Software, Inc.)** | UNITED STATES | ETSI |
| **Mavenir**<br>**(Mavenir Systems, Inc)** | UNITED STATES | ETSI |
| **MaxWave Micro**<br>**(MaxWave Microelectronics Ltd.)** | CHINA | CCSA |
| **MediaTek (Chengdu) Inc.**<br>**(MediaTek (Chengdu) Inc.)** | CHINA | CCSA |

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| **MediaTek (Hefei) Inc.**<br>**(MediaTek (Hefei) Inc.)** | CHINA | CCSA |
| **MediaTek (Shenzhen) Inc.**<br>**(MediaTek (Shenzhen) Inc.)** | CHINA | CCSA |
| **MediaTek (Wuhan) Inc.**<br>**(MediaTek (Wuhan) Inc.)** | CHINA | CCSA |
| **MediaTek Beijing Inc.**<br>**(MediaTek Beijing Inc.)** | CHINA | CCSA |
| **MediaTek Inc.**<br>**(MediaTek Incorporated)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **Mediatek India Technology Pvt.**<br>**(Mediatek India Technology Pvt. Ltd.)** | INDIA | TSDSI |
| **MediaTek Korea Inc.**<br>**(MediaTek Korea Inc.)** | KOREA (REPUBLIC OF) | TTA |
| **MediaTek UK**<br>**(MTK Wireless Ltd)** | UNITED KINGDOM | ETSI |
| **MeitY**<br>**(Ministry of Electronics & Information Technology)** | INDIA | TSDSI |
| **Meizu Technology**<br>**(Meizu Technology)** | CHINA | CCSA |
| **Mercedes-Benz AG**<br>**(Mercedes-Benz AG)** | GERMANY | ETSI |
| **Mesaqin.com s.r.o (Ltd.)**<br>**(Mesaqin.com s.r.o (Ltd.))** | CZECH REPUBLIC | ETSI |
| **Meta India**<br>**(Meta India Online Services Pvt Ltd)** | INDIA | TSDSI |
| **Meta Ireland**<br>**(Meta Platforms Ireland Ltd.)** | IRELAND | ETSI |
| **Meta USA**<br>**(Meta USA)** | UNITED STATES | ATIS |
| **Microchip Technology, Inc.**<br>**(Microchip Technology, Inc.)** | UNITED STATES | ATIS |
| **Microsoft Europe SARL**<br>**(Microsoft Europe SARL)** | FRANCE | ETSI |
| **MidWave Wireless**<br>**(MidWave Wireless)** | UNITED STATES | ATIS |
| **MIMIT**<br>**(Ministry of Enterprises and Made in Italy)** | ITALY | ETSI |
| **MinEA**<br>**(Ministry of Economic Affairs and Climate Policy)** | NETHERLANDS | ETSI |
| **MINECO**<br>**(MINISTRY OF ECONOMIC AFFAIRS AND DIGITAL TRANSFORMATION)** | SPAIN | ETSI |
| **MINISTERE DE L'INTERIEUR**<br>**(MINISTERE DE L'INTERIEUR)** | FRANCE | ETSI |
| **Ministère Economie et Finances**<br>**(Ministère de l'Economie et des Finances)** | FRANCE | ETSI |
| **Ministry of Transport SR**<br>**(Ministry of Transport of the Slovak Republic)** | SLOVAKIA | ETSI |
| **MITRE Corporation**<br>**(MITRE Corporation)** | UNITED STATES | ETSI |
| **Mitsubishi Electric Co.**<br>**(Mitsubishi Electric Co.)** | JAPAN | ARIB |
| **Mitsubishi Electric Corp**<br>**(Mitsubishi Electric Corporation)** | JAPAN | TTC |
| **Mitsubishi Electric RCE**<br>**(Mitsubishi Electric R&D Centre Europe)** | FRANCE | ETSI |
| **Motorola Mobile Com Technology**<br>**(MOTOROLA MOBILE COMMUNICATION TECHNOLOGY LTD.)** | CHINA | CCSA |
| **Motorola Mobility España SA**<br>**(Motorola Mobility España SA)** | SPAIN | ETSI |
| **Motorola Mobility France S.A.S**<br>**(Motorola Mobility France S.A.S)** | FRANCE | ETSI |
| **Motorola Mobility Germany GmbH**<br>**(Motorola Mobility Germany GmbH)** | GERMANY | ETSI |
| **Motorola Mobility UK Ltd.** | UNITED KINGDOM | ETSI |

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| **(Motorola Mobility UK Ltd.)** | | |
| **Motorola Solutions Germany**<br>**(Motorola Solutions Germany GmbH)** | GERMANY | ETSI |
| **Motorola Solutions UK Ltd.**<br>**(Motorola Solutions UK Ltd.)** | UNITED KINGDOM | ETSI |
| **MTCC**<br>**(Mobile Technology Convergence Center)** | KOREA (REPUBLIC OF) | TTA |
| **Murata Manufacturing Co Ltd.**<br>**(Murata Manufacturing Co Ltd.)** | JAPAN | ARIB |
| **MVG Industries**<br>**(MVG Industries)** | FRANCE | ETSI |
| **Nanjing Ericsson Panda Com Ltd**<br>**(NANJING ERICSSON PANDA COMMUNICATIONS LTD)** | CHINA | CCSA |
| **Nanjing Weibo**<br>**(Nanjing Weibo Software Technology Co., Ltd.)** | CHINA | CCSA |
| **National Instruments Corp.**<br>**(National Instruments Corporation)** | UNITED STATES | ETSI |
| **National Radio Research Agency**<br>**(National Radio Research Agency)** | KOREA (REPUBLIC OF) | TTA |
| **National Spectrum Consortium**<br>**(National Spectrum Consortium)** | UNITED STATES | ATIS |
| **National Technical Assistance**<br>**(National Technical Assistance Centre)** | UNITED KINGDOM | ETSI |
| **nbn co Limited**<br>**(nbn co Limited (ABN 86 136 533 741))** | AUSTRALIA | ETSI |
| **NCI Agency**<br>**(NATO Communication and Information Agency)** | NETHERLANDS | ETSI |
| **NCIS**<br>**(National Criminal Investigation Service)** | NORWAY | ETSI |
| **NCSC**<br>**(National Cyber Security Centre)** | UNITED KINGDOM | ETSI |
| **NDRE**<br>**(National Defence Radio Establishment)** | SWEDEN | ETSI |
| **NEC Corporation**<br>**(NEC Corporation)** | JAPAN | ARIB |
| **NEC Corporation**<br>**(NEC Corporation)** | JAPAN | ETSI |
| **NEC Corporation.**<br>**(NEC Corporation)** | JAPAN | TTC |
| **NEC Europe Ltd**<br>**(NEC Europe Ltd)** | UNITED KINGDOM | ETSI |
| **NEC Telecom MODUS Ltd.**<br>**(NEC Telecom MODUS Ltd.)** | UNITED KINGDOM | ETSI |
| **NEMERGENT**<br>**(NEMERGENT SOLUTIONS SL)** | SPAIN | ETSI |
| **NERCDTV**<br>**(Shanghai National Engineering Research Center of Digital Television Co.,Ltd.)** | CHINA | CCSA |
| **Netherlands Police**<br>**(Netherlands Police, Division MDC)** | NETHERLANDS | ETSI |
| **Netscout Systems Inc.**<br>**(Netscout Systems Inc.)** | UNITED STATES | ETSI |
| **Network Rail**<br>**(Network Rail infrastructure limited)** | UNITED KINGDOM | ETSI |
| **New H3C Technologies Co., Ltd.**<br>**(New H3C Technologies Co., Ltd.)** | CHINA | CCSA |
| **NextNav**<br>**(NextNav)** | UNITED STATES | ATIS |
| **NHK**<br>**(NHK (Japan Broadcasting Corporation))** | JAPAN | ARIB |
| **NICT**<br>**(National Institute of Information and Communications Technology)** | JAPAN | ARIB |
| **Niral**<br>**(Niral Networks Private Limited)** | INDIA | TSDSI |
| **NIST**<br>**(National Institute of Standards and Technology)** | UNITED STATES | ATIS |

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| **Nkom**<br>**(Norwegian Communications Authority)** | NORWAY | ETSI |
| **Nokia**<br>**(Nokia)** | UNITED STATES | ATIS |
| **Nokia Belgium**<br>**(Nokia Bell N.V.)** | BELGIUM | ETSI |
| **Nokia Corporation**<br>**(Nokia Corporation)** | FINLAND | ETSI |
| **Nokia Denmark**<br>**(Nokia Denmark A/S)** | DENMARK | ETSI |
| **Nokia France**<br>**(Nokia Networks France)** | FRANCE | ETSI |
| **Nokia Germany**<br>**(Nokia Solutions and Networks GmbH & Co. KG)** | GERMANY | ETSI |
| **Nokia Hungary**<br>**(Nokia Solutions and Networks Kft.)** | HUNGARY | ETSI |
| **Nokia Japan**<br>**(Nokia Japan)** | JAPAN | ARIB |
| **Nokia Korea**<br>**(Nokia Korea)** | KOREA (REPUBLIC OF) | TTA |
| **Nokia Poland**<br>**(Nokia Solutions and Networks Sp. z.o.o.)** | POLAND | ETSI |
| **Nokia Shanghai Bell**<br>**(Nokia Shanghai Bell Co., Ltd)** | CHINA | CCSA |
| **Nokia Solutions & Networks (I)**<br>**(Nokia Solutions and Networks India Pvt. Ltd.)** | INDIA | TSDSI |
| **Nokia UK**<br>**(Nokia UK Ltd.)** | UNITED KINGDOM | ETSI |
| **Nordic Semiconductor ASA**<br>**(Nordic Semiconductor ASA)** | NORWAY | ETSI |
| **NOVAMINT**<br>**(NOVAMINT)** | UNITED KINGDOM | ETSI |
| **NTIA**<br>**(National Telecommunications and Information Administration)** | UNITED STATES | ATIS |
| **NTPU**<br>**(National Taipei University)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **NTT**<br>**(Nippon Telegraph and Telephone Corporation (NTT))** | JAPAN | TTC |
| **NTT corporation**<br>**(Nippon Telegraph and Telephone Corporation)** | JAPAN | ETSI |
| **NTT DOCOMO INC.**<br>**(NTT DOCOMO INC.)** | JAPAN | TTC |
| **NTT DOCOMO INC..**<br>**(NTT DOCOMO INC.)** | JAPAN | ARIB |
| **NTT-AT Corp.**<br>**(NTT Advanced Technology Corporation)** | JAPAN | TTC |
| **NTU**<br>**(National Taiwan University)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **Nubia Technology Co.,Ltd**<br>**(Nubia Technology Co.,Ltd)** | CHINA | CCSA |
| **NUFRONT**<br>**(Nufront (Beijing) Technology Co., Ltd.)** | CHINA | CCSA |
| **NVIDIA**<br>**(NVIDIA Corporation)** | UNITED STATES | ATIS |
| **NXP Semiconductors Netherlands**<br>**(NXP Semiconductors Netherlands B.V.)** | NETHERLANDS | ETSI |
| **NYCU**<br>**(National Yang Ming Chiao Tung University)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **Odido**<br>**(Odido Netherlands B.V.)** | NETHERLANDS | ETSI |
| **Ofcom (CH)**<br>**(Ofcom (CH))** | SWITZERLAND | ETSI |
| **Ofcom (U.K.)**<br>**(Ofcom - Office of Communications (U.K.))** | UNITED KINGDOM | ETSI |
| **Oki Electric Industry Co. Ltd.** | JAPAN | TTC |

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| **(OKi Electric Industry Co., Ltd)** | | |
| **Omnispace**<br>**(Omnispace)** | UNITED STATES | ATIS |
| **ONE Media 3.0 LLC**<br>**(ONE Media 3.0 LLC)** | UNITED STATES | ATIS |
| **one2many B.V.**<br>**(one2many B.V.)** | NETHERLANDS | ETSI |
| **OnePlus**<br>**(OnePlus (Shenzhen) Technology Co., LTD)** | CHINA | CCSA |
| **OPPO**<br>**(Guangdong OPPO Mobile Telecommunications Corp.,Ltd.)** | CHINA | ETSI |
| **OPPO (chongqing) Intelligence**<br>**(OPPO (chongqing) Intelligence Technology Limited)** | CHINA | CCSA |
| **OPPO Beijing**<br>**(Beijing OPPO Telecommunications Corp., ltd.)** | CHINA | CCSA |
| **OptM Media**<br>**(OptM Media Solutions Private Limited)** | INDIA | TSDSI |
| **OQTEC**<br>**(OQ TECHNOLOGY)** | LUXEMBOURG | ETSI |
| **Oracle Corporation**<br>**(Oracle Corporation)** | UNITED STATES | ETSI |
| **Orange**<br>**(Orange)** | FRANCE | ETSI |
| **Orange Romania**<br>**(Orange Romania)** | ROMANIA | ETSI |
| **Orange Spain**<br>**(France Telecom España S.A.U.)** | SPAIN | ETSI |
| **Orange UK**<br>**(Orange Brand Services Ltd)** | UNITED KINGDOM | ETSI |
| **ORS**<br>**(Österreichische Rundfunksender GmbH & Co KG)** | AUSTRIA | ETSI |
| **OTD_US**<br>**(OTD_US)** | UNITED STATES | ATIS |
| **OTECH**<br>**(OTECH Germany GmbH)** | GERMANY | ETSI |
| **P.I. WORKS**<br>**(P.I. WORKS TR BILISIM HIZMETLERI A.S.)** | TÜRKIYE | ETSI |
| **Panasonic Holdings Corporation**<br>**(Panasonic Holdings Corporation)** | JAPAN | ARIB |
| **PANASONIC R&D Center Germany**<br>**(PANASONIC R&D Center Germany GmbH)** | GERMANY | ETSI |
| **PCCW Global B.V.**<br>**(PCCW Global B.V.)** | FRANCE | ETSI |
| **Peking University**<br>**(Peking University)** | CHINA | CCSA |
| **Pengcheng laboratory**<br>**(Pengcheng laboratory)** | CHINA | CCSA |
| **Peraton Labs**<br>**(Peraton Labs)** | UNITED STATES | ATIS |
| **Philips International B.V.**<br>**(Philips International B.V.)** | NETHERLANDS | ETSI |
| **PHY Wireless**<br>**(PHY Wireless)** | UNITED STATES | ATIS |
| **PIDS**<br>**(PIDS)** | NETHERLANDS | ETSI |
| **Pivotal Commware**<br>**(Pivotal Commware)** | UNITED STATES | ATIS |
| **Plan-S**<br>**(Plan S Uydu ve Uzay Teknolojileri A.S)** | TÜRKIYE | ETSI |
| **PML**<br>**(Purple Mountain Laboratories: Networking, Communications and Security)** | CHINA | CCSA |
| **Polaris Wireless**<br>**(Polaris Wireless)** | UNITED STATES | ATIS |
| **Polisen**<br>**(Polismyndigheten)** | SWEDEN | ETSI |

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| **POST Luxembourg**<br>**(POST Luxembourg)** | LUXEMBOURG | ETSI |
| **Prasar Bharati**<br>**(Prasar Bharati)** | INDIA | TSDSI |
| **Proximus Plc**<br>**(Proximus Plc)** | BELGIUM | ETSI |
| **PSCE**<br>**(Public Safety Communication Europe Forum)** | BELGIUM | ETSI |
| **PT PORTUGAL SGPS SA**<br>**(PT Portugal SGPS SA)** | PORTUGAL | ETSI |
| **PTS**<br>**(Swedish Post and Telecom Authority)** | SWEDEN | ETSI |
| **Public Safety Canada**<br>**(Public Safety Canada)** | CANADA | ETSI |
| **Qihoo 360**<br>**(Qihoo 360 Technology Co., Ltd.)** | CHINA | CCSA |
| **Qorvo**<br>**(Qorvo)** | UNITED STATES | ETSI |
| **Qualcomm Austria RFFE GmbH**<br>**(Qualcomm Austria RFFE GmbH)** | AUSTRIA | ETSI |
| **QUALCOMM Europe Inc. - Italy**<br>**(QUALCOMM Europe Inc. - Italy Branch Office)** | ITALY | ETSI |
| **QUALCOMM Europe Inc. - Spain**<br>**(QUALCOMM Europe Inc. - Spain Branch Office)** | SPAIN | ETSI |
| **Qualcomm Finland RFFE Oy**<br>**(Qualcomm Finland RFFE Oy)** | FINLAND | ETSI |
| **Qualcomm France**<br>**(Qualcomm France SARL)** | FRANCE | ETSI |
| **Qualcomm Germany**<br>**(Qualcomm Germany GmbH)** | GERMANY | ETSI |
| **Qualcomm Incorporated**<br>**(Qualcomm Incorporated)** | UNITED STATES | ATIS |
| **Qualcomm India Pvt Ltd**<br>**(Qualcomm India Pvt Ltd)** | INDIA | TSDSI |
| **QUALCOMM JAPAN LLC.**<br>**(QUALCOMM JAPAN LLC.)** | JAPAN | ARIB |
| **Qualcomm Korea**<br>**(Qualcomm Korea)** | KOREA (REPUBLIC OF) | TTA |
| **Qualcomm Tech. Netherlands B.V**<br>**(Qualcomm Technologies Netherlands B.V.)** | NETHERLANDS | ETSI |
| **Qualcomm Technologies Int**<br>**(Qualcomm Technologies International, Ltd)** | UNITED KINGDOM | ETSI |
| **Qualcomm Technologies Ireland**<br>**(QT Technologies Ireland Limited)** | IRELAND | ETSI |
| **Quanray**<br>**(Shanghai Quanray Electronics Co., Ltd.)** | CHINA | CCSA |
| **Quectel**<br>**(Quectel Wireless Solutions Co., Ltd.)** | CHINA | CCSA |
| **RadiSys**<br>**(RadiSys Inc.)** | CANADA | ETSI |
| **Rakuten Mobile, Inc**<br>**(Rakuten Mobile, Inc)** | JAPAN | ARIB |
| **RATEL**<br>**(Regulatory Authority For Electronic Communications and Postal Services)** | SERBIA | ETSI |
| **Reliance Jio**<br>**(Reliance Jio)** | INDIA | TSDSI |
| **RICHTEK KOREA**<br>**(RICHTEK KOREA)** | KOREA (REPUBLIC OF) | TTA |
| **RISE**<br>**(RISE Research Institutes of Sweden)** | SWEDEN | ETSI |
| **ROBERT BOSCH GmbH**<br>**(ROBERT BOSCH GmbH)** | GERMANY | ETSI |
| **Rogers Communications Canada**<br>**(Rogers Communications Canada Inc.)** | CANADA | ETSI |
| **ROHDE & SCHWARZ** | GERMANY | ETSI |

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| **(ROHDE & SCHWARZ GmbH & Co.KG)** | | |
| **Ruijie Network Co. Ltd**<br>**(Ruijie Network Co. Ltd)** | CHINA | CCSA |
| **SAICT**<br>**(Shenzhen Academy of Information and Communication Technology)** | CHINA | CCSA |
| **Samsung Electronics Co., Ltd**<br>**(Samsung Electronics Co., Ltd.)** | KOREA (REPUBLIC OF) | TTA |
| **Samsung Electronics Czech**<br>**(Samsung Electronics Czech)** | CZECH REPUBLIC | ETSI |
| **Samsung Electronics France SA**<br>**(Samsung Electronics France SA)** | FRANCE | ETSI |
| **Samsung Electronics GmbH**<br>**(Samsung Electronics GmbH)** | GERMANY | ETSI |
| **Samsung Electronics Iberia SA**<br>**(Samsung Electronics Iberia SA)** | SPAIN | ETSI |
| **Samsung Electronics Nordic AB**<br>**(Samsung Electronics Nordic AB)** | SWEDEN | ETSI |
| **Samsung Electronics Polska**<br>**(Samsung Electronics Polska)** | POLAND | ETSI |
| **Samsung Guangzhou Mobile R&D**<br>**(Samsung Guangzhou Mobile R&D Center)** | CHINA | CCSA |
| **Samsung Nanjing**<br>**(Samsung Electronic (China) R&D Center)** | CHINA | CCSA |
| **Samsung R&D Institute India**<br>**(Samsung R&D Institute India - Bangalore Pvt. Ltd)** | INDIA | TSDSI |
| **SAMSUNG R&D INSTITUTE JAPAN**<br>**(SAMSUNG R&D INSTITUTE JAPAN)** | JAPAN | ARIB |
| **Samsung R&D Institute UK**<br>**(Samsung R&D Institute UK)** | UNITED KINGDOM | ETSI |
| **Samsung Research America**<br>**(Samsung Research America)** | UNITED STATES | ATIS |
| **Samsung Shenzhen**<br>**(Samsung Network R&D Center-Shenzhen)** | CHINA | CCSA |
| **Sandvine Incorporated**<br>**(Sandvine Incorporated)** | CANADA | ETSI |
| **Sanechips**<br>**(Sanechips Technology Co. , Ltd.)** | CHINA | CCSA |
| **Sateliot**<br>**(Satelio IoT Services)** | SPAIN | ETSI |
| **Schindler**<br>**(Schindler Elevator Ltd)** | SWITZERLAND | ETSI |
| **SDI Squared**<br>**(SDI Squared LLC)** | UNITED STATES | ETSI |
| **Sectra Communications AB**<br>**(Sectra Communications AB)** | SWEDEN | ETSI |
| **Security Service**<br>**(Swedish Security Service)** | SWEDEN | ETSI |
| **Semtech Neuchatel SA**<br>**(Semtech Neuchatel SA)** | SWITZERLAND | ETSI |
| **Sennheiser Electronic GmbH**<br>**(Sennheiser Electronic GmbH & Co. KG)** | GERMANY | ETSI |
| **Sensus UK**<br>**(Sensus UK Systems Limited)** | UNITED KINGDOM | ETSI |
| **Sepura Ltd**<br>**(Sepura Limited)** | UNITED KINGDOM | ETSI |
| **Sequans Communications**<br>**(Sequans Communications)** | FRANCE | ETSI |
| **SES S.A.**<br>**(SES S.A.)** | LUXEMBOURG | ETSI |
| **SETS**<br>**(Society for Electronic Transactions and Security)** | INDIA | TSDSI |
| **SEU**<br>**(Southeast University)** | CHINA | CCSA |
| **SGDSN**<br>**(Secrétariat Général de la Défense et de la Sécurité Nationale (SGDSN))** | FRANCE | ETSI |

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| **SGITG**<br>**(State Grid Information & Telecommunication Group Co., Ltd.)** | CHINA | CCSA |
| **SGS Wireless**<br>**(SGS Wireless)** | UNITED KINGDOM | ETSI |
| **Shanghai Chen Si Electronics**<br>**(Shanghai Chen Si Electronics Technology Co., Ltd)** | CHINA | CCSA |
| **Shanghai Jiao Tong University**<br>**(Shanghai Jiao Tong University)** | CHINA | CCSA |
| **Shanghai Tejet Com Technology**<br>**(Shanghai Tejet Communications Technology Co., Ltd.)** | CHINA | CCSA |
| **SHARP Corporation**<br>**(SHARP Corporation)** | JAPAN | ARIB |
| **Shenzhen Heytap**<br>**(Shenzhen Heytap Technology Corp.,Ltd.)** | CHINA | CCSA |
| **ShenZhen Zhongxing Shitong**<br>**(ShenZhen Zhongxing Shitong Tech. Co.,Ltd.)** | CHINA | CCSA |
| **SIA**<br>**(Shenyang Institute of Automation, Chinese Academy of Sciences)** | CHINA | CCSA |
| **Siemens AG**<br>**(Siemens AG)** | GERMANY | ETSI |
| **Signalchip Innovations Pvt.**<br>**(Signalchip Innovations Pvt. Ltd.)** | INDIA | TSDSI |
| **SIST**<br>**(Slovenian Institute for Standardisation)** | SLOVENIA | ETSI |
| **Sisvel**<br>**(Sisvel International S.A.)** | LUXEMBOURG | ETSI |
| **SK Telecom**<br>**(SK TELECOM)** | KOREA (REPUBLIC OF) | TTA |
| **SKY Perfect JSAT Corporation**<br>**(SKY Perfect JSAT Corporation)** | JAPAN | ARIB |
| **Skylo Technologies**<br>**(Skylo Technologies)** | UNITED STATES | ATIS |
| **Skyworks Solutions Inc.**<br>**(Skyworks Solutions Inc.)** | UNITED STATES | ETSI |
| **SmarterMicro Inc.**<br>**(Smarter Microelectronics(Guangzhou) Co.,Ltd)** | CHINA | CCSA |
| **SnT - University of Luxembourg**<br>**(Interdisciplinary Centre for Security, Reliability and Trust/University of Luxembourg)** | LUXEMBOURG | ETSI |
| **SoftBank Corp.**<br>**(SoftBank Corp.)** | JAPAN | ARIB |
| **Softel Systems**<br>**(Softel Systems Pty Ltd)** | AUSTRALIA | ETSI |
| **Softil Ltd**<br>**(Softil Ltd)** | ISRAEL | ETSI |
| **Sony Corporation**<br>**(Sony Corporation)** | JAPAN | ARIB |
| **Sony Europe B.V.**<br>**(Sony Europe B.V.)** | UNITED KINGDOM | ETSI |
| **Sony Group Corporation**<br>**(Sony Group Corporation)** | JAPAN | ARIB |
| **Sooktha Consulting Pvt Ltd**<br>**(Sooktha Consulting Pvt Ltd)** | INDIA | TSDSI |
| **Southern Linc.**<br>**(Southern Linc.)** | UNITED STATES | ATIS |
| **Southwest Jiaotong university**<br>**(Southwest Jiaotong university)** | CHINA | CCSA |
| **SpaceX**<br>**(SpaceX Netherlands B.V)** | NETHERLANDS | ETSI |
| **Spark NZ Ltd**<br>**(Spark NZ Ltd)** | NEW ZEALAND | ATIS |
| **Spirent Communications**<br>**(Spirent Communications)** | UNITED STATES | ETSI |
| **Sporton International Inc**<br>**(Sporton International Inc.)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **Spreadtrum Communications** | CHINA | CCSA |

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| **(Spreadtrum Communications (Shanghai) Co., Ltd.)** | | |
| **SRTC**<br>**(The State Radio_monitoring_center Testing Center)** | CHINA | CCSA |
| **SS8**<br>**(SS8 Networks Inc.)** | UNITED STATES | ETSI |
| **SSNS**<br>**(Special Service for the National Security of Hungary)** | HUNGARY | ETSI |
| **Starpoint**<br>**(Beijing Starpoint Technology Company Limited)** | CHINA | CCSA |
| **STE IDIRECT IRELAND LTD**<br>**(ST ENGINEERING IDIRECT (IRELAND) LIMITED)** | IRELAND | ETSI |
| **Stellar**<br>**(Stellar telecommunications)** | FRANCE | ETSI |
| **STMicroelectronics**<br>**(STMicroelectronics International NV)** | SWITZERLAND | ETSI |
| **Sumitomo Elec. Industries, Ltd**<br>**(Sumitomo Electric Industries, Ltd.)** | JAPAN | ARIB |
| **SUTD**<br>**(Singapore University of Technology and Design)** | SINGAPORE | ETSI |
| **Swift Navigation**<br>**(Swift Navigation)** | UNITED STATES | ATIS |
| **SWISSCOM**<br>**(SWISSCOM SA)** | SWITZERLAND | ETSI |
| **SWR**<br>**(Südwestrundfunk)** | GERMANY | ETSI |
| **SyncTechno Inc.**<br>**(SyncTechno Inc.)** | KOREA (REPUBLIC OF) | TTA |
| **Syniverse**<br>**(M/s Syniverse Technologies Services India Pvt. Ltd.)** | INDIA | TSDSI |
| **TA**<br>**(Tantra Analyst)** | UNITED STATES | ETSI |
| **Tait Europe Limited**<br>**(Tait Europe Limited)** | AUSTRIA | ETSI |
| **Tata Elxsi Limited.**<br>**(Tata Elxsi Limited.)** | INDIA | TSDSI |
| **TCL**<br>**(Shenzhen TCL New Technology Company Ltd.)** | CHINA | CCSA |
| **TCS**<br>**(TATA Consultancy Services)** | INDIA | TSDSI |
| **TD Tech Ltd**<br>**(TD Tech Ltd)** | CHINA | CCSA |
| **TDF**<br>**(TDF SAS)** | FRANCE | ETSI |
| **Tech Mahindra Limited**<br>**(Tech Mahindra Limited)** | INDIA | TSDSI |
| **Tejas Network Limited**<br>**(Tejas Network Limited)** | INDIA | TSDSI |
| **Tektronix GmbH**<br>**(Tektronix GmbH)** | GERMANY | ETSI |
| **TELECOM ITALIA S.p.A.**<br>**(Telecom Italia S.p.A.)** | ITALY | ETSI |
| **Telefonica Germany GmbH**<br>**(Telefónica Germany GmbH & Co OHG)** | GERMANY | ETSI |
| **TELEFONICA S.A.**<br>**(TELEFONICA S.A.)** | SPAIN | ETSI |
| **Telekom Deutschland GmbH**<br>**(Telekom Deutschland GmbH)** | GERMANY | ETSI |
| **TELENOR ASA**<br>**(Telenor ASA)** | NORWAY | ETSI |
| **Telesat International Limited**<br>**(Telesat International Limited)** | UNITED KINGDOM | ETSI |
| **Telia Company AB**<br>**(Telia Company AB)** | SWEDEN | ETSI |
| **Telit Communications S.p.A.**<br>**(Telit Communications S.p.A.)** | ITALY | ETSI |

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|---|---|---|
| **Telstra Limited**<br>**(Telstra Limited)** | AUSTRALIA | ETSI |
| **TELUS**<br>**(TELUS)** | CANADA | ATIS |
| **Tencent**<br>**(Shenzhen city Tencent computer system Co. Ltd.)** | CHINA | CCSA |
| **Tencent Cloud**<br>**(Tencent cloud computing Beijing Co., Ltd)** | CHINA | CCSA |
| **Teradyne**<br>**(Teradyne)** | UNITED STATES | ATIS |
| **TerreStar Solutions Inc.**<br>**(TerreStar Solutions Inc.)** | CANADA | ATIS |
| **Texas A&M University**<br>**(Texas A&M University)** | UNITED STATES | ETSI |
| **TEXAS Instruments**<br>**(Texas Instruments France)** | FRANCE | ETSI |
| **THALES**<br>**(THALES)** | FRANCE | ETSI |
| **THURAYA TELECOM CO.**<br>**(THURAYA TELECOMMUNICATIONS COMPANY)** | UNITED ARAB EMIRATES | ETSI |
| **Tiami Networks**<br>**(Tiami Networks)** | UNITED STATES | ATIS |
| **TII**<br>**(Technology Innovation Institute)** | UNITED ARAB EMIRATES | ETSI |
| **T-Mobile Austria GmbH**<br>**(T-Mobile AUSTRIA GmbH)** | AUSTRIA | ETSI |
| **T-Mobile Polska S.A.**<br>**(T-Mobile Polska Spolka Akcyjna)** | POLAND | ETSI |
| **T-Mobile USA**<br>**(T-Mobile USA, Inc.)** | UNITED STATES | ETSI |
| **T-Mobile USA Inc.**<br>**(T-Mobile USA Inc.)** | UNITED STATES | ATIS |
| **TNO**<br>**(TNO)** | NETHERLANDS | ETSI |
| **Tongji University**<br>**(Tongji University)** | CHINA | CCSA |
| **Toshiba**<br>**(Toshiba)** | UNITED KINGDOM | ETSI |
| **TOWE Wireless**<br>**(Sushi TOWE Wireless Testing (Shenzhen) Co.,Ltd.)** | CHINA | ETSI |
| **TOYOTA Info Technology Center**<br>**(TOYOTA Info Technology Center USA, Inc.)** | UNITED STATES | ETSI |
| **TOYOTA MOTOR CORPORATION**<br>**(TOYOTA MOTOR CORPORATION)** | JAPAN | TTC |
| **TRAFICOM**<br>**(The Finnish Transport and Communications Agency)** | FINLAND | ETSI |
| **Trafikverket**<br>**(Trafikverket)** | SWEDEN | ETSI |
| **Transsion Holdings**<br>**(Transsion Holdings)** | CHINA | CCSA |
| **TransUnion**<br>**(TransUnion)** | UNITED STATES | ATIS |
| **Trimble**<br>**(Trimble)** | UNITED STATES | ATIS |
| **Tron Future Tech Inc.**<br>**(Tron Future Tech Inc.)** | TAIWAN, PROVINCE OF CHINA | ETSI |
| **TTP plc**<br>**(TTP plc)** | UNITED KINGDOM | ETSI |
| **Turk Telekomunikasyon A.S.**<br>**(Turk Telekomunikasyon A.S.)** | TÜRKIYE | ETSI |
| **TURKCELL**<br>**(Turkcell Iletisim Hizmetleri A.S.)** | TÜRKIYE | ETSI |
| **U.S. Department of Defense**<br>**(U.S. Department of Defense)** | UNITED STATES | ATIS |
| **U.S. Department of Transport.** | UNITED STATES | ATIS |

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|---|---|---|
| **(U.S. Department of Transportation)** | | |
| **U.S. National Security Agency**<br>**(US National Security Agency)** | UNITED STATES | ATIS |
| **Uangel**<br>**(Uangel Corporation)** | KOREA (REPUBLIC OF) | TTA |
| **ubinexus**<br>**(Beijing Ubinexus Technology Development Co., Ltd)** | CHINA | CCSA |
| **u-blox AG**<br>**(u-blox AG)** | SWITZERLAND | ETSI |
| **UESTC**<br>**(University of Electronic Science and Technology of China)** | CHINA | CCSA |
| **UL VS Ltd**<br>**(UL VS Ltd)** | UNITED KINGDOM | ETSI |
| **UMA**<br>**(Universidad de Malaga)** | SPAIN | ETSI |
| **umlaut**<br>**(umlaut communications GmbH)** | GERMANY | ETSI |
| **UNIBO**<br>**(ALMA MATER STUDIORUM Università di Bologna)** | ITALY | ETSI |
| **UniBw M**<br>**(University of the Bundeswehr Munich)** | GERMANY | ETSI |
| **Unicom Broadband Online**<br>**(Unicom Broadband Online Co., Ltd.)** | CHINA | CCSA |
| **Unicompay**<br>**(Unicompay Co., Ltd.)** | CHINA | CCSA |
| **Union Inter. Chemins de Fer**<br>**(Union Internationale des Chemins de Fer)** | FRANCE | ETSI |
| **Union Telephone Company**<br>**(Union Telephone Company)** | UNITED STATES | ATIS |
| **Unisoc**<br>**(Unisoc (Shanghai) Technologies Co., Ltd.)** | CHINA | CCSA |
| **Unisoc Beijing**<br>**(Beijing Unisoc Communications Technology Co., Ltd.)** | CHINA | CCSA |
| **UPV/EHU**<br>**(Universidad del País Vasco/Euskal Herriko Unibertsitatea)** | SPAIN | ETSI |
| **US Cellular Corporation.**<br>**(US Cellular Corporation/TDS.)** | UNITED STATES | ATIS |
| **UTIMACO TS GmbH**<br>**(UTIMACO TS GmbH)** | GERMANY | ETSI |
| **UTokyo**<br>**(The University of Tokyo)** | JAPAN | ETSI |
| **Vaan Megam**<br>**(Vaan Megam Networks)** | INDIA | TSDSI |
| **Valeo**<br>**(Valeo Telematik und Akustik GmbH)** | GERMANY | ETSI |
| **VALID SOLUCIONES TECNOLÓGICAS**<br>**(VALID SOLUCIONES TECNOLÓGICAS S.A.U)** | SPAIN | ETSI |
| **Valid8**<br>**(Valid8.com, Inc.)** | UNITED STATES | ETSI |
| **Vanchip**<br>**(Vanchip (Tianjin) Technology Co., Ltd.)** | CHINA | CCSA |
| **Verizon Denmark**<br>**(Verizon Denmark A/S)** | DENMARK | ETSI |
| **Verizon Spain**<br>**(Verizon Spain S.L.)** | SPAIN | ETSI |
| **Verizon Sweden**<br>**(Verizon Sweden Aktiebolag 2116)** | SWEDEN | ETSI |
| **Verizon Switzerland AG**<br>**(Verizon Switzerland AG)** | SWITZERLAND | ETSI |
| **Verizon UK Ltd**<br>**(Verizon UK Ltd)** | UNITED KINGDOM | ETSI |
| **Vestel**<br>**(Vestel Elektronik Sanayi ve Ticaret A.S)** | TÜRKIYE | ETSI |
| **ViaSat Satellite Holdings Ltd**<br>**(ViaSat Satellite Holdings Ltd)** | UNITED KINGDOM | ETSI |

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| **VIAVI Solutions**<br>**(Viavi Solutions UK Ltd.)** | UNITED KINGDOM | ETSI |
| **vivo Mobile Com. (Chongqing)**<br>**(vivo Mobile Communication (Chongqing) Co., Ltd)** | CHINA | CCSA |
| **vivo Mobile Communication (H)**<br>**(vivo Mobile Communication (Hangzhou) Co., Ltd.)** | CHINA | CCSA |
| **vivo Mobile Communication (S)**<br>**(vivo Mobile Communication (Shenzhen) Co., Ltd.)** | CHINA | CCSA |
| **vivo Mobile Communication Co.,**<br>**(vivo Mobile Communication Co., Ltd)** | CHINA | CCSA |
| **VIVO TECH GmbH**<br>**(VIVO TECH GmbH)** | GERMANY | ETSI |
| **Vodafone GmbH**<br>**(Vodafone GmbH)** | GERMANY | ETSI |
| **VODAFONE Group Plc**<br>**(Vodafone Group Plc)** | UNITED KINGDOM | ETSI |
| **Vodafone Ireland Plc**<br>**(Vodafone Ireland Plc)** | IRELAND | ETSI |
| **Vodafone Italia SpA**<br>**(Vodafone Italia SpA)** | ITALY | ETSI |
| **Vodafone Romania S.A.**<br>**(Vodafone Romania S.A.)** | ROMANIA | ETSI |
| **Vodafone Telekomünikasyon A.S.**<br>**(Vodafone Telekomünikasyon A.S.)** | TÜRKIYE | ETSI |
| **VoiceAge Corporation**<br>**(VoiceAge Corporation)** | CANADA | ETSI |
| **Volkswagen AG**<br>**(Volkswagen AG)** | GERMANY | ETSI |
| **VSENS**<br>**(Unicom Vsens Telecommunications Co., Ltd)** | CHINA | CCSA |
| **VTT**<br>**(VTT Technical Research Centre of Finland)** | FINLAND | ETSI |
| **WE Certification Oy**<br>**(WE Certification Oy)** | FINLAND | ETSI |
| **Wiliot Ltd.**<br>**(Wiliot Ltd.)** | ISRAEL | ETSI |
| **WILUS Inc.**<br>**(WILUS Inc.)** | KOREA (REPUBLIC OF) | TTA |
| **Wipro GE**<br>**(Wipro GE Healthcare Private Limited)** | INDIA | TSDSI |
| **Wisig Networks Pvt Ltd**<br>**(Wisig Networks Pvt Ltd)** | INDIA | TSDSI |
| **Wuhan CICT Mobile**<br>**(Wuhan CICT Mobile Communications Technology Co., Ltd.)** | CHINA | CCSA |
| **Wuhan Hongxin Technical**<br>**(Wuhan Hongxin Technical Services Co., Ltd.)** | CHINA | CCSA |
| **Wuhan Hongxin Technology**<br>**(Wuhan Hongxin Technology Development Co., Ltd.)** | CHINA | CCSA |
| **Xiaomi Communications**<br>**(Xiaomi Communications)** | CHINA | CCSA |
| **Xiaomi EV Technology**<br>**(Xiaomi EV Technology Co., Ltd.)** | CHINA | CCSA |
| **Xiaomi Technology**<br>**(Xiaomi Technology)** | CHINA | CCSA |
| **Xidian University**<br>**(Xidian University)** | CHINA | CCSA |
| **Xilinx Ireland**<br>**(Xilinx Ireland)** | IRELAND | ETSI |
| **Zhejiang Lab**<br>**(Zhejiang Lab)** | CHINA | CCSA |
| **Zhejiang University**<br>**(Zhejiang University)** | CHINA | CCSA |
| **ZITiS**<br>**(Central Office for Information Technology in the Security Sector)** | GERMANY | ETSI |
| **Zollkriminalamt (ZKA)** | GERMANY | ETSI |

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| **(Zollkriminalamt (ZKA))** | | |
| **ZONSON**<br>**(ZONSON SAMRT AUTO CORPORATION)** | CHINA | CCSA |
| **ZTE**<br>**(ZTE Telecom India Pvt Ltd)** | INDIA | TSDSI |
| **ZTE Corporation**<br>**(ZTE Corporation)** | CHINA | CCSA |
| **ZTE Corporation**<br>**(ZTE Corporation)** | CHINA | ETSI |
| **ZTE FRANCE SASU**<br>**(ZTE FRANCE SASU)** | FRANCE | ETSI |
| **ZTE Italia**<br>**(ZTE Italia S.R.L)** | ITALY | ETSI |
| **ZTE JAPAN K.K.**<br>**(ZTE JAPAN K.K..)** | JAPAN | TTC |
| **ZTE Japan K.K.**<br>**(ZTE Japan K.K.)** | JAPAN | ARIB |
| **ZTE Korea Limited**<br>**(ZTE Korea Limited)** | KOREA (REPUBLIC OF) | TTA |
| **ZTE Photonics**<br>**(ZTE Photonics Technology Co.,Ltd.)** | CHINA | CCSA |
| **ZXNE**<br>**(ZXNE CORPORATION)** | CHINA | CCSA |

Total : 781 Individual Members

Any comments or problems with this application? Please let us know...

# Appendix 10

The Wayback Machine - https://web.archive.org/web/20130527114611/http://www.3gpp.org/FAQ





About 3GPP

# FAQ

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## Membership

### Who can become an Individual Member of 3GPP and how much does it cost?

Individual Members are by definition members of the Organizational Partners of 3GPP. This means that members of standardization bodies such as ETSI, ARIB, TTA, TTC, ATIS and CCSA have a right to take part in 3GPP. If your company becomes an ETSI member, please be informed that for participation in 3GPP you need to pay 3 units of contribution as a minimum except SMEs, Users, Universities, Public Research Bodies who should pay 2 units (instead of 1). If you determine 2 units for your company based on ICT business turnover, you have to add another unit of contribution. If you require further guidance on how to participate in 3GPP activities you should contact 3GPP Membership

### Who may participate in 3GPP meetings?

To attend a 3GPP meeting, you must be a 3GPP Individual Member (i.e. you must be a Member of one of the Organizational Partners involved in the project; ARIB, CCSA, ETSI, ATIS, TTA or TTC. A non-member company should seek membership with one of the above partners to be eligible to contribute and participate at 3GPP Meetings.

### Who shall fill in the 3GPP Individual Member Application form?

The person legally responsible for the requesting company shall fill in the form.

### What shall I do if a 3GPP company or official contact details change?

All changes of correspondence should be notified to 3GPPMembership

### Different membership categories?

The different membership categories of 3GPP are described in Section B of the 3GPP Working Procedures Look here>>> .

### Who may become an observer?

The status of Observer may be granted by the Organizational Partners to an entity which has the qualifications to become a future Partner.

3GPP Website:

Search and download specs, docs, CRs and more from the 3GPP FTP Server:
Advanced FTP Search

3GPP News
3GPP Partners News
3GPPlive tweets

7178 unique visitors average per day




Takehiro Nakamura, talks about the Release 12 prioritization process in December 2012, prior to the end of his highly succesful term as RAN Chairman

Four new videos have been uploaded...

Partners
Project Coordination Group (PCG)
Membership
3GPP Award - Roll of Honour
Mobile Competence Centre
Funding & Finance
Liaisons-page
Legal matters
3GPP Satisfaction survey

3GPP Scope
Tools and Templates

### Who may become a Guest Member and do guests have to pay any fees?

The Guest Status is for potential Individual Members who may be granted permission to participate in 3GPP for a maximum period of 6 months. Guest status is granted on a case-by-case basis by the Organizational Partners (see also 3GPP Working Procedures Article 10 ). If you like to apply for a Guest status, please complete the on-line 3GPP Application form.

**IMPORTANT NOTICE: The online application form for 3GPP Individual membership and 3GPP guest status is under construction, therefore please send any request for membership to 3GPPmembership@etsi.org**

No membership fees are requested for Guest applications.

### Who can apply for market representative Partnership?

Organisation who have the ability to offer market advice to 3GPP and to bring into 3GPP a consensus view of market requirements (e.g.,services, features and functionality) falling within the 3GPP scope (see also 3GPP Working Procedures, Article 7 and Annex E ) .

### Can an ETSI Observer become an Individual Member of 3GPP?

No, an ETSI Observer may "observe" all activities, but their participation is limited to the ETSI General Assembly only. Therefore, ETSI Observers have no participation rights in 3GPP. ETSI Observers have access to ETSI documentation and of course to 3GPP documentation since that is openly published on the web.

3GPP does have it's own category called "Observer" but that is entirely different and is used for potential Partners.

### Can an ETSI Applicant apply for 3GPP Membership?

YES, an Applicant means that your request to become an ETSI Member will be addressed (and normally approved) at the next General Assembly and that the company has specified they want to participate in 3GPP activities. See also above regarding 3GPP fees.

### Can an ETSI Member apply for 3GPP Guest status?

Yes, any ETSI Member who pays 1 or 2 Units of Contribution are eligible for 3GPP Guest status.

## 3GPP email exploder lists

### Are there discussion archives for the 3GPP exploder lists?

Home page of listserv

Then, just follow the links to the archives. For example, the archives for the main RAN email list

### How do I subscribe to the 3GPP exploder lists?

follow the instructions found >>>here

## Legal Matters

### What is the 3GPP IPR Policy?

The 3GPP Organizational Partners have agreed that their IPR policies should be respected and that their respective members should be encouraged to declare "their willingness to grant licenses on fair reasonable terms and conditions and on non discriminatory basis" (Article 3.1 of the Third Generation Partnership Project). For more information look **Here**

The above-mentioned principles are further reflected in Article 55 of the 3GPP Technical Working Procedures which request that each Individual Members should declare "at the earliest opportunity, any IPR which they believe to be essential, or potentially essential, to any work ongoing within 3GPP".

### What is the 3GPP policy on licensing?

Some aspects of 3GPP systems are covered by essential Intellectual Property Rights (IPR) - that is, patented technologies without which equipment cannot be implemented. The IPR vests in - i.e. the patents are held by - individual companies, and not by 3GPP itself or any of its Organizational Partners (OPs). All Individual Members of 3GPP abide by the IPR policies of the OP to which they belong; all such policies are broadly similar see also "What is the 3GPP IPR Policy", and require IPR holders to make licences available to all third parties, whether or not they are 3GPP Individual Members, under fair, reasonable and non-discriminatory (FRAND) terms.

Neither 3GPP nor its component OPs offer an IPR search service. It is the responsibility of each manufacturer / system implementor to seek and obtain its own licences from the individual IPR holders.

For more information, and a guide to the IPRs declared to each 3GPP OP, look here>>>

(Answer drafted 2005-09-12 by JMM.)

## What is the 3G Patent Platform?

On the fringe of standardization activities some telecom companies have set up a voluntary arrangement for the licensing of essential patents required to meet the standards published for 3G systems has emerged.

Please find a historical recap of the creation of the 3G Patent Platform. Thank you to note that Phase 3 has not started yet.

1. Discussions started in the UMTS IPR working Group (1998).

2. The UMTS IPR working group operated within the UIAP (UMTS Intellectual Property Association) to define the functions of the 3G Patent Platform.

The 3G Patent Platform will provide services for:

Evaluating,
Certifying and,
Licensing

essential patents for 3G Mobile communications.

3. Implementation of the 3G Patent Platform scheme.

The 3G Patent Platform will operate within a new profit service company governed by the members (essential patent holders and licensees). As of today this NEW CO is not operational since it is waiting for the approval of the US/EC/Japanese competition law authorities in order to launch the above-described activities.

More information...

## Is it true that a number 3GPP members are looking at setting up a patents cooperative, with the aim of reducing the royalties they pay each other for the use of patented technology in third-generation mobile systems?

1. Discussion started in the UMTS IPR working Group (1998),
2. Creation of the UIAP (UMTS Intellectual Property Association) which has performed the function of the definition the 3G Patent Platform scheme (Evaluation of a patent, certification of essentiality, licensing arrangements, etc.) and which is the legal owner of the 3G Patent Platform Specification.
3. Implementation of the scheme:

As of today NEW CO (implementing the 3G Patent Platform) has not be incorporated and the Patent Platform scheme is not operational as it is awaiting for the approval of the US/EC competition law authorities.

ETSI follows the development of the 3G Patent Platform but, as a neutral standard body, cannot take an active participation in this market initiative.

## Who owns the Technical Specifications and the Technical Reports approved by 3GPP?

According to the Article 3.2.2 of the Third Generation Partnership Project Agreement, the 3GPP Organizational Partners jointly own copyright on the Technical Specifications and the Technical Reports approved by 3GPP.

## Does a company implementing a product based on the 3GPP specifications have to pay any royalties to the 3GPP organization?

The Third Generation Partnership Project is not a legal entity but a Partnership Project between different standardization organizations in the field of telecommunications.

## Are meeting contributions to ETSI TC SMG publically available?

The GSM standardization work was transferred from CEPT to ETSI in 1991. TC SMG was closed at meeting #32 and TC SMG created to continue the work. Like almost all ETSI Technical Committees, participation in TC SMG and its working groups was open to all ETSI member organizations. That is, any bona fide representative of an ETSI member was free to participate. Exceptionally, other individuals could participate **by express invitation of the chairman**. Each meeting report contains a list of participants with their corporate affiliations.

Until the late 1990s, all meeting documents were circulated in paper form. Electronic files started to take over from paper in around 1997. Meeting documents ("TDocs") were distributed by post (later, by fax) in batches prior to the meeting, to those persons registered as regular participants in SMG or the appropriate working group, and many more documents were produced during the course of the meeting itself. Although a provision existed (and still exists) in the context of the IPR Policy for contributors to place restrictions on the distribution of TDocs via a formal notification at the time the document was provided, this was seldom if ever invoked. In the absence of such a condition, all TDocs were free of any restriction on subsequent distribution. Thus no restriction has ever been placed on how meeting participants dispose of the documents subsequent to their distribution before, during, or after the meeting. There were no non-disclosure agreements.

ETSI maintains a paper archive of the SMG TDocs, and bona fide representatives of current ETSI members can, by appointment, make an accompanied search of the archives. This facility extends to members which may not have been members at the time the document was originally produced.

TC-approved versions of ETSI “deliverables” (see ETSI Directives for formal definition of this term) would have been transferred by the support officer of the committee to the secretariat team responsible for publishing ETSI deliverables. That team would have made cosmetic (non-technical) modifications to the draft deliverables before issuing them. Depending on the type of “deliverable”, those documents would have been issued via National Standards Organizations (NSOs) either for immediate publication, or first via either a one-step or two-step national public enquiry and vote process prior to final publication

by ETSI. In ETSI parlance, “publication” of a deliverable is the final step in the development cycle of a technical standard, and has a precise meaning. That meaning is not “making publically available”, since draft deliverables released for public enquiry or for vote are "publically available" but not yet "published".

If the confidentiality conditions described above had been imposed on a TDoc by its authors, if the text of that TDoc was in due course incorporated into an ETSI "deliverable", then those conditions are regarded as anulled from the date on which the deliverable is published.

Collections of TDocs / meeting reports have from time to time been made available **to ETSI members** in CD or DVD form.

### Is permission needed to use the 3GPP logo in marketing collaterals or on a web site?

ETSI (European Telecommunications Standards Institute) is the sole owner of the following acronyms:

ETSI,
DECT,
UMTS,
3GPP and
TIPHON,

as well as the ETSI, TIPHON and 3GPP logos. ETSI Members shall use these Trade Marks in accordance with Collective Letter 1943. Authorization is needed to use the above mentioned acronyms and logos.

For further information contact the ETSI Legal Team.

### Can I use computer code included with a 3GPP TS to implement a product?

Yes. Some 3GPP Technical Specifications include computer code such as ASN.1 or XML (protocols), C language (codecs), ...; and some include test patterns (codecs) for verifying implementations. These are published to allow users of these TSs to implement real-world products. No permission is required from 3GPP or its Organizational Partners (OPs) to use this code in the design of products - e.g. to compile the C to implement a codec in machine code.

Nevertheless, there may be essential IPR involved with such a design, and implementors are obliged to seek licences to use that technology. See also **What is the 3GPP policy on licensing ?**
Moreover, the copyright of all 3GPP TSs and TRs vests jointly by all the 3GPP OPs. Other than for in-house copies for the purpose of further development of the 3GPP standard or for product design purposes, etc. you may not reproduce any part of a 3GPP TS or TR without seeking permission: use the form available here. This means that you must not provide verbatim copies of source code (or lightly modified copies) without seeking permission from 3GPP.

Finally, you are reminded that 3GPP TSs and TRs have no legal status, and you should not design products directly to them. See the advice notice on the cover page of every 3GPP TS and TR. Instead, use the technically identical publication of one of the OPs.

## Specifications

### Where can the rules, protocols or software needed to develop applications for UMTS be found?

A good place to start is on the 3GPP website , and particularly the specifications list.

Look at the titles of the specs for those which are appropriate. Perhaps 21.111, 31.102 and 31.111 might be relevant.

### What is the correlation between Stage 1, Stage 2 (GSM 3.90 and GSM 02.90) and Phase 1, Phase 2?

The "stage" nomenclature was an ancient CCITT invention, related to ISDN standardisation. "Stage 1" refers to the service description from a service-user’s point of view. "Stage 2" is a logical analysis, breaking the problem down into functional elements and the information flows amongst them. "Stage 3" is the concrete implementation of the protocols between physical elements onto which the functional elements have been mapped.

### Is there any simple guide to the different CAMEL specifications?

Unfortunately there is no single document acting as a guide to the CAMEL standards. Initial plans were published in ETSI ETR 244 in 1995, though this is so old as to be more or less useless now. GSM 10.78 is the CAMEL project plan, and this is probably the best thing. This may have been available as a temp doc to SMG meeting no. 25, but is still only in draft form, and has never been made publicly available.

In the SS7 arena,

GSM 02.78 / UMTS 22.078 is the Stage 1 (requirements) document.
GSM 03.78 / UMTS 23.078 is the Stage 2 (functions, conceptual data flow)
GSM 09.78 / UMTS 29.078 is the Stage 3 (protocol) - CAMEL Application Part (CAP)
CAP has been released in several phases:

Release 1996 = Phase 1
Release 1997 = Phase 2
Release 1998 = Phase 2
Release 1999 = Phase 3 (GSM and UMTS common spec)

For UMTS, 21.978 is a feasibility study on CAMEL control of Voice over IP.

In the Intelligent Network area, CAMEL is an extension of Core INAP, under the control of ETSI SPAN3 (formerly SPS3) - ignore for simplicity the Stage 1 and Stage 2 specifications, which were under ETSI SPAN6 (formerly NA6). Core INAP was released in sevaral phases:

CS1 = ETS 300 374 series,
CS2 = EN 301 140 series,
CS3 = EN 301 931 series.

It had originally been intended to split CS3 into two releases, and also to produce a CS4. These plans now seem to be on hold. Tthe ETSI phasing of the various Capability Sets was not strictly aligned with the ITU-T "equivalents", and this was a source of some confusion. For further information on SPAN please contact : spansupport@etsi.org Very recently, SPAN has been reorganised, and SPAN3's work is now to be found within SPAN12.

IN CAMEL phase 1 is an enhancement of Core INAP CS1. The protocol is defined in the ETSI EN 301 152 series, which is a "delta" to ETS 300 374, and assumes a CAP according to GSM 09.78 v5.5.x (Phase 2+, Release 1996). IN CS3 includes CAMEL aspects (which were ignored for IN CS2).

## Where are the specifications which identify the Vcc voltages for the SIM interface?

3V and 1.8 V SIMs for GSM are specified in GSM 11.12 (phase 2) and GSM 11.18 (release 98) respectively.
However, in 3GPP we have developed a new specification (3G TS 31.101) which combines the physical/electrical/logical aspects of GSM 11.11, GSM 11.12 and GSM 11.18 into a single specification. The electrical and physical aspects have not really been changed compared to the GSM specification mentioned above (the logical and security aspects have been enhanced). It is recommended that you use this new specification as the basis for any new work.

## Are the 3GPP specifications produced only in word?

The 3GPP specs are published as ETSI deliverables, and these are available in PDF from http://pda.etsi.org/pda/queryform.asp . But you can download a free Word viewer (ie read only) from the Microsoft web site. PDF is inherently secure (more so than html, in fact), and because WordViewer is very simple (it can not handle macros, for example), it is pretty safe too.

ETSI has no plans at present to publish specifications in plain text or in html.

## Which group works with specifications covering the use of the GSM codec (either in C or Java based)?

The SMG11 and 3GPP SA4 specifications available from http://www.3gpp.org respectively deal with this. It gives you a list of specifications via the status list (look for the GSM specs in the MS-Access database at :
and you can then download the specs you need. If you do not have an ETSI EOL account, you can download the ETSI equivalent standards from http://pda.etsi.org/pda/queryform.asp .

## Does the ETSI GSM standard document collection also include GSM standard documents produced by the GSM Association and exactly what kind of GSM standards does ETSI produce?

The GSM specifications were originally started in committee GSM of CEPT. There (as "CEPT Recommendations") they were allocated a reference number of the form nn.nn, for example GSM 06.12. Even after transfer to ETSI about ten years ago, the GSM community (in Technical Committee SMG) continue to use these spec identifiers.

The specifications are grouped into 'Releases'. The original specifications were published by ETSI in 1994 and are now known as 'Phase 1'. The next release was known as 'Phase 2', and the next one as ... 'Phase 2+'. Within Phase 2+, there have been annual releases since 1996, which are known as R96, R97, R98 and R99. You can find the specifications on the SMG file server http://docbox.etsi.org/zArchive/SMG/ grouped into directories by Release. (You need an account on the ETSI server to have access to this directory.) Looking at a spec, you can tell which release it belongs to by the version number:

Version release:

3.x.x Phase 1
4.x.x Phase 2
5.x.x Phase 2+, R96
6.x.x Phase 2+, R97
7.x.x Phase 2+, R98
8.x.x Phase 2+, R99

There will (probably) not be a Release 2000, since the work has been subsumed by the third generation specifications under 3GPP.

All (nearly) the specs of all releases are published as ETSI deliverables, and most have undergone several revisions in each release. In order to match a GSM spec number and version with the corresponding ETSI deliverable, you should go to http://webapp.etsi.org/key/queryform.asp .

## Where would I find a document (e.g. UMTS 30.03 version 3.1.0) which does not appear on the 3GPP Status List?

Look at http://docbox.etsi.org/tech-org/smg/Document/smg/specs/UMTS/3003_320.zip but, an ETSI server account is needed to access this. It is a document stemming from the initial TC-SMG studies on UMTS, not a product of 3GPP. It was, in fact, published as an ETSI deliverable, TR 101 112, and this may be downloaded via http://pda.etsi.org/pda/queryform.asp .

In general, the cross-referencing between GSM and ETSI deliverables, and between 3GPP and ETSI deliverables may be found at http://webapp.etsi.org/key/queryform.asp

### Where are all the Change Requests (CRs) located?

The information on CRs is available via the 3GPP website .

The information is classed by series so it is very easy to locate the particular specification which interests you.

If, for example, you are looking for CRs on GSM 08.18 then you would use this link:

http://www.3gpp.org/ftp/Specs/html-info/0818-CRs.htm

### Where are all the current ETSI SMG specs located?

All the archives for the GSM documentation

An ETSI On-Line account is needed to access these documents. You can apply for an ETSI online account .

In general, the cross-referencing between GSM and ETSI deliverables, and between 3GPP and ETSI deliverables may be found here .

### Which group works on the W-CDMA and the Physical Layer of W-CDMA?

The radio aspects are standardised in TSG-RAN. The technical work is done in the 4 Working Groups of RAN (WG1 radio layer 1, WG2 radio layer 2/3, WG3 interfaces, WG4 RF measurements). I'd say you are interested in TSG-RAN WG1 then. Their specifications are numbered 25.2xx.

The temporary documents (meeting documents etc.) of WG1 are stored on ftp://ftp.3gpp.org/TSG_RAN/WG1_RL1 and the latest specifications (December 99) are or will be provided on ftp://ftp.3gpp.org/Specs/December_99/25_series.

### Where can I find the list of Abstract syntax notation (ASN.1) object identifiers?

The expandable list of object identifiers is available here >>> . To see the formal definition of the object identifiers, see the document cited on the right. The tree is not necessarily complete; further extensions may be included in the referenced document. For more information look here >>>

### Where can I find the 3GPP Confidentiality and Integrity algorithms?

The 3GPP Confidentiality and Integrity algorithms F8 & F9 (KASUMI) have been developed through the collaborative efforts of the 3GPP Organizational Partners . For more information and in order to download the algorithms look here >>>

### What is a Release - how does specification version numbering work?

To meet new market requirements, 3GPP specifications are continually being enhanced with new features. In order to provide developers with a stable platform for implementation while at the same time allowing the addition of new features, the 3GPP uses a system of parallel "releases". For more information look here >>>

### Where can I find information on the current status of 3GPP specifications?

New versions of many 3GPP specifications are made available shortly after the 3GPP TSG plenary meetings which take place four times a year (March, June, September and December). In order to identify what the current version is or and how to find information about older versions of specifications look here >>> .

### What is the system for numbering specifications? Which specifications contain information on specific topics?

All 3G and GSM specifications have a 3GPP specification number consisting of 4 or 5 digits. (e.g. 09.02 or 29.002). For a more complete description and examples look here >>>

## Technical Specification Group/Working Group

### Who are the TSG/WG Officials and Support team and Where can I find their contact details?

Each TSG/WG has a Chairman, up to two Vice-Chairmen (three Vice-Chairmen) in the case of TSGs), a secretary and a member of the support team. From the 3GPP structural organization page, click on the TSG or WG of interest to reach its home page. From there, click on the "List of elected officials" entry in the table.

### Where can I find the Terms of Reference for my TSG/WG?

The current Terms of Reference for each TSG/WG appear on the web pages of each TSG/WG.

### When did the Officials begin their Term of Office?

The four Technical Specification Groups (TSGs) have elected their 3GPP TSG officials at the Fort Lauderdale (FL) meeting in March.

The meeting reports for each TSG/WG will indicate the election/re-election/resignation of an official. A complete list of TSG/WG officials is available on the 3GPP web site.

### May I become an Official?

The TSG Chairman and Vice Chairmen are elected by the Technical Specification Group from amongst the Individual Member representatives. Each TSG can elect a maximum of two Vice Chairmen. Once elected, these candidates are proposed to the PCG for appointment.

The Working Group Chairman and Vice Chairmen are elected by the Working Group from amongst the Individual Member representatives. Each Working Group can elect a maximum of two Vice Chairmen.

A candidate for TSG or Working Group election shall provide a letter of support from his Organization and nominations may be made up to the point when an election takes place.

The TSG Chairman and Vice-Chairmen shall be appointed by the PCG on the proposal of the TSG.

The Chairman and the Vice-Chairmen shall be appointed for a two year term of office. The Chairman and Vice-Chairmen may be appointed for one further consecutive term. If, at the end of a Chairman or Vice Chairmans second term, no other candidates are available, the Chairman or Vice Chairmen may be appointed for a further term.

Chairman and Vice Chairmen should not be from the same region, Organizational Partner, or from the same group of companies, unless no other candidate is available.

Successive Chairmen should not be from the same Organizational Partner, the same region or from the same group of companies, unless no other candidate is available

### Where are my TSG/WGs documents stored?

Each TSG/WG has a specific area allocated on the 3GPP ftp server.

### Is the ETSI Secretariat responsible for the management of the Application Provider Codes for 3GPP ?

The ETSI secretariat does not actually allocate these number - unique number are obtained by the coding scheme that is defined in 31.110. Application identifiers for consist of two parts - a RID and a PIX.

The RID is simple: ISO/IEC have allocated the number 'A000000087' to the 3GPP. This was allocated to ETSI on behalf of the 3GPP.

The coding of the PIX is specified in annex B of 31.110. There are three different sorts of PIX:

3G UICC,
3G USIM, and
3G USIM toolkit

Each of these requires the use of the "Card issuer code" as defined in ITU-T recommendation E.118 [3]. This is a unique code given to each card issuer (for example, each GSM operator in the world has requested a card issuer code). So, any 3G operator that does not have a 2G system that uses SIMs will have to apply to the ITU-T in accordance with the procedures in E.118.

## Documents and TSG/WG Meetings

### How do I register for a meeting?

If you are a TSG/WG member you will receive information about forthcoming meetings via the e-mail exploder. This will indicate the path on the ftp server where the invitation and related documents may be found. You may also consult the Meetings area on the 3GPP Web where the latest invitations of each TSG/WG are stored together with the calendar of meetings.

### How do I submit a contribution for a meeting?

Each meeting invitation will contain details of how to register contributions for that meeting and who to send your contributions to.

### How do I obtain a document number for my contribution?

Each meeting invitation will contain details of how to register contributions for that meeting and who to send your contributions to.

### Where can I download documents for an upcoming meeting?

Each meeting invitation will contain details of where the documents are stored for the meeting. It is advisable for delegates attending a meeting to download the documents available prior to the meeting from the ftp server and onto their personal computers.

### Where can I find a temporary document template?

The document template is made available by each TSG/WG in the meeting respective folder on the ftp server.

### What happens if I am unable to attend a meeting?

You should contact your chairman and the meeting host indicating when you will be absent.

Work Items and Deliverables

### What is my role when my TSG/WGs has to approve a deliverable?

Approval of Technical Specifications and Technical reports by a TSG shall normally be by consensus.

Where consensus cannot be achieved in the TSG a vote may be taken.

When Technical Specifications and Technical Reports become sufficiently stable, they shall be put under change control of the relevant TSG. The further elaboration of these Technical Specifications and Technical Reports shall be achieved by Change Requests (CRs) to be approved by the TSG.

### What are the different types of deliverables?

3GPP shall prepare, approve and maintain documents known as Technical Specifications and Technical Reports. Such documents shall be drawn up by the TSGs and shall, following approval at that level, be submitted to the participating Organizational Partners to be submitted to their respective standardization processes.

### Can I write an 3GPP Document myself?

Why not?! If you wish to propose a deliverable then bring it to the attention of your chairman and the other members of the TSG/WG in order to discuss the subject.

Each proposed new Work Item shall be supported by at least four Individual Members, and their names shall be recorded in the Work Item definition prepared for the TSG approval. One or more persons shall be named as Rapporteur for the proposed Work Item, and the Rapporteur shall act as the prime contact point on technical matters and for information on progress throughout the drafting phases.The supporting Individual Members are expected to contribute to and progress the new work item throughout the drafting phases.

In addition to the above, TSGs shall approve new Work Items, giving all essential parameters. The proposal shall be entered into the 3GPP work programme, clearly marked as a new entry, for which a unique reference identity shall be allocated.

### Do I and my company have to support my TSG/WGs Work Items?

Neither you or your company is obliged to support the work items of your TSG/WG, however it is normal that if you and your company are supporting members of a Work Item that you be in agreement with their work and will normally support the production of the related deliverable.

## Miscellaneous

### How do I resolve the problem with the corrupt file warning in MSWord. Note that this only applies to MSWord2000?

**Problem**: When opening a document in Word 2000, the following error message appears: This document may be corrupt. To preserve the contents: Choose Select All from the Edit menu, then choose Copy from the Edit menu. Create a new document, then choose Paste from the Edit menu.

**Cause**: This may be related to something called list templates. A list template is created for every numbering or bulleting scheme defined in the document. Apparently, a minor change in a scheme, or even switching a list from numbered to bulleted creates a new template. In an arcane way, tables are also related to list templates. The template count increases automatically, but cannot be decreased by the user. When more than 1500 templates are defined in the list, the document becomes corrupt. There are more reasons why a document is corrupt, so the fix proposed will not solve the problem 100% of the times.

**Resolution**:

1. To solve the problem, you need to have MS Office 2000 Service Release 1/1a installed . To check this, in Word on the "Help" menu point to "About Microsoft Word". The first line in the window shows you the MSWord version you have. You should get something like: "Microsoft Word 2000 (9.0.3821 SR-1)". If you don't get SR-1 (or SR-1a) at the end, you need to install the Service Release. Contact your IT department or follow this link: http://support.microsoft.com/support/kb/articles/Q245/0/25.ASP
2. You have to introduce a new entry in the Windows registry. You can do this simply by clicking twice in the file "word_bug_fix.reg" attached. Note that modifying the Windows Registry incorrectly can cause serious problems; this fix simply

introduces a new entry in a MSWord part of the registry, but if you don't feel confident, contact your IT department or check the Microsoft link below.
3. Open MSWord normally. The fix proposed will open the corrupted files without warning and delete the unused list templates, so its count goes under 1500. The user will not notice anything, but this implies that the document is modified. When closing, MSWord will ask the user if he wants to save the changes, even if apparently no change has been made.

This bug is confirmed by Microsoft and it is listed in its Support Web Site. Follow this link to get the complete report: http://support.microsoft.com/support/kb/articles/q241/5/81.asp

### Do I need a password and user name to access the 3GPP Web site ?

No password is needed to access any information on the 3GPP Web site, all information is openly published.

### Can you give me information about which companies manufacture particular types of equipment. Or about what services are available on particular networks?

No. The 3GPP Support Team must remain neutral and must not show bias to any of its Individual Members. Such information may be available from the Global Mobile Suppliers Association (www.gsacom.com ) where you will find a statistics area which could be of help.

## Technical topics

### Where can I find a list of technical terms and abbreviations used in 3GPP documents?

Individual terms are defined in each 3GPP Technical Specification and Technical Report. A compendium of terms and abbreviations can be found in 3GPP TR 21.905. ETSI maintains a list of all terms and abbreviations defined in its publications in "TEDDI".

### What is the difference between a SIM and a USIM? What is a UICC?

The Universal Integrated Circuit Card (UICC) is the removable card bearing a silicon chip which holds 3GPP system subscriber information. The UICC is a general purpose card having both non-volatile memory and a general-purpose processor. Thus while it is used, in a 3GPP terminal, to hold (U)SIM information / applications, it is can also be used for other purposes, possibly unrelated to telecommunications. A common use of UICCs is in the well-known credit card format, and there is no reason why a single card could not hold (U)SIM functionality in addition to electronic purse / credit card functionality, or indeed any other application / data.

The Subscriber Identity Module (SIM) is the collection of functions which personalize a 3GPP terminal. The SIM contains static information about the services subscribed to, the phone number, the identity of the home network, a list of preferred roaming networks, and so on. The SIM also contains storage capacity for the subscriber's contacts' phone numbers. The term "SIM" is often misused for "UICC". The SIM concept was created during the early development of the GSM standards, and second-generation (based on GERAN) terminals up to and including Release 4 use SIM functionality.

For third generation systems (based on UTRAN), more complex functionality was called for, and the SIM evolved into the USIM or Universal Subscriber Identity Module. Release 99 3rd generations onwards use USIMs rather than SIMs. From Release 5 onwards, both second and third generation terminals use USIMs (though to maintain backwards compatibility with older networks and terminals, later Release 2nd generation USIMs are likely to implement Rel-4 SIM functionality in addition to Rel-5 or later USIM functionality).

For further information on the 3GPP Release system, see the Release page.

### What is an R-UIM?

Short answer: nothing to do with us!

Longer answer: the R-UIM is to 3GPP2 systems what the USIM is to 3GPP systems. (3GPP2 is an independent organization responsible for the standardization of CDMA2000.)

### I have transferred a movie file from my phone to my PC. Where can I find a player for 3gp files?

The 3gp file format is defined in 3GPP TS 26.244 and in TS 26.412. However, 3GPP has not defined a decoder. Your phone manufacturer may have supplied a player (check the CD-ROM which came with your phone) or look on its web site. Alternatively, search the Internet: a number of commercial players exist, and trial versions of some may be downloaded without charge.

### What formalities do I have to go through to get type approval for terminal equipment in Europe? Is there a single point of contact? What standards does my equipment need to conform to in order that I can place it on the market?

The legal requirements for the marketing of electrical products in Europe are governed by various EU Directives, depending on the nature of the equipment. Conformity with any of these Directives can be demonstrated by the use of Harmonized Standards,

whose title has been cited in the Official Journal of the European Union. The lists of relevant standards can be found on the Commission web site which can be accessed via http://www.newapproach.org .

General electrical equipment is covered by the EMC Directive & Low Voltage Directives, see http://ec.europa.eu/enterprise/electr_equipment/index_en.htm . The harmonized standards are listed at http://ec.europa.eu/enterprise/newapproach/standardization/harmstds/reflist/lvd.html and http://ec.europa.eu/enterprise/newapproach/standardization/harmstds/reflist/emc.html respectively. More general information on procedures to declare conformity and how equipment should be marked are contained on the web sites related to the two Directives.

Radio Equipment and Telecommunications Terminal Equipment is covered by the Radio and Telecommunications Terminal Equipment Directive, see http://ec.europa.eu/enterprise/rtte/index_en.htm , which also includes a link to the one-stop procedure for "placing on the market" (http://ec.europa.eu/enterprise/rtte/osn.htm ). The standards are listed at http://ec.europa.eu/enterprise/newapproach/standardization/harmstds/reflist/radiotte.html .

Further information on EU harmonized standards relevant to telecommunications can be found on the ETSI site at http://www.etsi.eu/WebSite/Standards/Harmonization.aspx , and the published standards themselves can be downloaded via http://pda.etsi.org/pda/queryform.asp .

## Where can I find the specification of the SIM Lock feature?

In clause 8 of 3GPP TS 22.022 .

## Is it possible to determine the date and time of publication of a particular version of a 3GPP document?

1) Meeting contributions (including Change Requests )

Meeting contributions ("TDocs") are uploaded to the public file server shortly before, or during, or shortly after the meeting at which they were discussed (or intended to be discussed). The timestamp of the file can be relied upon as a precise indication of the moment of upload. TDocs created very shortly before or during a meeting may not be uploaded until after the meeting, but will have been made available locally to the participants during the meeting. The timestamp of the Word (or whatever) file within the containing Zip file is a good indication of the earliest moment that the document could have been available. However, some authors will circulate draft or final copies of their TDocs on the relevant group's email exploder some days or even weeks prior to this time. This would be revealed by an examination of the exploder's archive.

2) Technical Specifications and Technical Reports

During the drafting phase (versions lower than 3.0.0), 3GPP TSs and TRs ("Specs") are under the control of their authors ("rapporteurs") and are handled like normal meeting contributions (see above). Revised versions incorporating text agreed by the responsible working group are often made available by the rapporteur via the group's email exploder shortly after the end of the meeting at which such text was discussed. Again, counsultation of the exploder archives can reveal this. Alternatively, a revised draft may be sent directly to the 3GPP Support Team, and it will be uploaded to the public file server (specs archive directory) shortly afterwards. Again, the time stamp of the Zip file can be relied upon to indicate when the upload occurred.

After formal approval by the TSG (versions 3.0.0 or greater), Specs are edited only by the Support Team. The first approved version is based upon the draft version formally approved by the TSG, and thereafter versions are generated whenever Change Requests are approved by the TSG. These versions are made available shortly after the TSG meeting at which such approval occurred. The date (year and month) shown at the top of the Spec's cover page indicates either the date of (the last day of) the meeting, or the month in which the new version was prepared. However a more precise indication of the date of availability can be obtained from the Spec's web page (via the table at http://www.3gpp.org/specification-numbering ) where a precise date is shown in the "available" column.

More information on the procedures relating to Spec handing can be found in 3GPP TR 21.900 .

Note that, in accordance with the statement at the foot of the cover page of all 3GPP Specs, 3GPP does not "publish" its Specs per se. Formal publication is the responsibility of the individual Standards Development Organizations which comprise the Organizational Partners of 3GPP. For further information, see http://www.3gpp.org/Official-Publications .


### 3GPP Plenary Meetings

Full Meeting Calendar

CT, RAN and SA TSG #60 meetings - Oranjestad, Aruba - From 11 to 19 June
GERAN TSG #59 - Sofia, BG - From 26 to 30 August

CT, RAN and SA TSG #61 meetings - Porto, PT - From 3 to 11 September

### Releases

About Releases

Release 12
Release 11
Release 10
Release 9
Release 8
Release 7
Release 6
Release 5
Release 4
Release 1999

### Keywords & Acronyms

Browse Technologies

NAS
LTE-Advanced
LTE
HSPA
The Evolved Packet Core
Carrier Aggregation explained
GPRS & EDGE
UMTS
HSPA
W-CDMA


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# Appendix 11

The Wayback Machine - https://web.archive.org/web/20140626000737/http://3gpp.org/specifications



## Specifications



3GPP specifications are published - free of charge - up to four times a year following the quarterly Technical Specification Group (TSG) plenary meetings. At each TSG round, specs can be

- Newly brought under change control (i.e. at least 80% complete)
- Unchanged from their previous versions
- Revised as a result of incorporating approved Change Requests (either in existing Releases or in the latest Release)
- At Release-freeze time, upgraded to that Release with no technical change

The 3GPP Mobile Competence Centre (MCC) aims to make all Specs available following a TSG round as soon as possible. The target dates are shown in the table below. Where very many CRs have to be implemented, or very many specifications are to be produced, a further week beyond the above deadlines may be required. These dates are agreed by the TSG Chairmen. Over the Christmas and New Year period, when the winter TSG round finishes shortly before the holiday period, an extra week or so is normally added to the final deadlines.

### Quick link to the specifications file server area

The link above takes you straight to the specifications, but you need to know what you are looking for.

To find a particular specification by series, look at the Numbering page.

## 3GPP specifications

The term "3GPP specification" covers all GSM (including GPRS and EDGE), W-CDMA (including HSPA) and LTE (including LTE-Advanced) specifications. The following terms are also used to describe networks using the 3G specifications: UTRAN, UMTS (in Europe) and FOMA (in Japan).

Revised versions of many of these specifications are produced up to four times a year following the quarterly TSG plenary meetings.

**The table below leads to information about:**

- Specifications arising from each plenary TSG meeting, including the latest versions of each specification that was not changed at that meeting. i.e. each directory holds a complete set of specifications.
- The month of the meeting and the meeting number
- The Status List (ZIPped RTF or Word format) summarizing the current version number for every release of every 3GPP specification following each TSG plenary meeting.
- Details of each specification (working group, rapporteur, the Project Manager in MCC (Mobile Competence Centre), the meeting at which it was, or is expected to be, "frozen" (i.e. the point after which only corrections are allowed) - all are in the Status lists.

Full details of the Specifications, their history and current status can be found in the 3GPP Specifications Status database.

See this link for specs awaited from the most recent Plenary meetings.

| year-month | remark<br><br>click here to see list of specs still awaited from current plenary round | latest status | specs directory | TSG CN # | TSG RAN* # | TSG T # | TSG SA # | TSG GERAN # | TSG CT # |
|---|---|---|---|---|---|---|---|---|---|
| 2014-03 | New/revised specs available by<br>GERAN: 2014-03-17<br>CT: 2014-03-19<br>SA: 2014-03-17<br>RAN: 2014-03-27 | StatusList | 2014-03 | | 63 | | 63 | 61 | 63 |
| 2013-12 | | StatusList | 2013-12 | | 62 | | 62 | 60 | 62 |



### Search

3GPP Website: Search for...

*Search and download specs, docs, CRs and more from the 3GPP FTP Server:*

ADVANCED FTP SEARCH

### Latest Video

from 3GPPlive




### News Feeds

- 3GPP News
- 3GPP tweets

### Statistics

12018 average visitors per day

171 people currently on the site

| year-month | remark<br><br>click here to see list of specs still awaited from current plenary round | latest status | specs directory | TSG CN # | TSG RAN* # | TSG T # | TSG SA # | TSG GERAN # | TSG CT # |
|---|---|---|---|---|---|---|---|---|---|
| 2013-09 | | StatusList | 2013-09 | | 61 | | 61 | 59 | 61 |
| 2013-06 | | StatusList | 2013-06 | | 60 | | 60 | 58 | 60 |
| 2013-03 | | StatusList | 2013-03 | | 59 | | 59 | 57 | 59 |
| 2012-12 | | StatusList | 2012-12 | | 58 | | 58 | 56 | 58 |
| 2012-09 | | StatusList | 2012-09 | | 57 | | 57 | 55 | 57 |
| 2012-06 | | StatusList | 2012-06 | | 56 | | 56 | 54 | 56 |
| 2012-03 | | StatusList | 2012-03 | | 55 | | 55 | 53 | 55 |
| 2011-12 | | StatusList | 2011-12 | | 54 | | 54 | 52 | 54 |
| 2011-09 | | StatusList | 2011-09 | | 53 | | 53 | 51 | 53 |
| 2011-06 | | StatusList | 2011-06 | | 52 | | 52 | 50 | 52 |
| 2011-03 | | StatusList | 2011-03 | | 51 | | 51 | 49 | 51 |
| 2010-12 | | StatusList | 2010-12 | | 50 | | 50 | 48 | 50 |
| 2010-09 | | StatusList | 2010-09 | | 49 | | 49 | 47 | 49 |
| 2010-06 | | StatusList | 2010-06 | | 48 | | 48 | 46 | 48 |
| 2010-03 | | StatusList | 2010-03 | | 47 | | 47 | 45 | 47 |
| 2009-12 | | StatusList | 2009-12 | | 46 | | 46 | 44 | 46 |
| 2009-09 | | StatusList | 2009-09 | | 45 | | 45 | 43 | 45 |
| 2009-06 | | StatusList | 2009-06 | | 44 | | 44 | 42 | 44 |
| 2009-03 | | StatusList | 2009-03 | | 43 | | 43 | 41 | 43 |
| 2008-12 | | StatusList | 2008-12 | | 42 | | 42 | 40 | 42 |
| 2008-09 | | StatusList | 2008-09 | | 41 | | 41 | 39 | 41 |
| 2008-06 | | StatusList | 2008-06 | | 40 | | 40 | 38 | 40 |
| 2008-03 | | StatusList | 2008-03 | | 39 | | 39 | 37 | 39 |
| 2007-12 | | StatusList | 2007-12 | | 38 | | 38 | 36 | 38 |
| 2007-09 | | StatusList | 2007-09 | | 37 | | 37 | 35 | 37 |
| 2007-06 | | StatusList | 2007-06 | | 36 | | 36 | 34 | 36 |
| 2007-03 | | StatusList | 2007-03 | | 35 | | 35 | 33 | 35 |
| 2006-12 | | StatusList | 2006-12 | | 34 | | 34 | 32 | 34 |

| year-month | remark<br><br>click here to see list of specs still awaited from current plenary round | latest status | specs directory | TSG CN # | TSG RAN* # | TSG T # | TSG SA # | TSG GERAN # | TSG CT # |
|---|---|---|---|---|---|---|---|---|---|
| 2006-09 | GERAN henceforward meets synchronously with other TSGs, so no further "delta" directories necessary. | StatusList | 2006-09 | | 33 | | 33 | 31 | 33 |
| 2006-06 | New at GERAN only. | | 2006-06 | | | | | 30 | |
| 2006-06 | | StatusList | 2006-06 | | 32 | | 32 | | 32 |
| 2006-04 | New at GERAN only. | | 2006-04 | | | | | 29 | |
| 2006-03 | | StatusList | 2006-03 | | 31 | | 31 | | 31 |
| 2006-01 | New at GERAN only. | | 2006-01 | | | | | 28 | |
| 2005-12 | | StatusList | 2005-12 | | 30 | | 30 | | 30 |
| 2005-11 | New at GERAN only. | | 2005-11 | | | | | 27 | |
| 2005-09 | | StatusList | 2005-09 | | 29 | | 29 | | 29 |
| 2005-08/09 | New at GERAN only. | | 2005-09 | | | | | 26 | |
| 2005-06 | New at GERAN only. | | 2005-06 | | | | | 25 | |
| 2005-06 | | StatusList | 2005-06 | | 28 | | 28 | | 28 |
| 2005-04 | New at GERAN only. | | 2005-04 | | | | | 24 | |
| 2005-03 | RAN closed and RANnew opened, CN and T closed, CT opened. | StatusList | 2005-03 | 27 | 27bis, 27 | 27 | 27 | | 27 |
| 2005-01 | New at GERAN only. | | 2005-01 | | | | | 23 | |
| 2004-12 | | StatusList | 2004-12 | 26 | 26 | 26 | 26 | | |
| 2004-11 | New at GERAN only. | | 2004-11 | | | | | 22 | |
| 2004-09 | | StatusList | 2004-09 | 25 | 25 | 25 | 25 | | |
| 2004-08 | New at GERAN only. | | 2004-08 | | | | | 21 | |
| 2004-06 | New at GERAN only. | | 2004-06 | | | | | 20 | |
| 2004-06 | | StatusList | 2004-06 | 24 | 24 | 24 | 24 | | |
| 2004-04 | New at GERAN only. | | 2004-04 | | | | | 19 | |
| 2004-03 | | StatusList | 2004-03 | 23 | 23 | 23 | 23 | | |
| 2004-02 | New at GERAN only. | | 2004-02 | | | | | 18 | |
| 2003-12 | | StatusList | 2003-12 | 22 | 22 | 22 | 22 | | |
| 2003-11 | New at GERAN only. | | 2003-11 | | | | | 17 | |
| 2003-09 | | StatusList | 2003-09 | 21 | 21 | 21 | 21 | | |

| year-month | remark<br><br>click here to see list of specs still awaited from current plenary round | latest status | specs directory | TSG CN # | TSG RAN* # | TSG T # | TSG SA # | TSG GERAN # | TSG CT # |
|---|---|---|---|---|---|---|---|---|---|
| 2003-09 | New at GERAN only. | | 2003-09 | | | | | 16 | |
| 2003-06 | New at GERAN only. | | 2003-06 | | | | | 15 | |
| 2003-06 | | StatusList | 2003-06 | 20 | 20 | 20 | 20 | | |
| 2003-04 | New at GERAN only. | | 2003-04 | | | | | 14 | |
| 2003-02 | | StatusList | 2003-03 | 19 | 19 | 19 | 19 | | |
| 2003-02 | New at GERAN only. | | 2003-02 | | | | | 13 | |
| 2002-12, 2002-11 | | StatusList | 2002-12 | 18 | 18 | 18 | 18 | 12 | |
| 2002-09 | | StatusList | 2002-09 | 17 | 17 | 17 | 17 | 11 | |
| 2002-06 | Rel-5 GERAN features content functionally frozen | | 2002-06 | | | | | 10 | |
| 2002-06 | Rel-5 features content functionally frozen (remainder, non-GERAN) | StatusList | 2002-06 | 16 | 16 | 16 | 16 | | |
| 2002-04 | | | 2002-04 | | | | | 9 | |
| 2002-03 | Rel-5 features content functionally frozen (part) | StatusList | 2002-03 | 15 | 15 | 15 | 15 | | |
| 2002-02 | | | | | | | | 8 | |
| 2001-12 | | StatusList | 2001-12 | 14 | 14 | 14 | 14 | | |
| 2001-11 | | | | | | | | 7 | |
| 2001-09 | | StatusList | 2001-09 | 13 | 13 | 13 | 13 | | |
| 2001-08 | | | | | | | | 6 | |
| 2001-06 | | StatusList | 2001-06 | 12 | 12 | 12 | 12 | 5 | |
| 2001-06 | Rel-4 GERAN features content functionally frozen | | | | | | | 4 | |
| 2001-03 | Rel-4 non-GERAN features content functionally frozen | StatusList | 2001-03 | 11 | 11 | 11 | 11 | | |
| 2001-01 | | | | | | | | 3 | |
| 2000-12, 2000-11 | | StatusList | 2000-12 | 10 | 10 | 10 | 10 | 2 | |
| 2000-11 | | | | | | | | | |
| 2000-09 | | StatusList | 2000-09 | 9 | 9 | 9 | 9 | 1 | |
| 2000-06 | | StatusList | 2000-06 | 8 | 8 | 8 | 8 | | |
| 2000-03 | | | | 7 | 7 | 7 | 7 | | |
| 1999-12 | R99 features content functionally frozen | | | 6 | 6 | 6 | 6 | | |

| year-month | remark<br><br>click here to see list of specs still awaited from current plenary round | latest status | specs directory | TSG CN # | TSG RAN* # | TSG T # | TSG SA # | TSG GERAN # | TSG CT # |
|---|---|---|---|---|---|---|---|---|---|
| 1999-10 | | | | 5 | 5 | 5 | 5 | | |
| 1999-06 | | | | | 4 | 4 | 4 | | |
| 1999-05 | | | | 4 | | | | | |
| 1999-04 | | | | 3 | 3 | 3 | 3 | | |
| 1999-03 | | | | 2 | 2 | 2 | 2 | | |
| 1998-12 | | | | 1 | 1 | 1 | 1 | | |

** TSG RAN was closed at the end of meeting 27 and re-opened for meeting 27 bis.*

If you plan to download a large number of specifications we recommend using an FTP client software tool such as:

- Ipswitch WS_FTP Pro
- FTPSync
- Filezilla

For additional information relating to 3GPP Specifications, their creation and maintenance, etc. go here.

## Confidential Algorithms

3GPP confidentiality and integrity algorithms The 3GPP Confidentiality and Integrity algorithms F8 & F9 (KASUMI) have been developed through the collaborative efforts of the 3GPP Organizational Partners. They may be used only for the development and operation of 3G Mobile Communications and services. Every Beneficiary must sign a Restricted Usage Undertaking with a Custodian and (...)
more »

## ASN.1

ASN.1 Object Identifiers Abstract syntax notation (ASN.1) object identifiers maintained by ETSI. ETSI is a recognized organization under the ITU-T (formerly CCITT) arc. The formal rules governing assignment of object identifier values are given in ETSI EG 200 351. Since the 3GPP technical specifications are based on GSM specifications, which use object identifiers under the ETSI node, it (...)
more »

## Drafting Rules

The Specification drafting rulesTR 21.801 are the rules for the structure and drafting of documents intended to become a 3GPP Technical Specification or Technical Report. These rules are intended to ensure that such documents are drafted in as uniform a manner as is practicable, irrespective of the technical content. 21.801 is based on the ISO/IEC Directives, Part 3, but is a self-contained (...)
more »

## Official Publications

The 3GPP Technical Specifications and Technical Reports have, in themselves, no legal standing. They only become "official" when transposed into corresponding publications of the Partner Organizations (or the national / regional standards body acting as publisher for the Partner). At this point, the specifications are referred to as UMTS within ETSI and FOMA within ARIB/TTC. Some TRs (...)
more »

Page reviewed and updated 2014-03-27, John M Meredith

### FULL MEETING CALENDAR

| | | | |
|---|---|---|---|
| GERAN | 63 | Ljubljana | 25-29 Aug 2014 |
| RAN | 65 | Edinburgh | 09-12 Sep 2014 |
| CT | 65 | Edinburgh | 10-11 Sep 2014 |
| SA | 65 | Edinburgh | 15-17 Sep 2014 |
| GERAN | 64 | San Francisco | 17-21 Nov 2014 |
| CT | 66 | Maui | 08-09 Dec 2014 |
| RAN | 66 | Maui | 08-11 Dec 2014 |
| SA | 66 | Maui | 10-12 Dec 2014 |
| CT | 67 | Shanghai | 09-10 Mar 2015 |

### ABOUT RELEASES

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- Release 6
- Release 5

### BROWSE TECHNOLOGIES

- LTE-Advanced
- LTE
- Carrier Aggregation Explained
- HetNet/Small Cells
- NAS
- The Evolved Packet Core
- HSPA
- UMTS
- W-CDMA

| | | | | | |
|---|---|---|---|---|---|
| **RAN** | **67** | **Shanghai** | 09-12 Mar 2015 | Release 4 | GPRS & EDGE |
| **GERAN** | **65** | **Shanghai** | 09-13 Mar 2015 | Release 1999 | |
| **SA** | **67** | **Shanghai** | 11-13 Mar 2015 | | |
| **GERAN** | **66** | 25-29 May 2015 | | | |
| **CT** | **68** | **Malmo** | 15-16 Jun 2015 | | |
| **RAN** | **68** | **Malmo** | 15-18 Jun 2015 | | |
| **SA** | **68** | **Malmo** | 17-19 Jun 2015 | | |

# Appendix 12

The Wayback Machine - https://web.archive.org/web/20140712212649/http://www.3gpp.org/specifications/79-specification-numbering



## Specification Numbering



All 3GPP specifications have a specification number consisting of 4 or 5 digits. (e.g. 09.02 or 29.002).

The first two digits define the series, followed by 2 further digits for the 01 to 13 series or 3 further digits for the 21 to 55 series.

The full title, specification number and latest version number for every specification can be found in the current status list (warning: large file!).

An automated list of Specification numbers - with the Title and details of the Specification Group responsible.

| Subject of specification series | 3G and beyond / GSM (R99 and later) | GSM only (Rel-4 and later) | GSM only (before Rel-4) |
|---|---|---|---|
| General information (long defunct) | | | 00 series |
| Requirements | 21 series | 41 series | 01 series |
| Service aspects ("stage 1") | 22 series | 42 series | 02 series |
| Technical realization ("stage 2") | 23 series | 43 series | 03 series |
| Signalling protocols ("stage 3") - user equipment to network | 24 series | 44 series | 04 series |
| Radio aspects | 25 series | 45 series | 05 series |
| CODECs | 26 series | 46 series | 06 series |
| Data | 27 series | 47 series (none exists) | 07 series |
| Signalling protocols ("stage 3") -(RSS-CN) and OAM&P and Charging (overflow from 32.- range) | 28 series | 48 series | 08 series |
| Signalling protocols ("stage 3") - intra-fixed-network | 29 series | 49 series | 09 series |
| Programme management | 30 series | 50 series | 10 series |
| Subscriber Identity Module (SIM / USIM), IC Cards. Test specs. | 31 series | 51 series | 11 series |
| OAM&P and Charging | 32 series | 52 series | 12 series |
| Access requirements and test specifications | | 13 series (1) | 13 series (1) |
| Security aspects | 33 series | (2) | (2) |
| UE and (U)SIM test specifications | 34 series | (2) | 11 series |
| Security algorithms (3) | 35 series | 55 series | (4) |
| LTE (Evolved UTRA) and LTE-Advanced radio technology | 36 series | - | - |
| Multiple radio access technology aspects | 37 series | - | - |

Note (1): The 13 series GSM specifications relate to European-Union-specific regulatory standards. On the closure of ETSI TC SMG, responsibility for these specifications was transferred to ETSI TC MSG, (Mobile Specification Group) and they do not appear on the 3GPP file server.

Note (2): The specifications of these aspects are spread throughout several series.

Note (3): Algorithms may be subject to export licensing conditions. See the relevant 3GPP page. See also the relevant ETSI pages.

Note (4): The original GSM algorithms are not published and are controlled by the GSM Association.

Technical Reports are of two classes:

> Those intended to be transposed and issued by the Organizational Partners as their own publications; and
>
> Those not intended for publication but which are simply 3GPP internal working documents, used, for example, for documenting planning and scheduling of work, or for holding the interim results of feasibility studies.

The first category have numbers of the form: xx.9xx

The second category have numbers of the form:
xx.8xx (feasibility study reports, etc) or, more rarely,
30.xxx / 50.xxx (planning and scheduling)

Missing Specs: Click here to see those Specs not yet available following the most recent round of TSG meetings.

The 3GPP Specifications are stored on the file server as zipped MS-Word files. The filenames have the following structure:

SM[-P[-Q]]-V.zip

where the character fields have the following significance ...

S = series number - 2 characters (see the table above)
M = mantissa (the part of the spec number after the series number) - 2 or 3 characters (see above)
P = optional part number - 1 or 2 digits if present
Q = optional sub-part number - 1 or 2 digits if present
V = version number, without separating dots - 3 digits

So for example:

> 21900-320.zip is 3GPP TR 21.900 version 3.2.0
> 0408-6g0.zip is 3GPP TS 04.08 version 6.16.0
> 32111-4-410 is 3GPP TS 32.111 part 4 version 4.1.0
> 29998-04-1-100 is 3GPP TS 29.998 part 4 sub-part 1 version 1.0.0

Further information:

**Latest version**
The latest versions of the approved specifications in the "latest" directory. The latest version of draft specs (i.e. those not yet under change control) are in the "latest-drafts" directory. See also the page on version numbering.

**Particular version**
All older versions of specifications (where available) are stored in the archive subdirectory. All versions of all releases of a given specification are placed directly under the name of the specification.

**Title or subject**
If you only know the title or the subject, but not the specification number, the best place to start looking is the complete list of all 3GPP specification numbers and titles. This list also shows the most recent version in each Release.

**Specs related to a particular working group**
Each 3GPP TSG Working Group has a home page, which lists the specifications under its responsibility. Follow the links from here

**Official versions published by recognized Standards Development Organizations**
The 3GPP Technical Specifications (and Technical Reports) which are publicly available from this site have, in themselves, no legal standing. They only become "official" when transposed into corresponding publications of the Partner Organizations. If you are looking for the official versions, see the official publications page.

## Yet more information:

**Work plan**
The 3GPP Work plan describes the new functionality currently being elaborated in the TSG working groups. It also indicates the expected timescales for their finalization.

**Releases (and phases, stages)**
An introduction to the 3GPP mechanism for specifications releases can be found here.

**Historical information**
If you need to look for old / superseded specifications or change requests, start here.

**TSG working methods**
The procedures for creating, enhancing and maintaining specifications are described in TR 21.900. A presentation outlining the release and change request process can be found here.

**3GPP Drafting rules**
The rules for drafting specifications are described in TR 21.801.

**Change Requests**
The change request mechanism is used when a correction or new functionality is required for an existing specification.

**Version numbering**
More information on the version numbering page.

Issuing new TS/TR numbers. More information on this page.

## FULL MEETING CALENDAR

| | | | |
|---|---|---|---|
| **GERAN** | **63** | **Ljubljana** | 25-29 Aug 2014 |
| **RAN** | **65** | **Edinburgh** | 09-12 Sep 2014 |
| **CT** | **65** | **Edinburgh** | 10-11 Sep 2014 |
| **SA** | **65** | **Edinburgh** | 15-17 Sep 2014 |
| **GERAN** | **64** | **San Francisco** | 17-21 Nov 2014 |
| **CT** | **66** | **Maui** | 08-09 Dec 2014 |
| **RAN** | **66** | **Maui** | 08-11 Dec 2014 |
| **SA** | **66** | **Maui** | 10-12 Dec 2014 |
| **CT** | **67** | **Shanghai** | 09-10 Mar 2015 |
| **RAN** | **67** | **Shanghai** | 09-12 Mar 2015 |
| **GERAN** | **65** | **Shanghai** | 09-13 Mar 2015 |
| **SA** | **67** | **Shanghai** | 11-13 Mar 2015 |
| **GERAN** | **66** | 25-29 May 2015 | |
| **CT** | **68** | **Malmo** | 15-16 Jun 2015 |
| **RAN** | **68** | **Malmo** | 15-18 Jun 2015 |
| **SA** | **68** | **Malmo** | 17-19 Jun 2015 |

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## BROWSE TECHNOLOGIES

LTE-Advanced
LTE
Carrier Aggregation Explained
HetNet/Small Cells
NAS
The Evolved Packet Core
HSPA
UMTS
W-CDMA
GPRS & EDGE

# Appendix 13