8366373

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

April 18, 2023

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APPLICATION NUMBER: *16/484,565*
FILING DATE: *August 08, 2019*
PATENT NUMBER: *10932207*
ISSUE DATE: *February 23, 2021*

Certified by

Performing the Functions and Duties of the
Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

DAINGEAN_0002562

Doc Code: PA
Document Description: Power of Attorney

PTO/AIA/82B (07-13)
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U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
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出願人による委任状
POWER OF ATTORNEY BY APPLICANT

私はここに、添付の伝送書もしくは下記枠内で特定された出願に対して、現時点より前に与えられたすべての委任状を破棄します。
I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

出願番号 Application Number	出願日 Filing Date

(注記：PTO/AIA82Aに同じ情報が明記されている場合、上の枠内は空欄でも可)
(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ 私は、下記顧客番号に関連する特許弁護士を、当方の弁護士あるいは代理人に指名し、添付の伝送書（PTO/AIA/82A）内もしくは上記に記載の特許出願に関連した米国特許商標庁との業務の全てを同弁護士あるいは代理人に委任します。
I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above:

54072

又は
OR

☐ 私は、添付のリスト(PTO/AIA/82C)に記載の特許弁護士を、当方の弁護士あるいは代理人に指名し、添付の伝送書（PTO/AIA/82A）内もしくは上記に記載の特許出願に関連した米国特許商標庁との業務の全てを同弁護士あるいは代理人に委任します。（注記: PTO/AIA/82C を記入すること。）
I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

添付の伝送書又は上記枠内にて特定された出願に対する郵便物送付先を下記のいずれかに登録または変更してください。
Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☑ 上記顧客番号に付随する住所
The address associated with the above-mentioned Customer Number

又は
OR

☐ 顧客番号に付随する住所
The address associated with Customer Number:

又は
OR

事務所または個人名 Firm or Individual Name					
住所 Address					
市 City		州 State		郵便番号 Zip	
国 Country					
電話番号 Telephone		メールアドレス Email			

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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出願人による委任状
POWER OF ATTORNEY BY APPLICANT

私は出願人であり（出願人が法人の場合、出願人名を下記枠内に記入）：
I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

Sharp Kabushiki Kaisha

☐ 発明者もしくは共同発明者である（下記役職の明記は不要）
Inventor or Joint Inventor (title not required below)

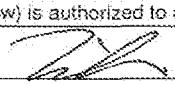
☐ 死亡したもしくは成年被後見人である発明者の法定代理人である（下記役職の明記は不要）
Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☑ 被譲渡人もしくは発明者が譲渡する義務を負う人物である
Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ 上記以外で、十分な独占的所有権を示す人物である（例：37 CFR 1.46(b)(2)に基づく申請が本出願において認められた、又は本書類と共にその申請がなされている場合）（出願人が法人の場合、署名者の役職を明記すること）
Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

特許出願人の署名
SIGNATURE of Applicant for Patent

下記署名者（役職は下記に記載）は出願人の代理人と認められている（出願人が法人の場合等）
The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

署名 Signature		署名日（任意） Date (Optional)	April 11, 2016
氏名 Name	Takashi NISHIDA		
役職 Title	Vice President, Head of Intellectual Property Unit, Corporate R&D Division; Sharp Kabushiki Kaisha		

注記: 署名 - 本書類は37 CFR 1.33に基づき署名されなければならない。署名の要件および証明に関しては37 CFR 1.4を参照。出願人が複数いる場合は、複数の書類を使うこと。

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☐ 提出書類 計＿＿＿＿＿枚。
Total of _____ forms are submitted.

Doc Code: PA
Document Description: Power of Attorney

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POWER OF ATTORNEY BY APPLICANT

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I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

出願番号 Application Number	出願日 Filing Date

(注記：PTO/AIA82Aに同じ情報が明記されている場合、上の枠内は空欄でも可)
(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

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I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above:

54072

又は
OR

☐ 私は、添付のリスト(PTO/AIA/82C)に記載の特許弁護士を、当方の弁護士あるいは代理人に指名し、添付の伝送書（PTO/AIA/82A）内もしくは上記に記載の特許出願に関連した米国特許商標庁との業務の全てを同弁護士あるいは代理人に委任します。(注記: PTO/AIA/82C を記入すること。)
I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

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Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☑ 上記顧客番号に付随する住所
The address associated with the above-mentioned Customer Number

又は
OR

☐ 顧客番号に付随する住所
The address associated with Customer Number:

又は
OR

事務所または個人名 Firm or Individual Name					
住所 Address					
市 City		州 State		郵便番号 Zip	
国 Country					
電話番号 Telephone		メールアドレス Email			

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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出願人による委任状
POWER OF ATTORNEY BY APPLICANT

私は出願人であり（出願人が法人の場合、出願人名を下記枠内に記入）：
I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

FG INNOVATION COMPANY LIMITED

- ☐ 発明者もしくは共同発明者である（下記役職の明記は不要）
  Inventor or Joint Inventor (title not required below)
- ☐ 死亡したもしくは成年被後見人である発明者の法定代理人である（下記役職の明記は不要）
  Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)
- ☑ 被譲渡人もしくは発明者が譲渡する義務を負う人物である
  Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)
- ☐ 上記以外で、十分な独占的所有権を示す人物である（例：37 CFR 1.46(b)(2)に基づく申請が本出願において認められた、又は本書類と共にその申請がなされている場合）（出願人が法人の場合、署名者の役職を明記すること）
  Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

特許出願人の署名
SIGNATURE of Applicant for Patent

下記署名者（役職は下記に記載）は出願人の代理人と認められている（出願人が法人の場合等）
The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

署名 Signature	Chie Ming Chou	署名日（任意） Date (Optional)	2019. 2. 21
氏名 Name	CHIE-MING CHOU		
役職 Title	CEO of FG INNOVATION COMPANY LIMITED		

注記: 署名 - 本書類は37 CFR 1.33に基づき署名されなければならない。署名の要件および証明に関しては37 CFR 1.4を参照。出願人が複数いる場合は、複数の書類を使うこと。

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☐ 提出書類 計_____枚。
Total of _____ forms are submitted.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	70404.4566/sg
	Application Number	
Title of Invention	TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Shoichi		SUZUKI	

Residence Information (Select One) US Residency ● Non US Residency Active US Military Service

City	Country of Residence [i]
Sakai City	JP

Mailing Address of Inventor:

Address 1	c/o Sharp Kabushiki Kaisha
Address 2	1 Takumi-cho, Sakai-ku
City	Sakai City, Osaka
State/Province	
Postal Code	590-8522
Country [i]	JP

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Wataru		OUCHI	

Residence Information (Select One) US Residency ◉ Non US Residency Active US Military Service

City	Country of Residence [i]
Sakai City	JP

Mailing Address of Inventor:

Address 1	c/o Sharp Kabushiki Kaisha
Address 2	1 Takumi-cho, Sakai-ku
City	Sakai City, Osaka
State/Province	
Postal Code	590-8522
Country [i]	JP

Inventor 3 Remove

Legal Name

PTO/AIA/14 (02-18)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	70404.4566/sg
	Application Number	
Title of Invention	TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT	

Prefix	Given Name	Middle Name	Family Name	Suffix
	Tomoki		YOSHIMURA	

Residence Information (Select One) US Residency ◉ Non US Residency Active US Military Service

City	Sakai City	Country of Residence [i]	JP

Mailing Address of Inventor:

Address 1	c/o Sharp Kabushiki Kaisha
Address 2	1 Takumi-cho, Sakai-ku

City	Sakai City, Osaka	State/Province	
Postal Code	590-8522	**Country** [i]	JP

Inventor 4 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Liqing		LIU	

Residence Information (Select One) US Residency ◉ Non US Residency Active US Military Service

City	Sakai City	Country of Residence [i]	JP

Mailing Address of Inventor:

Address 1	c/o Sharp Kabushiki Kaisha
Address 2	1 Takumi-cho, Sakai-ku

City	Sakai City, Osaka	State/Province	
Postal Code	590-8522	**Country** [i]	JP

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	54072		
Email Address	uspto@kbiplaw.com	Add Email	Remove Email

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	70404.4566/sg
	Application Number	
Title of Invention	TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT	

Application Information:

Title of the Invention	TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT		
Attorney Docket Number	70404.4566/sg	**Small Entity Status Claimed** ☐	
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	20	**Suggested Figure for Publication (if any)**	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	64072		

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	70404.4566/sg
	Application Number	
Title of Invention	TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT	

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	a 371 of international	PCT/JP2018/005323	2018-02-15

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)
2017-029042	JP	2017-02-20	

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	70404.4566/sg
	Application Number	
Title of Invention	TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	70404.4566/sg
	Application Number	
Title of Invention	TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 — Remove

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● Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	70404.4566/sg
	Application Number	
Title of Invention	TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT	

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Name of the Deceased or Legally Incapacitated Inventor:

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TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT

Technical Field

[0001]

The present invention relates to a terminal apparatus, a base station apparatus, a communication method, and an integrated circuit.

This application claims priority based on JP 2017-029042 filed on February 20, 2017, the contents of which are incorporated herein by reference.

Background Art

[0002]

A radio access method and a radio network for cellular mobile communications (hereinafter referred to as "Long Term Evolution (LTE: Registered Trademark)", or "Evolved Universal Terrestrial Radio Access (EUTRA)") have been studied in the 3rd Generation Partnership Project (3GPP) (NPLs 1, 2, 3, 4, 5). Further, in 3GPP, a new radio access method (hereinafter referred to as "New Radio (NR)") is being studied. In LTE, a base station apparatus is also referred to as an evolved NodeB (eNodeB). In NR, the base station apparatus is also referred to as gNodeB. In LTE, and in NR, a terminal apparatus is also referred to as a User Equipment (UE). LTE, as well as NR, is a cellular communication system in which multiple areas are deployed in a cellular structure, with each of the multiple areas being covered by a base station apparatus. A single base station apparatus may manage a plurality of cells.

[0003]

In NPL 6, it has been proposed to study a technique for reducing delay and/or overhead in an initial access procedure and a random access procedure (NPL 6).

Citation List

Non Patent Literature

[0004]

NPL 1: "3GPP TS 36.211 V13.0.0 (2015-12)", 6th January, 2016.

NPL 2: "3GPP TS 36.212 V13.0.0 (2015-12)", 6th January, 2016.

NPL 3: "3GPP TS 36.213 V13.0.0 (2015-12)", 6th January, 2016.

NPL 4: "3GPP TS 36.321 V13.0.0 (2015-12)", 14th January, 2016.

NPL 5: "3GPP TS 36.331 V13.0.0 (2015-12)", 7th January, 2016.

NPL 6: "Motivation for new SI proposal: Enhancements to initial access and scheduling for low-latency LTE", RP-162295, 5th December, 2016.

Summary of Invention

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Technical Problem

[0005]

An embodiment of the present invention provides a terminal apparatus capable of efficiently performing a random access to a base station apparatus, a base station apparatus communicating with the terminal apparatus, a communication method used for the terminal apparatus, a communication method used for the base station apparatus, an integrated circuit implemented on the terminal apparatus, and an integrated circuit implemented on the base station apparatus.

Solution to Problem

[0006]

(1) According to some aspects of the present invention, the following measures are provided. In other words, a first aspect of the present invention is a terminal apparatus which is a terminal apparatus including a higher layer processing unit configured to increment a transmission counter based on a failure of random access response reception or contention resolution, a receiver configured to receive information for indicating a higher layer parameter powerRampingStep(1) and information for indicating a higher layer parameter powerRampingStep(2), and a transmit power control unit configured to set a transmit power, wherein the transmit power for PRACH transmission in a first step of a 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(1), and the transmit power for PUSCH transmission in the first step of the 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(2).

[0007]

(2) A second aspect of the present invention is a communication method used for a terminal apparatus, the communication method including the steps of incrementing a transmission counter based on a failure of random access response reception or contention resolution, receiving information for indicating a higher layer parameter powerRampingStep(1) and information for indicating a higher layer parameter powerRampingStep(2), and setting a transmit power, wherein the transmit power for PRACH transmission in a first step of a 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(1), and the transmit power for PUSCH transmission in the first step of the 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(2).

Advantageous Effects of Invention

[0008]

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According to one aspect of the present invention, a terminal apparatus and a base station apparatus can efficiently perform a random access procedure.

Brief Description of Drawings

[0009]

FIG. 1 is a conceptual diagram of a radio communication system according to the present embodiment.

FIG. 2 is a diagram illustrating a schematic structure of a radio frame according to the present embodiment.

FIG. 3 is a diagram illustrating a schematic structure of an uplink slot according to the present embodiment.

FIG. 4 is a schematic block diagram illustrating a configuration of a terminal apparatus 1 according to the present embodiment.

FIG. 5 is a schematic block diagram illustrating a configuration of a target base station apparatus 3B according to the present embodiment.

FIG. 6 is a diagram illustrating one example of a 4 step contention based random access procedure according to the present embodiment.

FIG. 7 is a diagram illustrating one example of a 2 step contention based random access procedure according to the present embodiment.

FIG. 8 is a diagram illustrating a modified example of the 2 step contention based random access procedure according to the present embodiment.

FIG. 9 is a diagram illustrating one example of a non-contention based random access procedure according to the present embodiment.

FIG. 10 is a diagram illustrating one example of correspondence between events and forms of random access procedures according to the present embodiment.

FIG. 11 is a diagram illustrating another example of correspondence between events and forms of random access procedures according to the present embodiment.

FIG. 12 is a diagram illustrating one example of correspondence among resource sets for transmission of a random access preamble, transmission parameters for transmission of a message X, and random access preamble groups in the 2 step contention based random access procedure according to the present embodiment.

FIG. 13 is a diagram illustrating one example of correspondence between random access preambles and transmission parameters for transmission of the message X in the 2 step contention based random access procedure according to the present embodiment.

FIG. 14 is a diagram illustrating one example of correspondence between random access preamble groups and transmission parameters for transmission of the message X in the 2 step contention based random access procedure according to the present embodiment.

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FIG. 15 is a diagram illustrating another example of correspondence between random access preambles and transmission parameters for transmission of the message X in the 2 step contention based random access procedure according to the present embodiment.

FIG. 16 is a diagram illustrating one example of the 2 step contention based random access procedure according to the present embodiment.

FIG. 17 is a diagram illustrating one example of a transport block including a random access response and/or a contention resolution according to the present embodiment.

FIG. 18 is a diagram illustrating one example of random access preamble groups for random access procedures according to the present embodiment.

FIG. 19 is a diagram illustrating another example of random access preamble groups for random access procedures according to the present embodiment.

FIG. 20 is a diagram illustrating one example of a flow of a contention based random access procedure according to the present embodiment.

Description of Embodiments

[0010]

Embodiments of the present invention will be described below.

[0011]

FIG. 1 is a conceptual diagram of a radio communication system according to the present embodiment. In FIG. 1, the radio communication system includes terminal apparatuses 1 and a base station apparatus 3. The base station apparatus 3 includes a source base station apparatus 3A, a target base station apparatus 3B, and a Mobility Management Entity (MME)/Gateway (GW). Uu are radio access links between the terminal apparatuses 1 and the base station apparatus 3. The Uu include uplinks from the terminal apparatuses 1 to the base station apparatus 3 and downlinks from the base station apparatus 3 to the terminal apparatuses 1. X2 is a backhaul link between the source base station apparatus 3A and the target base station apparatus 3B. S1 is a backhaul link between the source base station apparatus 3A/target base station apparatus 3B and the MME/GW.

[0012]

The terminal apparatuses 1 may perform handover from the source base station apparatus 3A to the target base station apparatus 3B. The terminal apparatuses 1 may perform handover from a source cell to a target cell. The source cell may be managed by the source base station apparatus 3A. The target cell may be managed by the target base station apparatus 3B. The source base station apparatus 3A and the target base station apparatus 3B may be the same apparatus. In other words, the terminal apparatuses 1 may perform handover from the source cell managed by the source base station apparatus 3A

to the target cell managed by the source base station apparatus 3A. The source cell is also referred to as a source primary cell. The target cell is also referred to as a target primary cell.

[0013]

Hereinafter, carrier aggregation will be described.

[0014]

In the present embodiment, one or more serving cells are configured for the terminal apparatus 1. A technology in which the terminal apparatus 1 communicates via the plurality of serving cells is referred to as cell aggregation or carrier aggregation. In the carrier aggregation, multiple configured serving cells are also referred to as aggregated serving cells.

[0015]

Time Division Duplex (TDD) and/or Frequency Division Duplex (FDD) is applied to a radio communication system in the present embodiment. For cell aggregation, TDD may be applied to all multiple serving cells. Alternatively, serving cells to which TDD is applied and serving cells to which FDD is applied may be aggregated. In the present embodiment, the serving cells to which TDD is applied are also referred to as TDD serving cells.

[0016]

The multiple configured serving cells include one primary cell and one or more secondary cells. The primary cell is a serving cell in which an initial connection establishment procedure has been performed, a serving cell in which a Radio Resource Control (RRC) connection re-establishment procedure has been initiated, or a cell indicated as a primary cell during a handover procedure. The secondary cell may be configured at a point of time when or after a Radio Resource Control (RRC) connection is established.

[0017]

The primary cell may include a source primary cell and a target primary cell.

[0018]

A carrier corresponding to a serving cell in the downlink is referred to as a downlink component carrier. A carrier corresponding to a serving cell in the uplink is referred to as an uplink component carrier. The downlink component carrier and the uplink component carrier are collectively referred to as a component carrier.

[0019]

The terminal apparatus 1 can perform simultaneous transmission of multiple physical channels/multiple physical signals in multiple aggregated serving cells (component carriers). The terminal apparatus 1 can perform simultaneous reception of multiple physical channels/multiple physical signals in multiple aggregated serving cells (component carriers).

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[0020]

In a case that Dual Connectivity (DC) is configured for a terminal apparatus, a Master Cell Group (MCG) is a subset of all serving cells, and a Secondary Cell Group (SCG) is a subset of serving cells that are not part of the MCG. In a case that DC is not configured for the terminal apparatus, the MCG includes all serving cells. The MCG includes a primary cell and zero or more secondary cells. The SCG includes a primary secondary cell and zero or more secondary cells.

[0021]

The MCG may include one primary TAG and zero or more secondary TAGs. The SCG may include one primary TAG and zero or more secondary TAGs.

[0022]

The Timing Advance Group (TAG) is a group of serving cells configured by Radio Resource Control (RRC). The same timing advance value is applied to serving cells included in the same TAG. The timing advance is used to adjust PUSCH/PUCCH/SRS/DMRS transmission timings in the serving cells. The primary TAG of the MCG may include a primary cell and zero or more secondary cells. The primary TAG of the SCG may include a primary secondary cell and zero or more secondary cells. The secondary TAG may include one or more secondary cells. The secondary TAG does not include a primary cell and a primary secondary cell.

[0023]

FIG. 2 is a diagram illustrating a schematic structure of a radio frame according to the present embodiment. In FIG. 2, the horizontal axis is a time axis.

[0024]

Various field sizes in the time domain are expressed by the number of time units $T_s = 1/(15000 \times 2048)$ seconds. The length of a radio frame is $T_f = 307200 \times T_s = 10$ ms (milliseconds). Each of radio frames includes ten contiguous subframes in the time domain. The length of each of the subframes is $T_{subframe} = 30720 \times T_s = 1$ ms. Each of subframes i includes two contiguous slots in the time domain. The two contiguous slots in the time domain comprise a slot having a slot number n_s of 2i in the radio frame and a slot having a slot number n_s of 2i + 1 in the radio frame. The length of each of the slots is $T_{slot} = 153600 \times n_s = 0.5$ ms. Each of radio frames includes ten contiguous subframes in the time domain. Each of radio frames includes 20 contiguous slots ($n_s = 0, 1, ..., 19$) in the time domain. A subframe is also referred to as a Transmission Time Interval (TTI).

[0025]

A structure of a slot according to the present embodiment will be described below. FIG. 3 is a diagram illustrating a schematic structure of an uplink slot according to the present embodiment. FIG. 3 illustrates a structure of an uplink slot in one cell. In FIG. 3, the horizontal axis is a time axis, and the vertical axis is a frequency axis. In FIG. 3, 1 is a

Single Carrier-Frequency Division Multiple Access (SC-FDMA) symbol number/index, and k is a subcarrier number/index.

[0026]

The physical signal or the physical channel transmitted in each of the slots is expressed by a resource grid. In uplink, the resource grid is defined by multiple subcarriers and multiple SC-FDMA symbols. Each element within the resource grid is referred to as a resource element. The resource element is expressed by the subcarrier number/index k and the SC-FDMA symbol number/index l. In the present embodiment, a resource refers to a frequency-time resource.

[0027]

The resource grid is defined for each antenna port. In the present embodiment, description is given for one antenna port. The present embodiment may be applied to each of multiple antenna ports.

[0028]

An uplink slot includes multiple SC-FDMA symbols l ($l = 0, 1, \ldots, N^{UL}_{symb}$) in the time domain. N^{UL}_{symb} indicates the number of SC-FDMA symbols included in one uplink slot. For a normal Cyclic Prefix (CP), N^{UL}_{symb} is 7. For an extended Cyclic Prefix (CP), N^{UL}_{symb} is 6.

[0029]

The uplink slot includes multiple subcarriers k ($k = 0, 1, \ldots, N^{UL}_{RB} * N^{RB}_{SC}$) in the frequency domain. N^{UL}_{RB} is an uplink bandwidth configuration for a serving cell expressed by a multiple of N^{RB}_{SC}. N^{RB}_{SC} is a (physical) resource block size in the frequency domain expressed by the number of subcarriers. In the present embodiment, a subcarrier interval Δf is 15 kHz, and N^{RB}_{sc} is a size of 12 subcarriers. In other words, in the present embodiment, N^{RB}_{sc} is 180 kHz.

[0030]

A resource block is used to express mapping of a physical channel to resource elements. For the resource block, a virtual resource block and a physical resource block are defined. The physical channel is first mapped to the virtual resource block. Thereafter, the virtual resource block is mapped to the physical resource block. One physical resource block is defined by N^{UL}_{symb} consecutive SC-FDMA symbols in the time domain and N^{RB}_{SC} consecutive subcarriers in the frequency domain. Hence, one physical resource block includes ($N^{UL}_{symb} * N^{RB}_{SC}$) resource elements. One physical resource block corresponds to one slot in the time domain. The physical resource blocks are numbered ($0, 1, \ldots, N^{UL}_{RB} - 1$) in ascending order of frequencies in the frequency domain.

[0031]

A downlink slot according to the present embodiment includes multiple OFDM symbols. Since the structure of the downlink slot according to the present embodiment is the same as the structure of the uplink slot except that the resource grid is defined by

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multiple subcarriers and multiple OFDM symbols, the description of the structure of the downlink slot will be omitted.

[0032]

Physical channels and physical signals according to the present embodiment will be described.

[0033]

In FIG. 1, in uplink radio communication from the terminal apparatus 1 to the base station apparatus 3, the following uplink physical channels are used. The uplink physical channels are used by a physical layer for transmission of information output from a higher layer.

- Physical Uplink Control Channel (PUCCH)
- Physical Uplink Shared Channel (PUSCH)
- Physical Random Access Channel (PRACH)

The PUCCH is used to transmit Uplink Control Information (UCI). The uplink control information includes: downlink Channel State Information (CSI); a Scheduling Request (SR) used to request for a PUSCH (Uplink-Shared Channel: UL-SCH) resource for initial transmission; and a Hybrid Automatic Repeat request ACKnowledgement (HARQ-ACK) for downlink data (a Transport block, a Medium Access Control Protocol Data Unit (MAC PDU), a Downlink-Shared Channel (DL-SCH), or a Physical Downlink Shared Channel (PDSCH)). The HARQ-ACK indicates an acknowledgement (ACK) or a negative-acknowledgement (NACK). The HARQ-ACK is also referred to as HARQ feedback, HARQ information, HARQ control information, and ACK/NACK.

[0034]

The PUSCH is used for transmission of uplink data (UpLink-Shared CHannel (UL-SCH)). The PUSCH may be used to transmit the HARQ-ACK and/or channel state information along with the uplink data. Furthermore, the PUSCH may be used to transmit only the channel state information or to transmit only the HARQ-ACK and the channel state information. The PUSCH is used to transmit a random access message 3.

[0035]

The PRACH is used to transmit a random access preamble (random access message 1). The PRACH is used for indicating the initial connection establishment procedure, the handover procedure, the connection re-establishment procedure, synchronization (timing adjustment) for uplink transmission, and the request for the PUSCH (UL-SCH) resource.

[0036]

The random access preamble may be given by cyclic shifting a Zadoff-Chu sequence corresponding to a physical root sequence index u. The Zadoff-Chu sequence is generated based on the physical root sequence index u. In one cell, multiple random access preambles may be defined. The random access preamble may be determined by a

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random access preamble index. Different random access preambles corresponding to different random access preamble indexes correspond to different combinations of the physical root sequence index u and a cyclic shift. The physical root sequence index u and the cyclic shift may be given based at least on information included in system information.

[0037]

A Zadoff-Chu sequence $x_u(n)$ corresponding to the physical root sequence index u is given by Equation 1, where e is the Napier's number, N_{ZC} is the length of the Zadoff-Chu sequence $x_u(n)$, and n is an integer incremented from 0 to N_{ZC} - 1.

[0038]

Equation 1

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

[0039]

A random access preamble (random access preamble sequence) $x_{u,v}(n)$ is given by Equation 2. C_v is a cyclic shift value. X mod Y is a function for outputting a remainder acquired by dividing X by Y.

[0040]

Equation 2

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

[0041]

In FIG. 1, the following uplink physical signal is used in the uplink radio communication. The uplink physical signal is not used for transmitting information output from the higher layer, but is used by the physical layer.

· Uplink Reference Signal (UL RS)

According to the present embodiment, the following two types of uplink reference signals are used.

· Demodulation reference signal (DMRS)

· Sounding reference signal (SRS)

DMRS is associated with transmission of PUSCH or PUCCH. The DMRS is time-multiplexed with the PUSCH or the PUCCH. The base station apparatus 3 uses the DMRS in order to perform channel compensation of the PUSCH or the PUCCH. Transmission of both of the PUSCH and the DMRS is hereinafter referred to simply as

transmission of the PUSCH. Transmission of both of the PUCCH and the DMRS is hereinafter referred to simply as transmission of the PUCCH.

[0042]

SRS is not associated with the transmission of PUSCH or PUCCH. The base station apparatus 3 may use the SRS for measuring a channel state. The SRS is transmitted in the last SC-FDMA symbol in an uplink subframe or in an SC-FDMA symbol in a UpPTS.

[0043]

In FIG. 1, the following downlink physical channels are used for downlink radio communication from the base station apparatus 3 to the terminal apparatus 1. The downlink physical channels are used by the physical layer for transmission of information output from the higher layer.

· Physical broadcast channel (PBCH)

· Physical control format indicator channel (PCFICH)

· Physical hybrid automatic repeat request indicator channel (PHICH)

· Physical downlink control channel (PDCCH)

· Enhanced physical downlink control channel (EPDCCH)

· Physical downlink shared channel (PDSCH)

· Physical multicast channel (PMCH)

The PBCH is used for broadcasting a Master Information Block (MIB, a Broadcast CHannel (BCH)) that is commonly used by the terminal apparatuses 1. The MIB is transmitted at intervals of 40 ms, and, within the interval, the MIB is repeatedly transmitted every 10 ms. Specifically, initial transmission of the MIB is performed in a subframe 0 in a radio frame that satisfies SFN mod 4 = 0, and re-transmission (repetition) of the MIB is performed in subframes 0 in all the other radio frames. A system frame number (SFN) is a radio frame number. The MIB is system information. For example, the MIB includes information indicating the SFN.

[0044]

The PCFICH is used for transmission of information indicating a region (OFDM symbols) to be used for transmission of the PDCCH.

[0045]

The PHICH is used for transmission of a HARQ indicator for uplink data (UpLink-Shared CHannel (UL-SCH)) received by the base station apparatus 3. The HARQ indicator indicates a HARQ-ACK.

[0046]

The PDCCH and the EPDCCH are used to transmit downlink control information (DCI). The downlink control information is also referred to as DCI format. The downlink control information includes a downlink grant and an uplink grant. The downlink grant is also referred to as a downlink assignment or a downlink allocation.

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[0047]

One downlink grant is used for the scheduling of one PDSCH within one serving cell. The downlink grant is used for the scheduling of the PDSCH within the same subframe as the subframe on which the downlink grant is transmitted.

[0048]

One uplink grant is used for the scheduling of one PUSCH within one serving cell. The uplink grant is used for the scheduling of the PUSCH within the fourth or later subframe after the subframe in which the uplink grant is transmitted.

[0049]

CRC parity bits added to a downlink grant or an uplink grant are scrambled with a Cell-Radio Network Temporary Identifier (C-RNTI), a Temporary C-RNTI, a Semi Persistent Scheduling (SPS) C-RNTI, or a Random Access-Radio Network Temporary Identifier (RA-RNTI). The C-RNTI and the SPS C-RNTI are identifiers for identifying a terminal apparatus within a cell. The Temporary C-RNTI is used during a contention based random access procedure. The RA-RNTI is used for the scheduling of a random access response. An uplink grant to which CRC parity bits scrambled with the RNTI are added is also referred to as an uplink grant for the RNTI or an uplink grant corresponding to the RNTI. The PDCCH including the uplink grant to which the CRC parity bits scrambled with the RNTI are added is also referred to as the PDCCH for the RNTI, the PDCCH corresponding to the RNTI, the PDCCH directed to the RNTI, or the PDCCH including the RNTI.

[0050]

The C-RNTI is used to control the PDSCH or the PUSCH in one subframe. The terminal apparatus 1 may transmit the PUSCH including a transport block based on the detection of the PDCCH including an uplink grant to which CRC parity bits scrambled with the C-RNTI are added. The re-transmission of the transport block may be indicated by the PDCCH including the uplink grant to which the CRC parity bits scrambled with the C-RNTI are added.

[0051]

The SPS C-RNTI is used to periodically allocate a resource for the PDSCH or the PUSCH. The terminal apparatus 1 detects the PDCCH including an uplink grant to which CRC parity bits scrambled with the SPS C-RNTI are added, and in a case that it is determined that the uplink grant is valid as an SPS activation command, the uplink grant is stored as a configured uplink grant. The MAC layer of the terminal apparatus 1 considers that the configured uplink grant is periodically generated. A subframe in which the configured uplink grant is considered to be generated is given by a first period and a first offset. The terminal apparatus 1 receives information for indicating the first period from the base station apparatus 3. The re-transmission of the transport block transmitted in the periodically allocated PUSCH is indicated by the uplink grant to which the CRC

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parity bits scrambled with the SPS C-RNTI are added. The configured uplink grant is also referred to as an uplink grant configured by Medium Access Control (MAC) or a first configured uplink grant.

[0052]

The PDSCH is used to transmit downlink data (downlink shared channel (DL-SCH)). The PDSCH is used to transmit a random access message 2 (random access response). The PDSCH is used to transmit a handover command. The PDSCH is used to transmit system information including a parameter used for an initial access.

[0053]

The PMCH is used to transmit multicast data (multicast channel (MCH)).

[0054]

In FIG. 1, the following downlink physical signals are used for the downlink radio communication. The downlink physical signals are not used for transmission of information output from the higher layer, but are used by the physical layer.

· Synchronization Signal (SS)

· Downlink Reference Signal (DL RS)

The synchronization signal is used for the terminal apparatus 1 to take synchronization in the frequency domain and the time domain in the downlink. The synchronization signal includes a Primary Synchronization Signal (PSS) and a Second Synchronization Signal (SSS).

[0055]

The downlink reference signal is used for the terminal apparatus 1 to perform channel compensation on a downlink physical channel. The downlink reference signal is used for the terminal apparatus 1 to calculate downlink channel state information.

[0056]

According to the present embodiment, the following seven types of downlink reference signals are used.

· Cell-specific reference signal (CRS)

· UE-specific reference signal (URS) relating to the PDSCH

· Demodulation reference signal (DMRS) relating to the EPDCCH

· Non-zero power channel state information - reference signal (NZP CSI-RS)

· Zero Power Chanel State Information - Reference Signal (ZP CSI-RS)

· Multimedia broadcast and multicast service over single frequency network reference signal (MBSFN RS)

· Positioning reference signal (PRS)

The downlink physical channels and the downlink physical signals are collectively referred to as a downlink signal. The uplink physical channels and the uplink physical signals are collectively referred to as an uplink signal. The downlink physical channels and the uplink physical channels are collectively referred to as a physical channel. The

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downlink physical signals and the uplink physical signals are collectively referred to as a physical signal.

[0057]

The BCH, the MCH, the UL-SCH, and the DL-SCH are transport channels. A channel used in a Medium Access Control (MAC) layer is referred to as a transport channel. A unit of the transport channel used in the MAC layer is also referred to as a transport block (TB) or a MAC Protocol Data Unit (PDU). A Hybrid Automatic Repeat reQuest (HARQ) is controlled for each transport block in the MAC layer. The transport block is a unit of data that the MAC layer delivers to the physical layer. In the physical layer, the transport block is mapped to a codeword, and coding processing is performed for each codeword.

[0058]

The base station apparatus 3 and the terminal apparatus 1 exchange (transmit and/or receive) a signal in the higher layer. For example, the base station apparatus 3 and the terminal apparatus 1 may transmit and/or receive, in a Radio Resource Control (RRC) layer, RRC signaling (also referred to as a Radio Resource Control message (RRC message) or Radio Resource Control information (RRC information)). Furthermore, the base station apparatus 3 and the terminal apparatus 1 may transmit and/or receive, in the Medium Access Control (MAC) layer, a MAC Control Element (CE). Here, the RRC signaling and/or the MAC CE is also referred to as higher layer signaling.

[0059]

The PUSCH and the PDSCH are used to transmit the RRC signaling and the MAC CE. Here, the RRC signaling transmitted from the base station apparatus 3 in the PDSCH may be signaling common to multiple terminal apparatuses 1 in a cell. The RRC signaling transmitted from the base station apparatus 3 in the PDSCH may be signaling dedicated to a certain terminal apparatus 1 (also referred to as dedicated signaling or UE specific signaling). A cell-specific parameter may be transmitted by using the signaling common to the multiple terminal apparatuses 1 in the cell or the signaling dedicated to the certain terminal apparatus 1. A UE-specific parameter may be transmitted by using the signaling dedicated to the certain terminal apparatus 1.

[0060]

Configurations of apparatuses according to the present embodiment will be described below.

[0061]

FIG. 4 is a schematic block diagram illustrating a configuration of the terminal apparatus 1 according to the present embodiment. As illustrated, the terminal apparatus 1 is configured to include a radio transmission and/or reception unit 10 and a higher layer processing unit 14. The radio transmission and/or reception unit 10 is configured to include an antenna unit 11, a radio frequency (RF) unit 12, and a baseband unit 13. The

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higher layer processing unit 14 is configured to include a medium access control layer processing unit 15 and a radio resource control layer processing unit 16. The radio transmission and/or reception unit 10 is also referred to as a transmitter, a receiver or a physical layer processing unit.

[0062]

The higher layer processing unit 14 outputs uplink data (transport block) generated by a user operation or the like, to the radio transmission and/or reception unit 10. The higher layer processing unit 14 performs processing of the Medium Access Control (MAC) layer, the Packet Data Convergence Protocol (PDCP) layer, the Radio Link Control (RLC) layer, and the Radio Resource Control (RRC) layer.

[0063]

The medium access control layer processing unit 15 included in the higher layer processing unit 14 performs processing of the Medium Access Control layer. The medium access control layer processing unit 15 controls transmission of a scheduling request, based on various types of configuration information/parameters managed by the radio resource control layer processing unit 16.

[0064]

The radio resource control layer processing unit 16 included in the higher layer processing unit 14 performs processing of the Radio Resource Control layer. The radio resource control layer processing unit 16 manages various types of configuration information/parameters of its own apparatus. The radio resource control layer processing unit 16 sets various types of configuration information/parameters based on higher layer signaling received from the base station apparatus 3. Namely, the radio resource control unit 16 sets the various configuration information/parameters in accordance with the information indicating the various configuration information/parameters received from the base station apparatus 3.

[0065]

The radio transmission and/or reception unit 10 performs processing of the physical layer, such as modulation, demodulation, coding, decoding, and the like. The radio transmission and/or reception unit 10 demultiplexes, demodulates, and decodes a signal received from the base station apparatus 3, and outputs the information resulting from the decoding to the higher layer processing unit 14. The radio transmission and/or reception unit 10 generates a transmit signal by modulating and coding data, and performs transmission to the base station apparatus 3.

[0066]

The RF unit 12 converts (down-converts) a signal received via the antenna unit 11 into a baseband signal by orthogonal demodulation and removes unnecessary frequency components. The RF unit 12 outputs the processed analog signal to the baseband unit.

[0067]

The baseband unit 13 converts the analog signal input from the RF unit 12 into a digital signal. The baseband unit 13 removes a portion corresponding to a Cyclic Prefix (CP) from the digital signal resulting from the conversion, performs Fast Fourier Transform (FFT) of the signal from which the CP has been removed, and extracts a signal in the frequency domain.

[0068]

The baseband unit 13 generates an SC-FDMA symbol by performing an Inverse Fast Fourier Transform (IFFT) of the data, adds CP to the generated SC-FDMA symbol, generates a baseband digital signal, and converts the baseband digital signal into an analog signal. The baseband unit 13 outputs the analog signal resulting from the conversion, to the RF unit 12.

[0069]

The RF unit 12 removes unnecessary frequency components from the analog signal input from the baseband unit 13 using a low-pass filter, up-converts the analog signal into a signal of a carrier frequency, and transmits the up-converted signal via the antenna unit 11. Furthermore, the RF unit 12 amplifies power. Furthermore, the RF unit 12 may have a function of controlling transmit power. The RF unit 12 is also referred to as a transmit power control unit.

[0070]

FIG. 5 is a schematic block diagram illustrating a configuration of the target base station apparatus 3B according to the present embodiment. As illustrated, the target base station apparatus 3B is configured to include a radio transmission and/or reception unit 30 and a higher layer processing unit 34. The radio transmission and/or reception unit 30 is configured to include an antenna unit 31, an RF unit 32, and a baseband unit 33. The higher layer processing unit 34 is configured to include a medium access control layer processing unit 35 and a radio resource control layer processing unit 36. The radio transmission and/or reception unit 30 is also referred to as a transmitter, a receiver or a physical layer processing unit. The configuration of the source base station apparatus 3A may be the same as the configuration of the target base station apparatus 3B.

[0071]

The higher layer processing unit 34 performs processing of the Medium Access Control (MAC) layer, the Packet Data Convergence Protocol (PDCP) layer, the Radio Link Control (RLC) layer, and the Radio Resource Control (RRC) layer.

[0072]

The medium access control layer processing unit 35 included in the higher layer processing unit 34 performs processing of the Medium Access Control layer. The medium access control layer processing unit 35 performs processing associated with a scheduling request, based on various types of configuration information/parameters managed by the radio resource control layer processing unit 36. The higher layer processing unit 34 may

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transmit information to another base station apparatus and an MME/GW 3C. The higher layer processing unit 34 may receive information from the other base station apparatus and the MME/GW 3C.

[0073]

The radio resource control layer processing unit 36 included in the higher layer processing unit 34 performs processing of the Radio Resource Control layer. The radio resource control layer processing unit 36 generates, or acquires from a higher node, downlink data (transport block) allocated on a physical downlink shared channel, system information, an RRC message, a MAC Control Element (CE), and the like, and performs output to the radio transmission and/or reception unit 30. Furthermore, the radio resource control layer processing unit 36 manages various types of configuration information/parameters for each of the terminal apparatuses 1. The radio resource control layer processing unit 36 may set various types of configuration information/parameters for each of the terminal apparatuses 1 via the higher layer signal. Namely, the radio resource control layer processing unit 36 transmits/broadcasts information indicating various types of configuration information/parameters.

[0074]

The functionality of the radio transmission and/or reception unit 30 is similar to the functionality of the radio transmission and/or reception unit 10, and hence description thereof is omitted.

[0075]

Each of the units having the reference signs 10 to 16 included in the terminal apparatus 1 may be configured as a circuit. Each of the units having the reference signs 30 to 36 included in the base station apparatus 3 may be configured as a circuit.

[0076]

A random access procedure will be described below in detail. The random access procedure includes a contention based random access procedure and a non-contention based random access procedure. The contention based random access procedure includes a 2 step contention based random access procedure and a 4 step contention based random access procedure. In other words, types/forms of random access procedure may include the 2 step contention based random access procedure, the 4 step contention based random access procedure, and the non-contention based random access procedure.

[0077]

FIG. 6 is a diagram illustrating one example of the 4 step contention based random access procedure according to the present embodiment. The 4 step contention based random access procedure includes a first step (600), a second step (602), a third step (604), and a fourth step (606).

[0078]

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In the first step (600), the terminal apparatus 1 transmits a random access preamble. The random access preamble is included in the PRACH. In the first step (600), the MAC layer itself of the terminal apparatus 1 selects a random access preamble index. That is, in the first step (600), the base station apparatus 3 does not notify the terminal apparatus 1 of the random access preamble index.

[0079]

In the second step (602), the terminal apparatus 1 receives a random access response. The random access response is included in the PDSCH. Here, the PDCCH for the RA-RNTI is used for scheduling of the PDSCH including the random access response. The value of the RA-RNTI may be given based on a PRACH resource used for transmission of the random access preamble in the first step (600). The random access response includes a random access preamble identifier for indicating the random access preamble index, an uplink grant, information for indicating a Temporary C-RNTI, and information for indicating a timing advance. In a case that the random access response includes a random access preamble identifier corresponding to the random access preamble transmitted in the first step (600), the terminal apparatus 1 considers that the random access response has successfully been received.

[0080]

In the third step (604), the terminal apparatus 1 transmits an identifier of the terminal apparatus 1. Here, the identifier of the terminal apparatus 1 may be a C-RNTI. The identifier of the terminal apparatus 1 or the C-RNTI is included in the PUSCH. Here, the PUSCH for the identifier of the terminal apparatus 1 or the C-RNTI is scheduled by the uplink grant included in the random access response.

[0081]

In the fourth step (606), the terminal apparatus 1 receives contention resolution. The contention resolution may be a UE contention resolution identifier or the C-RNTI. In a case that the terminal apparatus 1 has transmitted the C-RNTI in the PUSCH in the third step (604) and the terminal apparatus 1 has received the PDCCH for the C-RNTI, the terminal apparatus 1 may consider that the contention resolution has successfully been performed and that the random access procedure has successfully completed.

[0082]

Information for indicating the UE contention resolution identifier is included in the PDSCH. Here, the PDCCH for the Temporary C-RNTI is used for scheduling of the PDSCH. In a case that (i) the terminal apparatus 1 does not transmit the C-RNTI in the PUSCH in the third step (604), (ii) the terminal apparatus 1 transmits the identifier of the terminal apparatus 1 in the PUSCH in the third step (604), (iii) the terminal apparatus 1 receives the PDCCH for the Temporary C-RNTI, (iv) the PDSCH scheduled by the PDCCH includes the information for indicating the UE contention resolution identifier, and (v) the UE contention resolution identifier matches the identifier of the terminal

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apparatus 1 transmitted in the third step (604), the terminal apparatus 1 may consider that the contention resolution has successfully been performed and that the random access procedure has successfully completed.

[0083]

FIG. 7 is a diagram illustrating one example of the 2 step contention based random access procedure according to the present embodiment. The 2 step contention based random access procedure includes a first step (700) and a second step (702).

[0084]

In the first step (700), a random access preamble and an identifier of the terminal apparatus 1 are transmitted. Here, the identifier of the terminal apparatus 1 may be a C-RNTI. The random access preamble may be included in the PRACH. The identifier of the terminal apparatus 1 may be included in the PUSCH. The random access preamble and the identifier of the terminal apparatus 1 may be included in an identical physical channel. In the first step (700), the MAC layer itself of the terminal apparatus 1 selects a random access preamble index. That is, in the first step (700), the base station apparatus 3 does not notify the terminal apparatus 1 of the random access preamble index.

[0085]

In the second step (702), the terminal apparatus 1 receives contention resolution. The contention resolution may be a UE contention resolution identifier or the C-RNTI. In a case that the terminal apparatus 1 has transmitted the C-RNTI in the first step (700) and the terminal apparatus 1 has received the PDCCH including the C-RNTI, the terminal apparatus 1 may consider that the contention resolution has successfully been performed and that the random access procedure has successfully completed.

[0086]

The UE contention resolution identifier is included in the PDSCH. Here, a DCI format to which a CRC scrambled with an X-RNTI is added may be used for scheduling of the PDSCH. The X-RNTI may be given based at least on a resource (PRACH resource) used for the transmission of the random access preamble in the first step (700) and/or a resource (PUSCH resource) used for the transmission of the identifier of the terminal apparatus 1. The X-RNTI may be an RA-RNTI.

[0087]

In a case that (i) the terminal apparatus 1 does not transmit the C-RNTI in the first step (700), (ii) the terminal apparatus 1 transmits the identifier of the terminal apparatus 1 in the first step (700), (iii) the terminal apparatus 1 receives the PDCCH for the X-RNTI, (iv) the PDSCH scheduled by the PDCCH includes information for indicating the UE contention resolution identifier, and (v) the UE contention resolution identifier matches the identifier of the terminal apparatus 1 transmitted in the first step (700), the terminal apparatus 1 may consider that the contention resolution has successfully been performed and that the random access procedure has successfully completed. The PDSCH

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scheduled by the PDCCH for the X-RNTI may include some or all of an uplink grant, information for indicating the C-RNTI, and information for indicating a timing advance. In other words, the contention resolution may include some or all of the uplink grant, the information for indicating the C-RNTI, and the information for indicating the timing advance. The PDSCH scheduled by the PDCCH for the X-RNTI may not include information for indicating the random access preamble index. Here, the terminal apparatus 1 may set the C-RNTI to the value of the information for indicating the C-RNTI.

[0088]

FIG. 8 is a diagram illustrating a modification example of the 2 step contention based random access procedure according to the present embodiment. The modification example of the 2 step contention based random access procedure includes a first step (800), a second step (802), a third step (804), and a fourth step (806). The first step (800) is the same as the first step (700). The second step (802) is the same as the second step (602). The third step (804) is the same as the third step (604). The fourth step (806) is the same as the fourth step (606). That is, after the first step of the 2 step contention based random access procedure, a transition may be performed from the 2 step contention based random access procedure to the 4 step contention based random access procedure.

[0089]

In a case that the base station apparatus 3 detects a random access preamble and cannot detect an identifier of the terminal apparatus 1 in the first step (800), the base station apparatus 3 transmits a random access response in the second step (802). In other words, in a case that the base station apparatus 3 detects the random access preamble and cannot detect the identifier of the terminal apparatus 1 in the first step of the 2 step contention based random access procedure, the base station apparatus 3 may initiate the second step of the 4 step contention based random access procedure. In a case that the base station apparatus 3 detects the random access preamble and the identifier of the terminal apparatus 1 in the first step of the 2 step contention based random access procedure, the base station apparatus 3 may initiate the second step of the 2 step contention based random access procedure.

[0090]

After the first step (700, 800) of the 2 step contention based random access procedure, the terminal apparatus 1 may monitor the contention resolution of the second step (702) and the random access response of the second step (802). In other words, in the second step (702, 802), the terminal apparatus 1 may monitor the PDCCH associated with the random access response and the PDCCH associated with the contention resolution. The PDCCH associated with the random access response may be the PDCCH for the RA-RNTI. The PDCCH associated with the contention resolution may be the PDCCH for the X-RNTI.

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[0091]

After the first step (600) of the 4 step contention based random access procedure, the terminal apparatus 1 may monitor the random access response of the second step (602). In other words, in the second step (602), the terminal apparatus 1 may monitor the PDCCH associated with the random access response. In the second step (602), the terminal apparatus 1 may not monitor the contention resolution. In other words, in the second step (602), the terminal apparatus 1 may not monitor the PDCCH associated with the contention resolution.

[0092]

FIG. 9 is a diagram illustrating one example of the non-contention based random access procedure according to the present embodiment. The non-contention based random access procedure includes a zeroth step (900), a first step (902), and a second step (904).

[0093]

In the zeroth step (900), the terminal apparatus 1 receives a random access preamble allocation. The random access preamble allocation may be included in a handover command or the PDCCH for the C-RNTI. The random access preamble allocation may indicate a random access preamble index. The PDCCH including the random access preamble allocation is also referred to as a PDCCH order or a PDCCH order for indicating initiation of the random access procedure.

[0094]

In the first step (902), the terminal apparatus 1 selects a random access preamble based on the random access preamble allocation, and transmits the selected random access preamble. The random access preamble is included in the PRACH. In the first step (902), the MAC layer itself of the terminal apparatus 1 does not select the random access preamble index.

[0095]

In the second step (904), the terminal apparatus 1 receives the random access response. The random access response is included in the PDSCH. Here, the PDCCH for the RA-RNTI is used for scheduling of the PDSCH including the random access response. The value of the RA-RNTI may be given based on a PRACH resource used for the transmission of the random access preamble in the first step (900). The random access response includes a random access preamble identifier indicating the random access preamble index, an uplink grant, information indicating a Temporary C-RNTI, and information indicating a timing advance. In a case that the random access response includes a random access preamble identifier corresponding to the random access preamble transmitted in the first step (900), the reception of the random access response is considered to be successful. In a case that the random access response includes a random access preamble identifier corresponding to the random access preamble transmitted in the first step (900), the random access preamble allocation is notified, and

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the MAC itself of the terminal apparatus 1 does not select the random access preamble index, the terminal apparatus 1 considers the random access procedure to have successfully completed.

[0096]

In the zeroth step (900), in a case that the random access preamble allocation indicates a first prescribed value, the terminal apparatus 1 may initiate the 4 step contention based random access procedure. In other words, the case that the MAC itself of the terminal apparatus 1 does not select the random access preamble index may be a case in which the random access preamble allocation is not the first prescribed value.

[0097]

In the zeroth step (900), in a case that the random access preamble allocation indicates a second prescribed value, the terminal apparatus 1 may initiate the 2 step contention based random access procedure. In other words, in the case that the MAC itself of the terminal apparatus 1 does not select the random access preamble index may be a case that the random access preamble allocation differs from any of the first prescribed value and the second prescribed value.

[0098]

FIG. 10 is a diagram illustrating one example of correspondence between events and forms of random access procedures according to the present embodiment. The random access procedures are performed for (event i) initial access from RRC_IDLE, (event ii) RRC connection re-establishment, (event iii) handover, (event iv) downlink data arrival during RRC_CONNECTED, (event v) uplink data arrival during RRC_CONNECTED, and (event vi) time adjustment for a secondary TAG. The random access procedure for (event iv) downlink data arrival during RRC_CONNECTED may be performed in a case that an uplink synchronization status is asynchronous. The random access procedure for (event v) uplink data arrival during RRC_CONNECTED may be performed in a case that the uplink synchronization status is asynchronous or in a case that there is no PUCCH resource for a scheduling request.

[0099]

The random access procedures related to event i to event v may be performed in a primary cell. A first step in the random access procedure related to event vi may be performed in a secondary cell. In other words, the random access procedure performed for (event vi) time adjustment for a secondary TAG is initiated in the secondary cell belonging to the secondary TAG.

[0100]

The random access procedure for (event i) initial access from RRC_IDLE may include the 4 step contention based random access procedure and the 2 step contention based random access procedure. The random access procedure for (event i) initial access from RRC_IDLE may not include the non-contention based random access procedure.

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The random access procedure for (event i) initial access from RRC_IDLE may be initiated by the RRC.

[0101]

The random access procedure for (event ii) RRC connection re-establishment may include the 4 step contention based random access procedure and the 2 step contention based random access procedure. The random access procedure for (event ii) RRC connection re-establishment may not include the non-contention based random access procedure. The random access procedure for (event ii) RRC connection re-establishment may be initiated by the RRC.

[0102]

The random access procedures including the 4 step contention based random access procedure may mean that the 4 step contention based random access procedure is supported, the 4 step contention based random access procedure is enabled, or the 4 step contention based random access procedure is applicable. The same applies to the 2 step random access procedure and the non-contention based random access procedure.

[0103]

System information transmitted/broadcast by the base station apparatus 3 (cell) may include PRACH information and random access information. The PRACH information may include information for indicating a PRACH resource, information of the physical root sequence index u related to a random access preamble, and information of the cyclic shift C_v for the random access preamble. The physical root sequence index u and the cyclic shift C_v are used to determine a random access preamble sequence. The random access information may include information for indicating the number of random access preambles and information for indicating the number of random access preambles for the contention based random access procedure. In addition, the system information may include information for the 2 step contention based random access procedure. The information for the 2 step contention based random access procedure may include information for indicating that the 2 step contention based random access procedure is supported in the cell, information for indicating a resource for transmitting an identifier of the terminal apparatus 1 in the first step of the 2 step contention based random access procedure, information for indicating a modulation scheme for data including the identifier of the terminal apparatus 1 in the first step of the 2 step contention based random access procedure, and/or information for indicating a Reference Signal Received Power (RSRP) threshold. Here, the system information does not include a random access preamble allocation for a zeroth step of the non-contention based random access procedure.

[0104]

The terminal apparatus 1 measures RSRP from a downlink reference signal of the cell. The terminal apparatus 1 may initiate either the 2 step contention based random

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access procedure or the 4 step contention based random access procedure based on the measured RSRP and the threshold of the RSRP. In a case that the measured RSRP does not exceed the threshold of the RSRP, the terminal apparatus 1 may initiate the 4 step contention based random access procedure. In a case that the measured RSRP exceeds the threshold of the RSRP, the terminal apparatus 1 may initiate the 2 step contention based random access procedure.

[0105]

The random access procedure for (event iii) handover may include the 4 step contention based random access procedure, the 2 step contention based random access procedure, and the non-contention based random access procedure. A handover command may include the above-described PRACH information, the above-described random access information, the above-described information for the 2 step contention based random access procedure, and/or the random access preamble allocation for the zeroth step of the non-contention based random access procedure.

[0106]

The terminal apparatus 1 may initiate one of the 4 step contention based random access procedure, the 2 step contention based random access procedure, and the non-contention based random access procedure based on the information included in the handover command.

[0107]

In a case that the handover command includes the random access preamble allocation, the terminal apparatus 1 may initiate the non-contention based random access procedure.

[0108]

In a case that the handover command does not include the random access preamble allocation and the handover command includes the information for the 2 step contention based random access procedure, the terminal apparatus 1 may initiate either the 2 step contention based random access procedure or the 4 step contention based random access procedure based on the measured RSRP and the threshold of the RSRP.

[0109]

In a case that the handover command does not include the random access preamble allocation and the handover command includes the information for the 2 step contention based random access procedure, the terminal apparatus 1 may initiate either the 2 step contention based random access procedure or the 4 step contention based random access procedure based on the measured RSRP and the threshold of the RSRP. Here, in a case that the measured RSRP does not exceed the threshold of the RSRP, the terminal apparatus 1 may initiate the 4 step contention based random access procedure. Here, in a case that the measured RSRP exceeds the threshold of the RSRP, the terminal apparatus 1 may initiate the 2 step contention based random access procedure.

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[0110]

In a case that the handover command includes the random access preamble allocation and the random access preamble allocation indicates a first prescribed value, the terminal apparatus 1 may initiate the 4 step contention based random access procedure.

[0111]

In a case that the handover command includes the random access preamble allocation, the random access preamble allocation indicates a second prescribed value, and the handover command includes the information for the 2 step contention based random access procedure, the terminal apparatus 1 may initiate the 2 step contention based random access procedure.

[0112]

In a case that the handover command does not include the random access preamble allocation and the handover command does not include the information for the 2 step contention based random access procedure, the terminal apparatus 1 may initiate the 4 step contention based random access procedure.

[0113]

The random access procedure for (event iv) downlink data arrival during RRC_CONNECTED may include the 4 step contention based random access procedure and the non-contention based random access procedure. The random access procedure for (event iv) downlink data arrival during RRC_CONNECTED may not include the 2 step contention based random access procedure. The random access procedure for (event iv) downlink data arrival during RRC_CONNECTED is initiated by a PDCCH order.

[0114]

In a case that the random access preamble allocation included in the PDCCH order is a value other than the first prescribed value, the terminal apparatus 1 may initiate the non-contention based random access procedure. In a case that the random access preamble allocation included in the PDCCH order is the first prescribed value, the terminal apparatus 1 may initiate the 4 step contention based random access procedure. Even in a case that the random access preamble allocation included in the PDCCH order is the second prescribed value, the terminal apparatus 1 may initiate the 4 step contention based random access procedure.

[0115]

The random access procedure for (event v) uplink data arrival during RRC_CONNECTED may include the 4 step contention based random access procedure and the 2 step contention based random access procedure. The random access procedure for (event v) uplink data arrival during RRC_CONNECTED may not include the non-contention based random access procedure. The random access procedure for (event v) uplink data arrival during RRC_CONNECTED is initiated by the MAC itself.

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[0116]

The random access procedure performed for (event vi) time adjustment for a secondary TAG is initiated by a PDCCH order. In other words, the random access preamble allocation included in the PDCCH order for indicating initiation of the random access procedure in a secondary cell indicates a value other than the first prescribed value.

[0117]

FIG. 11 is a diagram illustrating another example of correspondence between events and forms of random access procedures according to the present embodiment. The random access procedures are initiated by (event A) RRC, (event B) MAC itself, or (event C) PDCCH order.

[0118]

The random access procedure initiated by (event A) RRC may include the 4 step contention based random access procedure, the 2 step contention based random access procedure, and the non-contention based random access procedure.

[0119]

The random access procedure initiated by (event B) MAC itself may include the 4 step contention based random access procedure and the 2 step contention based random access procedure. The random access procedure initiated by (event B) MAC itself may not include the non-contention based random access procedure.

[0120]

The random access procedure initiated by a PDCCH order may include the 4 step contention based random access procedure and the non-contention based random access procedure. The random access procedure initiated by the PDCCH order may not include the 2 step contention based random access procedure.

[0121]

The random access procedure initiated in a primary cell based on (event C) PDCCH order may include the 4 step contention based random access procedure and the non-contention based random access procedure. The random access procedure initiated in the primary cell based on (event C) PDCCH order may not include the 2 step contention based random access procedure.

[0122]

The random access procedure initiated in a secondary cell based on (event D) PDCCH order may include the non-contention based random access procedure. The random access procedure initiated in the secondary cell based on (event D) PDCCH order may not include the 4 step contention based random access procedure and the 2 step contention based random access procedure.

[0123]

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In the first step of the 2 step contention based random access procedure, a resource for the transmission of the random access preamble and a resource for the identifier of the terminal apparatus 1 may be time-multiplexed. The resource for the transmission of the random access preamble and the resource for the identifier of the terminal apparatus 1 may be frequency-multiplexed. Data including the identifier of the terminal apparatus 1 in the first step of the 2 step contention based random access procedure is also referred to as a message X. The message X may be transmitted through information bits and may be channel-coded. The resource for the transmission of the random access preamble may be a PRACH resource. A resource for transmission of the message X may be a PUSCH resource.

[0124]

FIG. 12 is a diagram illustrating one example of correspondence among resource sets for transmission of a random access preamble, transmission parameters for transmission of the message X, and random access preamble groups in the 2 step contention based random access procedure according to the present embodiment. In the first step of the 2 step contention based random access procedure, a resource set for the transmission of the random access preamble, a transmission parameter for the transmission of the message X, and a random access preamble group may correspond to each other. In FIG. 12, a resource set 1202, a random access preamble group 1212, and a transmission parameter 1222 for the transmission of the message X correspond to each other. In FIG. 12, a resource set 1204, a random access preamble group 1214, and a transmission parameter 1224 for the transmission of the message X correspond to each other. In a case that the terminal apparatus 1 selects the resource set 1202, the terminal apparatus 1 selects a resource from the resource set 1202, and selects a random access preamble from the random access preamble group 1212, transmits the selected random access preamble by using the selected resource, and transmits the message X based on the transmission parameter 1222. The transmission parameter 1222 may include multiple transmission parameter sets. The terminal apparatus 1 may select one transmission parameter set from the transmission parameter 1222. The transmission parameter is also referred to as scheduling information.

[0125]

A base station apparatus may transmit information for indicating the resource set 1202, information for indicating the resource set 1204, information for indicating the random access preamble group 1212, information for indicating the random access preamble group 1214, information for indicating the transmission parameter 1222 for the transmission of the message X, and information for indicating the transmission parameter 1224 for the transmission of the message X. The information may be included in the PDCCH or the PDSCH. The information may be included in downlink control

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information, RRC signaling, MAC CE, and/or higher layer signaling. The resource set 1202 and the resource set 1204 may correspond to different cells.

[0126]

The terminal apparatus 1 may select, among multiple resource sets for the transmission of the random access preamble, a set to be used to initiate the random access procedure. For example, the terminal apparatus 1 may select one set among multiple resource sets for the transmission of the random access preamble based on measurement using a downlink physical signal (a synchronization signal and/or a downlink reference signal). The measurement using the downlink physical signal may be measurement of a downlink path loss and/or downlink physical signal reception power. The downlink path loss may be calculated based on a downlink physical signal transmit power and the downlink physical signal reception power.

[0127]

FIG. 13 is a diagram illustrating one example of correspondence between random access preambles and transmission parameters for transmission of the message X in the 2 step contention based random access procedure according to the present embodiment. The random access preamble group 1212 may include random access preambles 1212A1, 1212B1, and 1212C1. The transmission parameter for the transmission of the message X may include transmission parameters 1222A1, 1222B1, and 1222C1. The random access preamble 1212A1 corresponds to the transmission parameter 1222A1. The random access preamble 1212B1 corresponds to the transmission parameter 1222B1. The random access preamble 1212C1 corresponds to the transmission parameter 1222C1. The terminal apparatus 1 may select a set of a random access preamble and a transmission parameter. The terminal apparatus 1 may select a random access preamble from a random access preamble group, and select a transmission parameter corresponding to the selected random access preamble. The terminal apparatus 1 may select a transmission parameter and select a random access preamble corresponding to the selected transmission parameter. The terminal apparatus 1 may randomly select a random access preamble from the random access preamble group 1212. The terminal apparatus 1 may transmit the selected random access preamble by using a selected resource, and transmit the message X based on the selected transmission parameter.

[0128]

FIG. 14 is a diagram illustrating one example of correspondence between random access preamble groups and transmission parameters for transmission of the message X in the 2 step contention based random access procedure according to the present embodiment. The random access preamble group 1212 may include random access preamble groups 1212A2, 1212B2, and 1212C2. The transmission parameter 1222 for the transmission of the message X may include transmission parameters 1222A2, 1222B2, and 1222C2. The random access preamble group 1212A2 corresponds to the transmission

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parameter 1222A2. The random access preamble group 1212B2 corresponds to the transmission parameter 1222B2. The random access preamble group 1212C2 corresponds to the transmission parameter 1222C2.

[0129]

The terminal apparatus 1 may select a set of a random access preamble group and a transmission parameter. The terminal apparatus 1 may select a random access preamble and select a transmission parameter corresponding to a group to which the selected random access preamble belongs. The terminal apparatus 1 may randomly select a random access preamble from the random access preamble group 1212. The terminal apparatus 1 may transmit the selected random access preamble by using a selected resource, and transmit the message X based on the selected transmission parameter.

[0130]

The terminal apparatus 1 may select one group among the multiple random access preamble groups {1212A2, 1212B2, 1212C2}, select a random access preamble from the selected group, and select a transmission parameter corresponding to the selected random access preamble. Here, the terminal apparatus 1 may randomly select a random access preamble from the selected group. For example, the terminal apparatus 1 may select one group among the multiple random access preamble groups {1212A2, 1212B2, 1212C2} based on measurement using a downlink physical signal (a synchronization signal and/or a downlink reference signal), the size of the message X, a value A1 given in accordance with information received from the base station apparatus 3, and/or a value A2 given in accordance with the information received from the base station apparatus 3. The terminal apparatus 1 may select one group among the multiple random access preamble groups {1212A2, 1212B2, 1212C2} based on whether or not the size of the message X is greater than the value A1 and/or whether or not the result of the measurement using the downlink physical signal is greater than the value A2. For example, in a case that the size of the message X is greater than the value A1 and the result of the measurement using the downlink physical signal is smaller than the value A2, the terminal apparatus 1 may select the random access preamble group 1212A2. For example, in a case that the size of the message X is equal to or smaller than the value A1, or in a case that the result of the measurement using the downlink physical signal is equal to or greater than the value A2, the terminal apparatus 1 may select the random access preamble group 1212B2.

[0131]

Here, the value A2 may be given based on a value indicated by the information received from the base station apparatus 3 and/or a maximum transmit power value for a serving cell in which the terminal apparatus 1 performs the random access procedure. The value A1 and the value A2 may be configured separately for the random access preamble group 1212 and the random access preamble group 1214. The terminal apparatus 1 may separately configure a parameter for calculating the values A1 and A2 for the random

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access preamble group 1212 and a parameter for calculating the values A1 and A2 for the random access preamble group 1214. The base station apparatus 3 may transmit information for indicating the multiple parameters.

[0132]

The transmission parameter for transmission of the message X includes a parameter D1 related to a modulation scheme, a parameter D2 related to a resource, a parameter D3 related to the size (the number of bits) of the message X, a parameter D4 related to initialization of a scrambling sequence used for scrambling of coded bits or modulation symbols of the message X, a parameter D5 related to code spreading of the message X, a parameter D6 related to a DMRS associated with transmission of a PUSCH including the message X, and/or a parameter D7 related to a transmit power. The transmission parameter may include parameters other than the parameters D1 to D7.

[0133]

The modulation scheme may include Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM). The parameter D2 related to a resource may be associated with a subframe, a transmission bandwidth, and/or a transmission frequency. The transmission bandwidth and the transmission frequency may be represented by a physical resource block or a subcarrier. The size of the message X may be the number of information bits of the message X before coding. The scrambling sequence may be a pseudo-random sequence. The scrambling sequence may be given by a Gold sequence and/or one or more M sequences.

[0134]

The terminal apparatus 1 generates a DMRS based on the parameter D6 related to a DMRS. The DMRS is given based on a DMRS sequence r_{PUSCH}. The DMRS sequence r_{PUSCH} is defined by Equation 3, where $r^{(\alpha)}$ is an RS sequence given by Equation 4, w is an orthogonal cover code, e^x is an exponential function the base of which is the Napier's number e, j is an imaginary number, α is a cyclic shift, r' is a base sequence, and M_{RS_SC} is the length of the base sequence r'. M_{RS_SC} may be the number of resource elements (subcarriers) corresponding to the DMRS in one SC-FDMA symbol. The base sequence may be given based on a Zadoff-Chu sequence, a Gold sequence, and/or an M sequence.

[0135]

Equation 3

$$r_{\mathrm{PUSCH}}\left(m \cdot M_{\mathrm{RS\_sc}} + n\right) = w\ (m) r^{(\alpha)}(n), \quad m = 0,1 \quad 0 \le n < M_{\mathrm{RS\_sc}}$$

[0136]

Equation 4

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$$r^{(\alpha)}(n) = e^{j\alpha n} r'(n), \quad 0 \le n < M_{\mathrm{RS\_sc}}$$

[0137]

The parameter D6 related to a DMRS may include a parameter used to determine the orthogonal cover code w, a parameter used to determine the cyclic shift α, a parameter used to determine the base sequence r', a parameter used to determine the length M_{RS_SC} of the base sequence r', and/or a parameter used to determine the resources (resource elements) corresponding to the DMRS.

[0138]

FIG. 15 is a diagram illustrating another example of correspondence between random access preambles and transmission parameters for the transmission of the message X in the 2 step contention based random access procedure according to the present embodiment. The random access preamble group 1212A may include random access preambles 1212A21, 1212A22, and 1212A23. The transmission parameter 1222A2 for the transmission of the message X may include transmission parameters 1222A21, 1222A22, 1222A23, and 1222A24. The random access preamble 1212A21 corresponds to the transmission parameters 1222A21 and 1222A24. The random access preamble 1212A22 corresponds to the transmission parameters 1222A22 and 1222A24. The random access preamble 1212A23 corresponds to the transmission parameters 1222A23 and 1222A24. 1222A24 may correspond to all the random access preambles belonging to the group 1212A2.

[0139]

The terminal apparatus 1 may select a random access preamble and select a transmission parameter corresponding to the selected random access preamble. The terminal apparatus 1 may randomly select a random access preamble from the random access preamble group 1212A2. The terminal apparatus 1 may select the random access preamble 1212A21, and select the transmission parameter 1222A21 and the transmission parameter 1222A24 corresponding to the selected random access preamble 1212A21. The terminal apparatus 1 may transmit the selected random access preamble and transmit the message X based on the selected transmission parameter.

[0140]

The transmission parameters 1222A21, 1222A22, and 1222A23 may include some of the parameters D1 to D6 described above, and the transmission parameter 1222A24 may include the remainder of the parameters D1 to D6 described above. For example, the transmission parameter 1222A21 may include the parameter D4 related to initialization of a scrambling sequence used for scrambling of coded bits or modulation symbols of the message X, the parameter D5 related to code spreading of the message X, the parameter

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D6 related to a DMRS associated with transmission of a PUSCH including the message X, and/or the parameter D7 related to a transmit power. For example, the transmission parameter 1222A24 may include the parameter D1 related to a modulation scheme, the parameter D2 related to a resource, and/or the parameter D3 related to the size (number of bits) of the message X. The transmission parameters 1222A21, 1222A22, 1222A23, and 1222A24 may include parameters other than the parameters D1 to D7 described above.

[0141]

The embodiments illustrated in FIG. 13 and FIG. 14 may be applied to the random access preamble group 1214 and the transmission parameter 1224. The embodiment illustrated in FIG. 15 may be applied to the random access preamble groups 1212B2 and 1212C2 and the transmission parameters 1222B2 and 1222C2.

[0142]

In the first step of the 2 step contention based random access procedure, information related to a random access preamble may be transmitted together with the message X. The message X may include the information related to the random access preamble. The information related to the random access preamble may include information for indicating a random access preamble index(information A), information for indicating a resource for transmission of the random access preamble (information B), and/or information related to a random access preamble sequence (information C). In the first step of the 2 step contention based random access procedure, the terminal apparatus 1 may transmit a random access preamble having an index 1 by using a PRACH resource, and transmit the message X including the information A for indicating the index 1 of the random access preamble by using a PUSCH. The information related to a random access preamble sequence (information C) may indicate a physical root sequence index and/or a cyclic shift.

[0143]

FIG. 16 is a diagram illustrating one example of the 2 step contention based random access procedure according to the present embodiment. In 1600 and 1602 in FIG. 16, the terminal apparatus 1A and the terminal apparatus 1B initiate the 2 step contention based random access procedure. The random access preamble 1212A21 selected by the terminal apparatus 1A differs from the random access preamble 1212A22 selected by the terminal apparatus 1B. However, a transmission parameter to which the random access preamble 1212A21 selected by the terminal apparatus 1A corresponds may be the same as a transmission parameter to which the random access preamble 1212A24 selected by the terminal apparatus 1B corresponds. The transmission parameter may be 1222A24.

[0144]

In 1600, the terminal apparatus 1A transmits the random access preamble 1212A21. In 1600, the terminal apparatus 1A transmits, based on the transmission

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parameter 1222A24, the message X including an identifier of the terminal apparatus 1A and an index of the random access preamble 1222A21. In 1602, the terminal apparatus 1B transmits the random access preamble 1212A22. In 1602, the terminal apparatus 1B transmits, based on the transmission parameter 1222A24, the message X including an identifier of the terminal apparatus 1B and an index of the random access preamble 1222A21.

[0145]

In a case that the base station apparatus 3 successfully detects the random access preamble 1212A21 and the random access preamble 1212A22, successfully receives/detects the message X transmitted by the terminal apparatus 1A, and fails to receive/detect the message transmitted by the terminal apparatus 1B, the base station apparatus 3 transmits a contention resolution based on the identifier of the terminal apparatus 1A (1604), and transmits a random access response corresponding to the random access preamble 1212A22 (1606). In a case that the terminal apparatus 1B receives the random access response, the terminal apparatus 1B transmits the identifier of the terminal apparatus 1B by using a PUSCH, based on an uplink grant included in the random access response (1608). Next, the terminal apparatus 1B receives the contention resolution (1610). In a case that the message X transmitted by the terminal apparatus 1A includes information for indicating the index of the random access preamble 1212A21, the base station apparatus 3 may not transmit a random access response corresponding to the random access preamble 1212A21. Note that information for indicating a random access preamble may be represented by a scrambling sequence used for scrambling of coding bits or modulation symbols of the message X, code spreading of the message X, and/or a DMRS associated with transmission of a PUSCH including the message X.

[0146]

In 1604 and 1606 in FIG. 16, the random access response and the contention resolution may be included in the same PDSCH. In other words, in 1604 and 1606 in FIG. 16, a transport block including the random access response and the contention resolution may be transmitted by using the PDSCH. A DCI format to which a CRC scrambled with the above-described RA-RNTI or the above-described X-RNTI is added may be used for scheduling of the PDSCH. FIG. 17 is a diagram illustrating one example of a transport block including a random access response and/or a contention resolution according to the present embodiment. In FIG. 17, the transport block includes a header 1700 and n RAR/CR {1721, 1722,..., 172n}. The RAR/CR is a random access response or a contention resolution. The header 1700 includes n subheaders {1701, 1702,..., 170n}. Each of the headers may correspond to each of the RAR/CR. For example, the subheader 1701 may correspond to the RAR/CR 1721.

[0147]

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Each of the subheaders {1701, 1702,... 170n} may include a random access preamble identifier for indicating a random access preamble index. In a case that the subheader 1701 includes a random access preamble identifier for indicating the random access preamble index transmitted in the first step of the 2 step contention based random access procedure, the terminal apparatus 1 may check the RAR/CR 1721 corresponding to the subheader 1701.

[0148]

A subheader may include a flag for indicating that a random access response is included in a RAR/CR to which the subheader corresponds. A subheader may include a flag for indicating that a contention resolution is included in a RAR/CR to which the subheader corresponds. A subheader may include a flag for indicating that which of a random access response and a contention resolution is included in a RAR/CR to which the subheader corresponds. Based on the flag, the terminal apparatus 1 may identify which of a random access response and a contention resolution is included in the RAR/CR.

[0149]

In a case that the flag included in the subheader indicates that the RAR/CR includes a contention resolution, the subheader may not include the random access preamble identifier, and the subheader may include information for indicating an index of a resource for transmission of the message X. In a case that the subheader 1701 includes information for indicating an index of a resource for the transmission of the message X in the first step of the 2 step contention based random access procedure, the terminal apparatus 1 may check the RAR/CR 1721 corresponding to the subheader 1701. The index of the resource for the transmission of the message X may be assigned to a frequency-time resource. Different indexes may be assigned to different resources corresponding to different transmission parameters.

[0150]

An RAR/CR may include a flag for indicating that a random access response is included in the RAR/CR. An RAR/CR may include a flag for indicating that a contention resolution is included in the RAR/CR. An RAR/CR may include a flag for indicating which of a random access response and a contention resolution is included in the RAR/CR. Based on the flag, the terminal apparatus 1 may identify which of a random access response and a contention resolution is included in the RAR/CR.

[0151]

In a case that a random access preamble identifier included in a subheader is set to a prescribed value, the terminal apparatus 1 may determine that an RAR/CR to which the subheader corresponds includes a contention resolution. The prescribed value may be 0. The prescribed value may be 1. Based on a value set in a header field included in a

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transport block, the terminal apparatus 1 may determine that the transport block includes a contention resolution and/or a random access response.

[0152]

In a given cell, a random access preamble group corresponding to the 2 step contention based random access procedure may be the same as a random access preamble group corresponding to the 4 step contention based random access procedure. In a given cell, a resource set for transmission of a random access preamble corresponding to the 2 step contention based random access procedure may be the same as a resource set for transmission of a random access preamble corresponding to the 4 step contention based random access procedure. For example, in FIG. 12, the resource sets 1202 and 1204 for transmission of a random access preamble and the random access preamble groups 1212 and 1214 may be used for transmission of a random access preamble corresponding to the 4 step contention based random access procedure. The method for the terminal apparatus 1 to select a random access preamble group, illustrated in FIG. 14, may be applied to the 4 step contention based random access procedure.

[0153]

FIG. 18 is a diagram illustrating one example of random access preamble groups for random access procedures according to the present embodiment. In FIG. 18, group configurations for the 4 step contention based random access procedure and the 2 step contention based random access procedure are the same. In FIG. 18, the group 1212A2 includes random access preambles having indexes 6 to 20, the group 1212B2 includes random access preambles having indexes 21 to 41, and the group 1212C2 includes random access preambles having indexes 42 to 63. The terminal apparatus 1 may select one group among the groups {1212A2, 1212B2, 1212C2} in the first step of the 4 step contention based random access procedure, and may select one group among the groups {1212A2, 1212B2, 1212C2} in the first step of the 2 step contention based random access procedure.

[0154]

FIG. 18 is a diagram illustrating one example of random access preamble groups for random access procedures according to the present embodiment. In FIG. 18, group configurations for the 4 step contention based random access procedure is the same as group configurations for the 2 step contention based random access procedure. In FIG. 18, the group 1212A2 includes random access preambles having indexes 6 to 20, the group 1212B2 includes random access preambles having indexes 21 to 41, and the group 1212C2 includes random access preambles having indexes 42 to 63. The terminal apparatus 1 may select one group among the groups {1212A2, 1212B2, 1212C2} in the first step of the 4 step contention based random access procedure, and may select one group among the groups {1212A2, 1212B2, 1212C2} in the first step of the 2 step contention based random access procedure.

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[0155]

FIG. 19 is a diagram illustrating another example of random access preamble groups for random access procedures according to the present embodiment. In FIG. 19, a group configuration for the 4 step contention based random access procedure is different from a group configuration for the 2 step contention based random access procedure. In FIG. 19, the group 1212A2 includes random access preambles having indexes 6 to 20, the group 1212B2 includes random access preambles having indexes 21 to 63, a group 1212A2' includes random access preambles having indexes 6 to 41, and a group 1212B2' includes random access preambles having indexes 42 to 63. The terminal apparatus 1 may select one group among the groups {1212A2', 1212B2'} in the first step of the 4 step contention based random access procedure, and may select one group among the groups {1212A2, 1212B2} in the first step of the 2 step contention based random access procedure.

[0156]

The terminal apparatus 1 may select one group among the multiple random access preamble groups {1212A2, 1212B2} based on measurement using a downlink physical signal (a synchronization signal and/or a downlink reference signal), the size of the message X, the value A1 given in accordance with information received from the base station apparatus 3, and/or the value A2 given in accordance with the information received from the base station apparatus 3. The terminal apparatus 1 may select one group among the multiple random access preamble groups {1212A2, 1212B2} based on measurement using a downlink physical signal (a synchronization signal and/or a downlink reference signal), the size of the message X, a value A3 given in accordance with the information received from the base station apparatus 3, and/or a value A4 given in accordance with the information received from the base station apparatus 3. Here, the values A1, A2, A3, and A4 may be configured separately. The base station apparatus 3 may transmit information used to determine the value A1, information used to determine the value A2, information used to determine the value A3, and information used to determine the value A4. Note that the method illustrated in FIG. 14 may be used as a method for determining a group.

[0157]

In FIG. 18 and FIG. 19, the random access preambles having the indexes 0 to 5 may be used in the non-contention based random access procedure.

[0158]

FIG. 20 is a diagram illustrating one example of a flow of a contention based random access procedure according to the present embodiment.

[0159]

In step 2000, the terminal apparatus 1 sets a transmission counter (PREAMBLE_TRANSMISSION_COUNTER) and a power ramp up counter to 0. The

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transmission counter (PREAMBLE_TRANSMISSION_COUNTER) is used to determine whether to notify the higher layer (RRC) of a random access problem. The power ramp up counter is used for (1) configuration of a transmit power P_{PRACH} for PRACH transmission in the first step of the 4 step contention based random access procedure, (2) configuration of the transmit power P_{PRACH} for the PRACH transmission in the first step of the 2 step contention based random access procedure, and (3) configuration of the transmit power P_{PUSCH} for the PUSCH transmission in the first step of the 2 step contention based random access procedure.

[0160]

In step 2001, the terminal apparatus 1 may select a type/form of contention random access procedure (the 2 step contention based random access procedure or the 4 step contention based random access procedure), and perform the contention based random access procedure based on the selected type/form.

[0161]

In step 2002, the terminal apparatus 1 determines whether random access response reception or contention resolution is successful. In a case that the random access response reception or the contention resolution is successful, the terminal apparatus 1 terminates the contention based random access procedure.

[0162]

In a case that the random access response reception or the contention resolution fails, the terminal apparatus 1 proceeds to step 2003.

[0163]

An example of the case in that the random access response reception fails will be described. The MAC of the terminal apparatus 1 may monitor a PDCCH for a random access response in a random access response window in a case that a random access preamble is transmitted (initial transmission or retransmission) in the first step (600) of the 4 step contention based random access procedure. In a case that the random access response is not received in the random access response window, the MAC of the terminal apparatus 1 may proceed to step 2003. In a case that all of the received random access responses do not include a random access identifier corresponding to the transmitted random access preamble, the MAC of the terminal apparatus 1 may proceed to step 2003.

[0164]

An example of the case in that the random access response reception or the contention resolution fails will be described. In a case that a random access preamble and an identifier of the terminal apparatus 1 are transmitted in the first step (700, 800) of the 2 step contention based random access procedure, the MAC of the terminal apparatus 1 may start a first timer (first mac-ContentionResolutionTimer). Here, the MAC of the terminal apparatus 1 may monitor a PDCCH for contention resolution and a PDCCH for a the random access response while the first timer (first mac-ContentionResolutionTimer)

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is running. In a case that the identifier of the terminal apparatus 1 is transmitted in the third step (804) of the 2 step contention based random access procedure, the MAC of the terminal apparatus 1 may start a second timer (second mac-ContentionResolutionTimer). Here, the MAC of the terminal apparatus 1 may monitor a PDCCH for contention resolution while the second timer (second mac-ContentionResolutionTimer) is running. In a case that the first timer (first mac-ContentionResolutionTimer) or the second timer (second mac-ContentionResolutionTimer) expires, the MAC of the terminal apparatus 1 may assume that the contention resolution has failed. In a case that the MAC of the terminal apparatus 1 considers that the contention resolution is unsuccessful and the MAC of the terminal apparatus 1 has not received a power ramping suspension notification from the lower layer (physical layer), the MAC of the terminal apparatus 1 may proceed to step 2003. Here, the length of the first timer (first mac-ContentionResolutionTimer) and/or the length of the second timer (second mac-ContentionResolutionTimer) may be given based on higher layer (RRC) information (parameter) received from the base station apparatus 3. Here, the second timer (second mac-ContentionResolutionTimer) may be the first timer (first mac-ContentionResolutionTimer). In this case, the higher layer (RRC) information (parameter) may not indicate the length of the second timer (second mac-ContentionResolutionTimer).

[0165]

In step 2003, the MAC of the terminal apparatus 1 determines whether the power ramping suspension notification has been received from the lower layer (physical layer). In a case that the power ramping suspension notification has not been received from the lower layer (physical layer), the MAC of the terminal apparatus 1 may increment the transmission counter (PREAMBLE_TRANSMISSION_COUNTER) by one and proceed to step 2006 (step 2004). In a case that the power ramping suspension notification has been received from the lower layer (physical layer), the MAC of the terminal apparatus 1 may proceed to step 2006. Here, a common transmission counter (PREAMBLE_TRANSMISSION_COUNTER) may be used regardless of the selected type/form of random access procedure. In a case that the MAC indicates to the physical layer of the terminal apparatus 1 to transmit the random access preamble but the transmission of the random access preamble is dropped, the physical layer of the terminal apparatus 1 may indicate the power ramping suspension notification to the MAC. In a case that the MAC indicates to the physical layer of the terminal apparatus 1 to transmit the random access preamble and the identifier of the terminal apparatus 1 but the transmission of the random access preamble and the identifier of the terminal apparatus 1 is dropped, the physical layer of the terminal apparatus 1 may indicate the power ramping suspension notification to the MAC. The physical layer of the terminal apparatus 1 may

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drop transmission of a PUSCH including the identifier of the terminal apparatus 1 based on drop of transmission of a PRACH including the random access preamble.

[0166]

In step 2006, the MAC of the terminal apparatus 1 may determine whether the transmission counter (PREAMBLE_TRANSMISSION_COUNTER) has a prescribed value A. In a case that the transmission counter (PREAMBLE_TRANSMISSION_COUNTER) does not have the prescribed value A, the MAC of the terminal apparatus 1 may proceed to step 2010. In a case that the transmission counter (PREAMBLE_TRANSMISSION_COUNTER) has the prescribed value A, the MAC of the terminal apparatus 1 may indicate a random access problem to the higher layer (RRC) (step 2008). Based on the indication of the random access problem from the lower layer (MAC), the higher layer (RRC) may consider that a radio link failure is detected and perform a leaving RRC_CONNECTED procedure or an RRC connection re-establishment procedure. In the leaving RRC_CONNECTED procedure and the RRC connection re-establishment procedure, the RRC requires the MAC to reset the MAC. In a case that the reset of the MAC is requested by the higher layer (RRC) of the terminal apparatus 1, the MAC of the terminal apparatus 1 stops the random access procedure which has been continued. Here, the prescribed value A may be the maximum number of transmissions or the maximum number of attempts. Here, the prescribed value A may be given based on the higher layer (RRC) information (parameter) received from the base station apparatus 3.

[0167]

In a case that the MAC of the terminal apparatus 1 determines that the random access procedure has failed in step 2002, the MAC of the terminal apparatus 1 may determine whether to increment the power ramp up counter by one (step 2010). Note that, in a case that the random access procedure has failed in step 2002 and no power ramping suspension notification has been received from the lower layer (physical layer), the MAC of the terminal apparatus 1 may determine whether to increment the power ramp up counter by one. In other words, in a case that the random access procedure has failed in step 2002 and the power ramping suspension notification has been received from the lower layer (physical layer), the MAC of the terminal apparatus 1 may not determine whether to increment the power ramp up counter by one.

[0168]

In a case that the MAC of the terminal apparatus 1 determines to increment the power ramp up counter by one, the MAC of the terminal apparatus 1 may increment the power ramp up counter by one (step 2012). After step 2012, the MAC of the terminal apparatus 1 may proceed to step 2001 and perform the selected type/form of contention based random access procedure. In a case that the MAC of the terminal apparatus 1 determines not to increment the power ramp up counter by one, the MAC of the terminal

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apparatus 1 may proceed to step 2001 and perform the selected type/form of contention based random access procedure.

[0169]

In step 2010, the MAC of the terminal apparatus 1 may determine whether to increment the power ramp up counter based on the transmission counter (PREAMBLE_TRANSMISSION_COUNTER). In step 2010, in a case that the remainder of dividing the transmission counter (PREAMBLE_TRANSMISSION_COUNTER) is a prescribed value B, the MAC of the terminal apparatus 1 may determine to increment the power ramp up counter by one. Here, the prescribed value B may be given based on the higher layer (RRC) information (parameter) received from the base station apparatus 3. The prescribed value B may be 1 or an integer greater than 1. The MAC itself of the terminal apparatus 1 may adjust the value of the power ramp up counter such that the power ramp up counter does not exceed the transmission counter (PREAMBLE_TRANSMISSION_COUNTER).

[0170]

A method of configuring the transmit power P_{PRACH} for transmission of a PRACH including a random access preamble will be described below. The transmit power P_{PRACH} for the transmission of the PRACH may be given by Equation 5.

[0171]

Equation 5

P_{PRACH} = min{, PREAMBLE_RECEIVED_TARGET_POWER + } [dBm]

where

- is the configured UE transmit power defined in [6] for subframe *i* of serving cell .
- is the downlink path loss estimate calculated in the UE for serving cell .

[0172]

$P_{CMAX,c}(i)$ is a maximum transmit power for a subframe i of a serving cell c, PL_c is a downlink path loss (path loss estimate) in the serving cell c and is calculated by the terminal apparatus 1, and min is a function that returns a minimum value among a plurality of input values. PREAMBLE_RECEIVED_TARGET_POWER is given by Equation 6.

[0173]

Equation 6

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PREAMBLE_RECEIVED_TARGET_POWER

= preambleInitialReceivedTargetPower(m) + DELTA_PREAMBLE(F)

+ (PREAMBLE_TRANSMISSION_COUNTER – 1) * powerRampingStep(m);

where

- preambleInitialReceivedTargetPower(m) is configured by higher layers (RRC) for m=0 and m=1. For 4 step contention based random access procedure and non-contention based random access procedure then m=0, and for 2 step contention based random access procedure then m=1.
- powerRampingStep(m) is configured by higher layers (RRC) for m=0 and m=1.
- DELTA_PREAMBLE(F) is configured by higher layers (RRC). Each DELTA_PREAMBLE(F) value corresponds to a PRACH format (F).

[0174]

preambleInitialReceivedTargetPower(m) is configured by the higher layer (RRC), powerRampingStep(m) is a step size of transmit power ramp up, and powerRampingStep(m) is configured by the higher layer (RRC). m is 0 for the 4 step contention based random access response procedure and the non-contention based random access procedure. m is 1 for the 2 step contention based random access procedure. In other words, preambleInitialReceivedTargetPower(0) and preambleInitialReceivedTargetPower(1) may be configured by the higher layer. In other words, powerRampingStep(0) and powerRampingStep(1) are configured by the higher layer. The base station apparatus 3 may transmit higher layer (RRC) information (parameter) for indicating preambleInitialReceivedTargetPower(0) and higher layer (RRC) information (parameter) for indicating preambleInitialReceivedTargetPower(1). The base station apparatus 3 may transmit higher layer (RRC) information (parameter) for indicating powerRampingStep(0) and higher layer (RRC) information (parameter) for indicating powerRampingStep(1).

[0175]

Common preambleInitialReceivedTargetPower may be used for the 2 step contention based random access response procedure, the 4 step contention based random access response procedure, and the non-contention based random access procedure. Common powerRampingStep may be used for the 2 step contention based random access response procedure, the 4 step contention based random access response procedure, and the non-contention based random access procedure.

[0176]

DELTA_PREAMBLE (F) may be configured by the higher layer. Each DELTA_PREAMBLE (F) may correspond to a PRACH format (F). The PRACH format may be a random access preamble format. The PRACH format may include a CP length,

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the length of a random access preamble sequence, and the number of repetitions of the random access preamble sequence. The base station apparatus 3 may transmit higher layer (RRC) information (parameter) for indicating DELTA_PREAMBLE (F).

PREAMBLE_TRANSMISSION_COUNTER is the transmission counter described above.

[0177]

In other words, the terminal apparatus 1 may ramp up the transmit power for the transmission of the PRACH transmitted in the first step of the 2 step contention based random access procedure, based on a failure of random access response reception or contention resolution. In other words, the terminal apparatus 1 may ramp up the transmit power for the transmission of the PRACH transmitted in the first step of the 4 step contention based random access procedure, based on a failure of random access response reception or contention resolution.

[0178]

A method of configuring the transmit power P_{PUSCH} for transmission of a PUSCH will be described below.

[0179]

In a case that an entire transmission bandwidth for the PUSCH transmitted in the first step (700, 800) of the 2 step contention based random access procedure is included in a transmission bandwidth for the PRACH transmitted in the first step (700, 800) of the 2 step contention based random access procedure, the transmit power P_{PUSCH} for the transmission of the PUSCH may be given based on the transmit power P_{PRACH} for the transmission of the PRACH. For example, the transmit power P_{PUSCH} for the transmission of the PUSCH may be the same as the transmit power P_{PRACH} for the transmission of the PRACH.

[0180]

The transmit power $P_{PUSCH,c}(i)$ for transmission of a PUSCH in the subframe (i) of the serving cell c may be given by Equation 7.

[0181]

Equation 7

$$P_{PUSCH,c}(i) = \min \begin{Bmatrix} P_{CMAX,c}(i), \\ 10\log_{10}(M_{PUSCH,c}(i)) + P_{O\_PUSCH,c} + \alpha_c \cdot PL_c + \Delta_{TF,c}(i) + f_c(i) + \Delta P_{rampup}(2) \end{Bmatrix} \text{ [dBm]}$$

[0182]

$M_{PUSCH,c}$ is a transmission bandwidth for the PUSCH in the subframe (i) of the serving cell c, and is expressed by the number of physical resource blocks. $P_{O\_PUSCH,c}$ is configured by the higher layer, α_c is configured by the higher layer, $\Delta_{TF,c}$ (i) is given based at least on a higher layer parameter, and f_c (i) is given based on a TPC command

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included in downlink control information. For the transmit power P_{PUSCH} for the transmission of the PUSCH transmitted in the first step (700, 800) of the 2 step contention based random access procedure, ΔPrampup(2) may be given by Equation 8. Otherwise, $\Delta P_{rampup}(2)$ may be 0.

[0183]

Equation 8

$$\Delta P_{rampup}(2) = (\text{PREAMBLE\_TRANSMISSION\_COUNTER} - 1) * \text{powerRampingStep}(2)$$

[0184]

powerRampingStep(2) is configured by the higher layer. The base station apparatus 3 may transmit higher layer (RRC) information (parameters) for indicating powerRampingStep(2). powerRampingStep(2) may be defined separately from powerRampingStep(0) and powerRampingStep(1). In Equation 8, powerRampingStep(1) may be used instead of powerRampingStep(2).

[0185]

PREAMBLE_TRANSMISSION_COUNTER is the transmission counter described above.

[0186]

In other words, the terminal apparatus 1 may ramp up the transmit power for the transmission of the PUSCH transmitted in the first step of the 2 step contention based random access procedure, based on a failure of the reception of a random access response or contention resolution.

[0187]

The terminal apparatus 1 may ramp up the transmit power for the transmission of the PUSCH transmitted in the first step of the 2 step contention based random access procedure, based on a failure of random access response reception or contention resolution in the 2 step contention based random access procedure.

[0188]

The terminal apparatus 1 may ramp up the transmit power for the transmission of the PUSCH transmitted in the first step of the 2 step contention based random access procedure, based on a failure of random access response reception or contention resolution in the 4 step contention based random access procedure.

[0189]

In a case that a random access response is received as the second step of the 4 step contention based random access procedure, the terminal apparatus 1 may reset the value of $f_c(i)$. Here, an initial value $f_c(0)$ of $f_c(i)$ may be given based on $\Delta P_{rampup}(0)$ and $\delta_{msg2,c}$. $\Delta P_{rampup}(0)$ is given by Equation 9. Here, $\delta_{msg2,c}$ is indicated by a TPC command included in the random access response.

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[0190]
Equation 9

$$\Delta P_{rampup}(0) = (\text{PREAMBLE\_TRANSMISSION\_COUNTER} - 1) * powerRampingStep(0)$$

[0191]
In a case that a random access response is received as the second step of the 2 step contention based random access procedure, the terminal apparatus 1 may reset the value of $f_c(i)$. Here, the initial value $f_c(0)$ of $f_c(i)$ may be given based on $\Delta P_{rampup}(1)$ and $\delta_{msg2,c}$. $\Delta P_{rampup}(1)$ is given by Equation 10. Here, $\delta_{msg2,c}$ is indicated by a TPC command included in the random access response.
[0192]
Equation 10

$$\Delta P_{rampup}(1) = (\text{PREAMBLE\_TRANSMISSION\_COUNTER} - 1) * \text{powerRampingStep}(1)$$

[0193]
In a case that a contention resolution is received as the second step of the 2 step contention based random access procedure, the terminal apparatus 1 may reset the value of $f_c(i)$. Here, the initial value $f_c(0)$ of $f_c(i)$ may be given based on $\Delta P_{rampup}(1)$ and $\delta_{msg2,c}$. Here, $\delta_{msg2,c}$ is indicated by a TPC command included in the contention resolution.
[0194]
In a case that a contention resolution is received as the second step of the 2 step contention based random access procedure, the terminal apparatus 1 may set the value of $f_c(i)$ based on Equation 11. ΔP_{rampup_2step} may be given based on $\Delta P_{rampup}(2)$. Here, $\delta_{msg2,c}$ is indicated by a TPC command included in the contention resolution.
[0195]
Equation 11

$$f_c(i) = f_c(i-1) + \Delta P_{\text{rampup\_2step}} + \delta_{msg2,c}$$

[0196]
Various aspects of the terminal apparatus 1 according to the present embodiment will be described below.
[0197]
(1) A first aspect of the present embodiment is a terminal apparatus 1 including the higher layer processing unit 14 configured to perform a random access procedure and the reception unit 10 configured to receive a physical channel (PDCCH order), wherein the

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random access procedure includes a 2 step contention based random access procedure, a 4 step contention based random access procedure, and a non-contention based random access procedure, the physical channel indicates initiation of one of the 4 step-contention based random access procedure and the non-contention based random access procedure, and the higher layer processing unit is configured to initiate one of the 4 step contention based random access procedure and the non-contention based random access procedure based on the physical channel.

[0198]

(2) In the first aspect of the present embodiment, the higher layer processing unit 14 initiates one of the 2 step contention based random access procedure and the 4 step contention based random access procedure for initial access and RRC connection re-establishment.

[0199]

(3) In the first aspect of the present embodiment, for handover, the higher layer processing unit 14 initiates one of the 2 step contention based random access procedure, the 4 step contention based random access procedure, and the non-contention based random access procedure.

[0200]

(4) In the first aspect of the present embodiment, in a case that the MAC layer initiates the random access procedure, the higher layer processing unit 14 initiates one of the 2 step contention based random access procedure and the 4 step contention based random access procedure.

[0201]

(5) In the first aspect of the present embodiment, in a case that the physical channel indicates initiation of the random access procedure in a secondary cell belonging to a secondary TAG, the physical channel indicates initiation of the non-contention based random access procedure.

[0202]

(6) A second aspect of the present embodiment is the terminal apparatus 1 including the higher layer processing unit 14 configured to control a 2 step contention based random access procedure, and the transmission unit 10 configured to transmit a random access preamble and data as a first step of the 2 step contention based random access procedure, wherein the data includes information of the random access preamble, and the information of the random access preamble includes part or all of the following information A to information C.

Information A: Information for indicating an index of the random access preamble

Information B: Information for indicating a resource for the transmission of the random access preamble

Information C: Information related to a sequence of the random access preamble

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(7) A third aspect of the present embodiment is the base station apparatus 3 including the higher layer processing unit 34 configured to control a 2 step contention based random access procedure, and the reception unit 30 configured to receive a random access preamble and data as a first step of the 2 step contention based random access procedure, wherein the data includes information of the random access preamble.

[0203]

The information of the random access preamble includes part or all of the following information A to information C.

Information A: Information for indicating an index of the random access preamble

Information B: Information for indicating a resource for transmission of the random access preamble

Information C: Information related to a sequence of the random access preamble

(8) A fourth aspect of the present embodiment is the terminal apparatus 1 including the higher layer processing unit 14 configured to control a 2 step contention based random access procedure, and the transmission unit 10 configured to transmit a random access preamble and data as a first step of the 2 step contention based random access procedure, wherein one or both of (1) a parameter related to initialization of a scrambling sequence used for scrambling of a physical channel including the data and (2) a parameter used for generation of a DeModulation Reference Signal (DMRS) associated with the physical channel including the data is determined based on one or both of (3) an index of the random access preamble and (4) a resource for transmission of the random access preamble.

[0204]

(9) A fifth aspect of the present embodiment is the base station apparatus 3 including the higher layer processing unit 34 configured to control a 2 step contention based random access procedure, and the reception unit 30 configured to receive a random access preamble and data as a first step of the 2 step contention based random access procedure, wherein one or both of (1) a scrambling sequence used for scrambling of a physical channel including the data and (2) a parameter used for generation of a demodulation reference signal associated with the physical channel including the data is determined based on one or both of (3) an index of the random access preamble and (4) a resource for transmission of the random access preamble.

[0205]

(10) A sixth aspect of the present embodiment is the terminal apparatus 1 including the higher layer processing unit 14 configured to control a 2 step contention based random access procedure, and the transmission unit 10 configured to transmit a random access preamble and data as a first step of the 2 step contention based random access procedure, wherein the higher layer processing unit 14 (1) selects one group of multiple random access preamble groups, (2) selects the random access preamble from

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the selected group, and (3) selects, from multiple transmission parameters, a transmission parameter corresponding to the selected group, and the data is transmitted based on the selected transmission parameter.

[0206]

(11) A seventh aspect of the present embodiment is the terminal apparatus 1 including the higher layer processing unit 14 configured to increment a transmission counter based on a failure of random access response reception or contention resolution, the receiver 10 configured to receive information for indicating a higher layer parameter powerRampingStep(1) and information for indicating a higher layer parameter powerRampingStep(2), and a transmit power control unit 12 configured to set a transmit power, wherein the transmit power for PRACH transmission in a first step of a 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(1), and the transmit power for PUSCH transmission in the first step of the 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(2).

[0207]

In the second to fifth aspects of the present embodiment, the data may be the message X. In the third and fourth aspects of the present embodiment, the parameter related to initialization of a scrambling sequence used for scrambling of a physical channel including the data may be the parameter D4 related to initialization of a scrambling sequence used for scrambling of coded bits or modulation symbols of the message X. In the third and fourth aspects of the present embodiment, the parameter used for generation of a demodulation reference signal associated with the physical channel including the data may be the parameter D6 related to a DMRS associated with transmission of a PUSCH including the message X. In the sixth aspect of the present embodiment, the transmission parameters may include the parameters D1 to D7 described above, and may include parameters other than the parameters D1 to D7.

[0208]

Consequently, the terminal apparatus and the base station apparatus can efficiently perform a random access procedure with each other.

[0209]

The base station apparatus 3 according to one aspect of the present invention can also be realized as an aggregation (an apparatus group) including multiple apparatuses. Each of the apparatuses configuring such an apparatus group may include some or all portions of each function or each functional block of the base station apparatus 3 according to the above-described embodiment. The apparatus group may include each general function or each functional block of the base station apparatus 3. Furthermore,

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the terminal apparatus 1 according to the above-described embodiment can also communicate with the base station apparatus as the aggregation.

[0210]

Furthermore, the base station apparatus 3 according to the above-described embodiment may serve as an Evolved Universal Terrestrial Radio Access Network (EUTRAN). Furthermore, the base station apparatus 3 according to the above-described embodiment may have some or all portions of the functions of a node higher than an eNodeB.

[0211]

A program running on an apparatus according to one aspect of the present invention may serve as a program that controls a Central Processing Unit (CPU) and the like to cause a computer to operate in such a manner as to realize the functions of the above-described embodiment according to one aspect of the present invention. Programs or the information handled by the programs are temporarily read into a volatile memory, such as a Random Access Memory (RAM) while being processed, or stored in a non-volatile memory, such as a flash memory, or a Hard Disk Drive (HDD), and then read by the CPU to be modified or rewritten, as necessary.

[0212]

Moreover, the apparatuses in the above-described embodiment may be partially enabled by a computer. In such a case, a program for realizing such control functions may be recorded on a computer-readable recording medium to cause a computer system to read the program recorded on the recording medium for execution. It is assumed that the "computer system" refers to a computer system built into the apparatuses, and the computer system includes an operating system and hardware components such as a peripheral device. Furthermore, the “computer-readable recording medium” may be any of a semiconductor recording medium, an optical recording medium, a magnetic recording medium, and the like.

[0213]

Moreover, the "computer-readable recording medium" may include a medium that dynamically retains a program for a short period of time, such as a communication line that is used to transmit the program over a network such as the Internet or over a communication line such as a telephone line, and may also include a medium that retains a program for a fixed period of time, such as a volatile memory within the computer system for functioning as a server or a client in such a case. Furthermore, the above-described program may be configured to realize some of the functions described above, and additionally may be configured to realize the functions described above, in combination with a program already recorded in the computer system.

[0214]

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Furthermore, each functional block or various characteristics of the apparatuses used in the above-described embodiment may be implemented or performed on an electric circuit, that is, typically an integrated circuit or multiple integrated circuits. An electric circuit designed to perform the functions described in the present specification may include a general-purpose processor, a Digital Signal Processor (DSP), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), or other programmable logic devices, discrete gates or transistor logic, discrete hardware components, or a combination thereof. The general-purpose processor may be a microprocessor, or the processor may be a processor of known type, a controller, a micro-controller, or a state machine instead. The general-purpose processor or the above-mentioned circuits may be constituted of a digital circuit, or may be constituted of an analog circuit. Furthermore, in a case that with advances in semiconductor technology, a circuit integration technology appears that replaces the present integrated circuits, it is also possible to use an integrated circuit based on the technology.

[0215]

Note that the invention of the present patent application is not limited to the above-described embodiments. In the embodiment, apparatuses have been described as an example, but the invention of the present application is not limited to these apparatuses, and is applicable to a terminal apparatus or a communication apparatus of a fixed-type or a stationary-type electronic apparatus installed indoors or outdoors, for example, an AV apparatus, a kitchen apparatus, a cleaning or washing machine, an air-conditioning apparatus, office equipment, a vending machine, and other household apparatuses.

[0216]

The embodiments of the present invention have been described in detail above referring to the drawings, but the specific configuration is not limited to the embodiments and includes, for example, an amendment to a design that falls within the scope that does not depart from the gist of the present invention. Furthermore, various modifications are possible within the scope of one aspect of the present invention defined by claims, and embodiments that are made by suitably combining technical means disclosed according to the different embodiments are also included in the technical scope of the present invention. Furthermore, a configuration in which constituent elements, described in the respective embodiments and having mutually the same effects, are substituted for one another is also included in the technical scope of the present invention.

Industrial Applicability

[0217]

An aspect of the present invention can be utilized, for example, in a communication system, communication equipment (for example, a cellular phone

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apparatus, a base station apparatus, a radio LAN apparatus, or a sensor device), an integrated circuit (for example, a communication chip), or a program.

Reference Signs List

[0218]

1 (1A, 1B, 1C) Terminal apparatus
3 Base station apparatus
10 Radio transmission and/or reception unit
11 Antenna unit
12 RF unit
13 Baseband unit
14 Higher layer processing unit
15 Medium access control layer processing unit
16 Radio resource control layer processing unit
30 Radio transmission and/or reception unit
31 Antenna unit
32 RF unit
33 Baseband unit
34 Higher layer processing unit
35 Medium access control layer processing unit
36 Radio resource control layer processing unit

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Claims

[Claim 1]

A terminal apparatus comprising:

a higher layer processing unit configured to increment a transmission counter based on a failure of random access response reception or contention resolution;

a receiver configured to receive information for indicating a higher layer parameter powerRampingStep(1) and information for indicating a higher layer parameter powerRampingStep(2); and

a transmit power control unit configured to set a transmit power; wherein

the transmit power for PRACH transmission in a first step of a 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(1), and

the transmit power for PUSCH transmission in the first step of the 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(2).

[Claim 2]

A communication method used for a terminal apparatus, the communication method comprising the steps of:

incrementing a transmission counter based on a failure of random access response reception or contention resolution;

receiving information for indicating a higher layer parameter powerRampingStep(1) and information for indicating a higher layer parameter powerRampingStep(2);

setting a transmit power; wherein

the transmit power for PRACH transmission in a first step of a 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(1), and

the transmit power for PUSCH transmission in the first step of the 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(2).

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Abstract

A terminal apparatus increments a transmit counter based on a failure of random access response reception or contention resolution, and receives information for indicating a higher layer parameter powerRampingStep(1) and information for indicating a higher layer parameter powerRampingStep(2). A transmit power for PRACH transmission in a first step of a 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(1), and a transmit power for PUSCH transmission in the first step of the 2 step contention based random access procedure is given based at least on the transmission counter and the higher layer parameter powerRampingStep(2).

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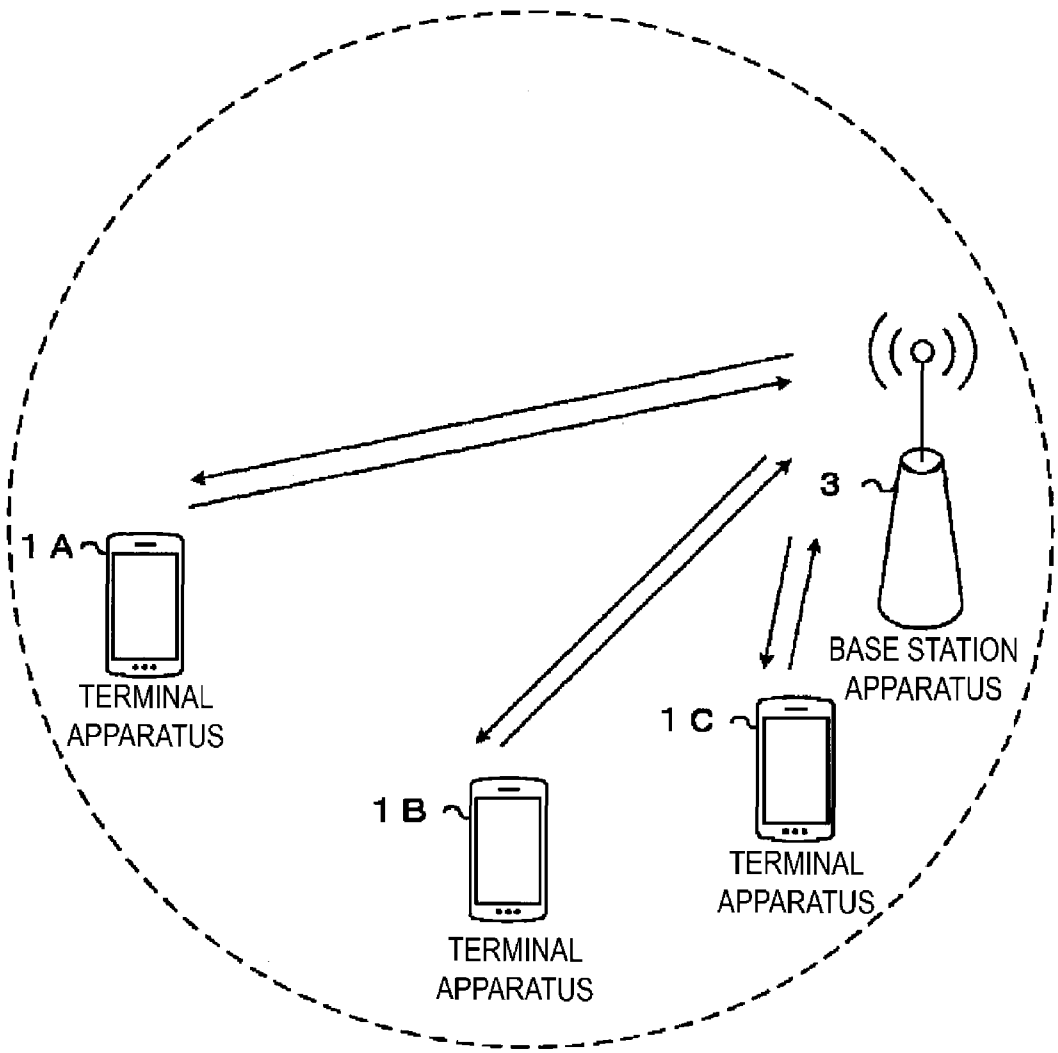

1 A
TERMINAL
APPARATUS
3
BASE STATION
APPARATUS
1 B
TERMINAL
APPARATUS
1 C
TERMINAL
APPARATUS

FIG. 1

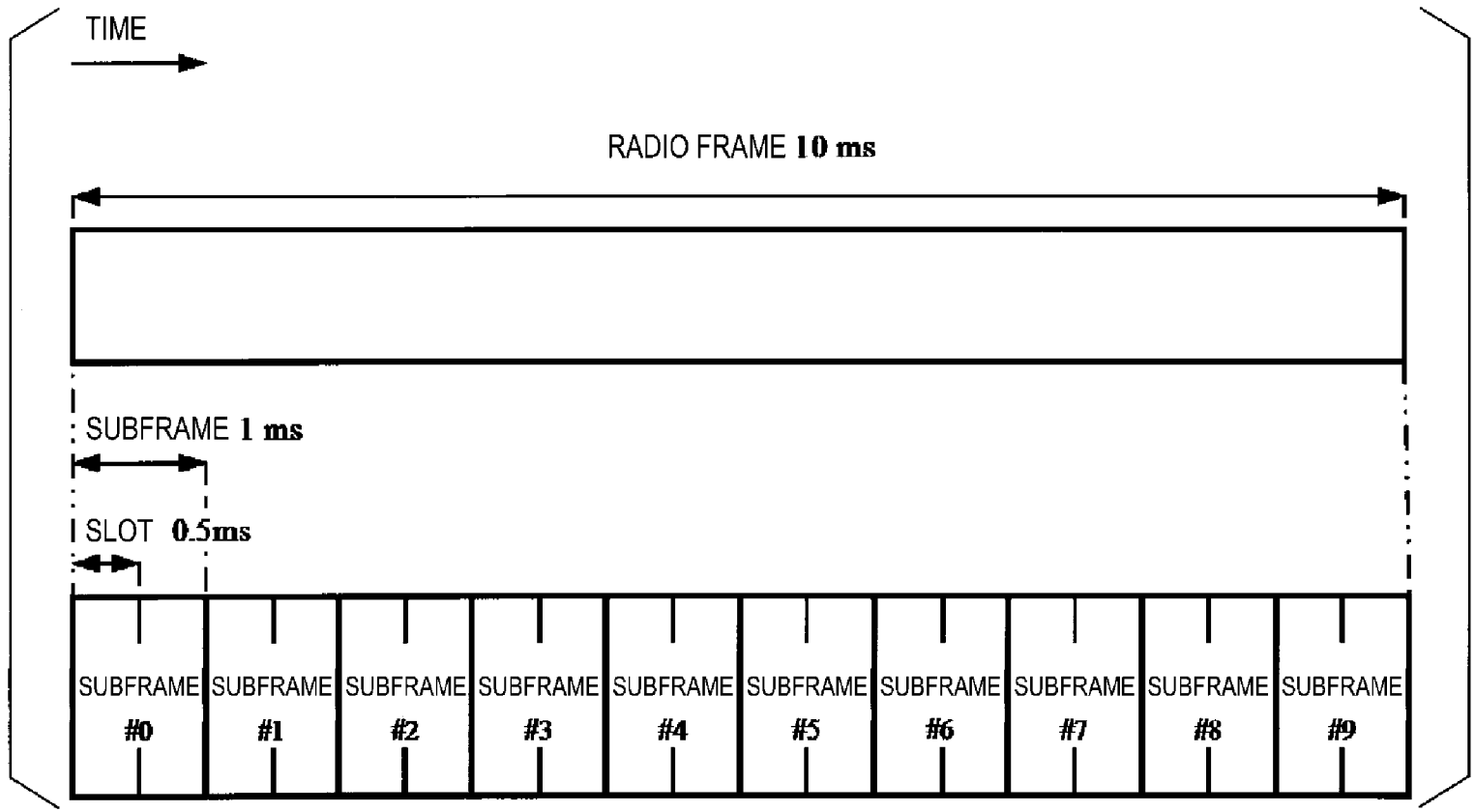


FIG. 2

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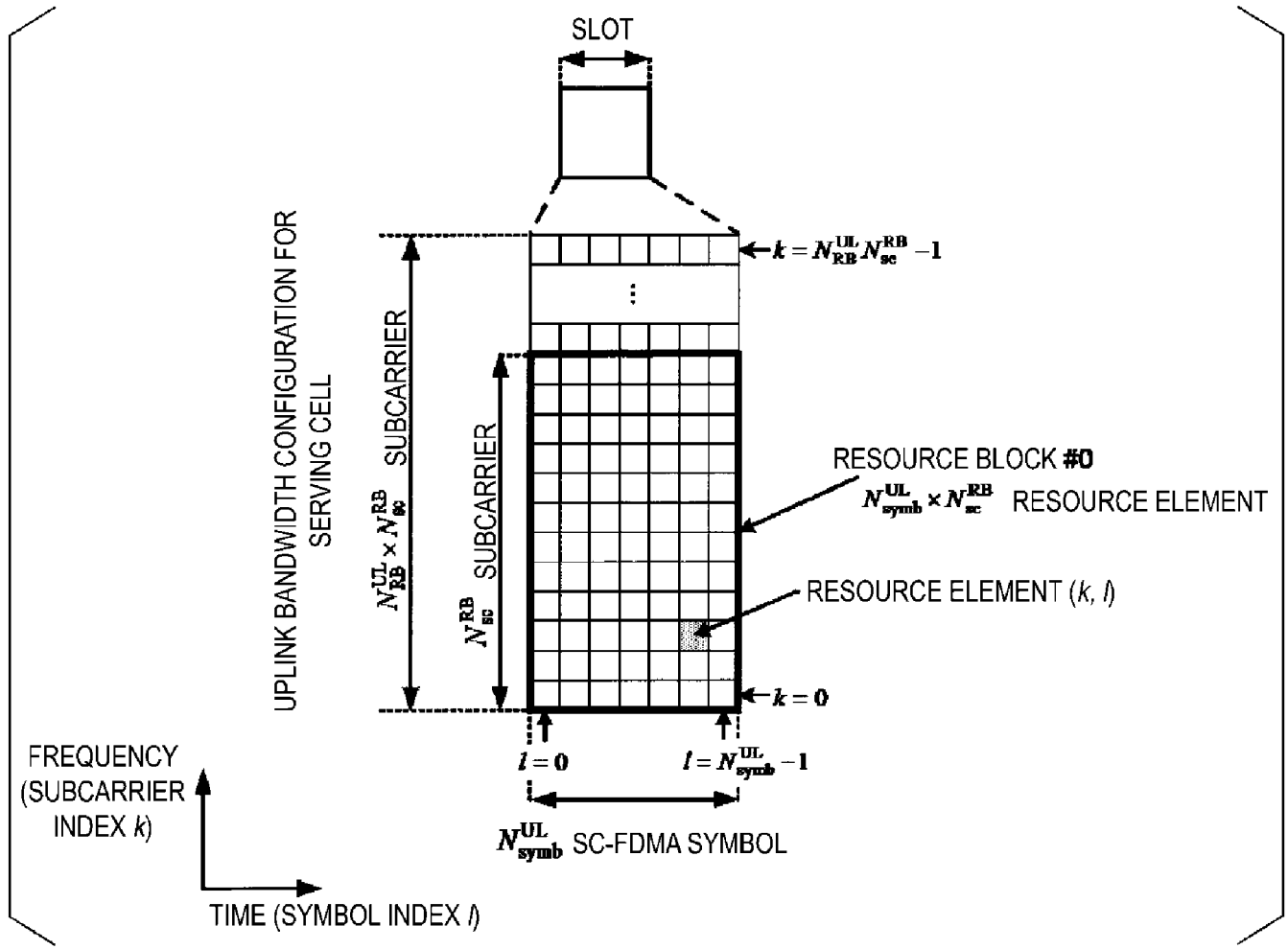


FIG. 3

DAINGEAN_0002629

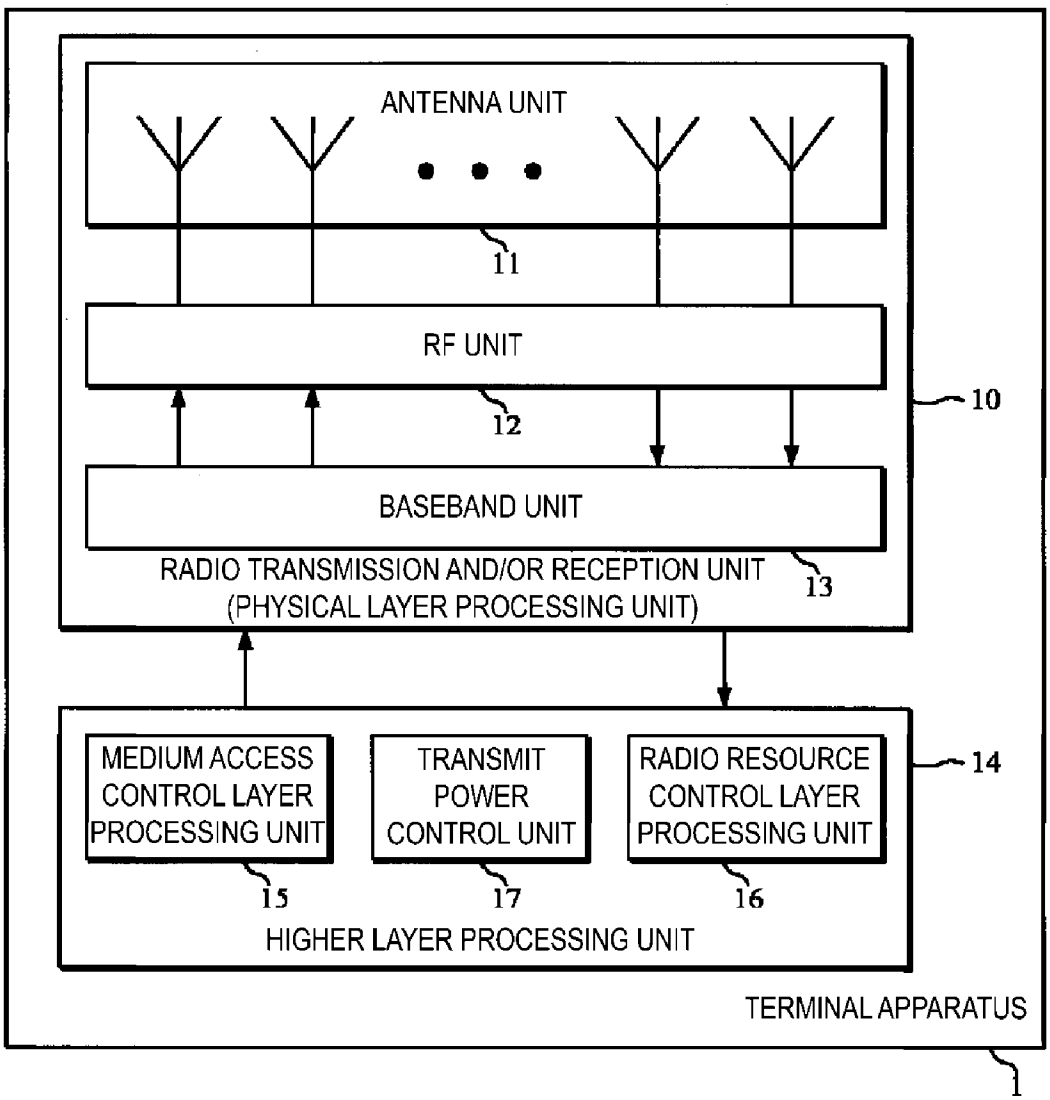


FIG. 4

DAINGEAN_0002630

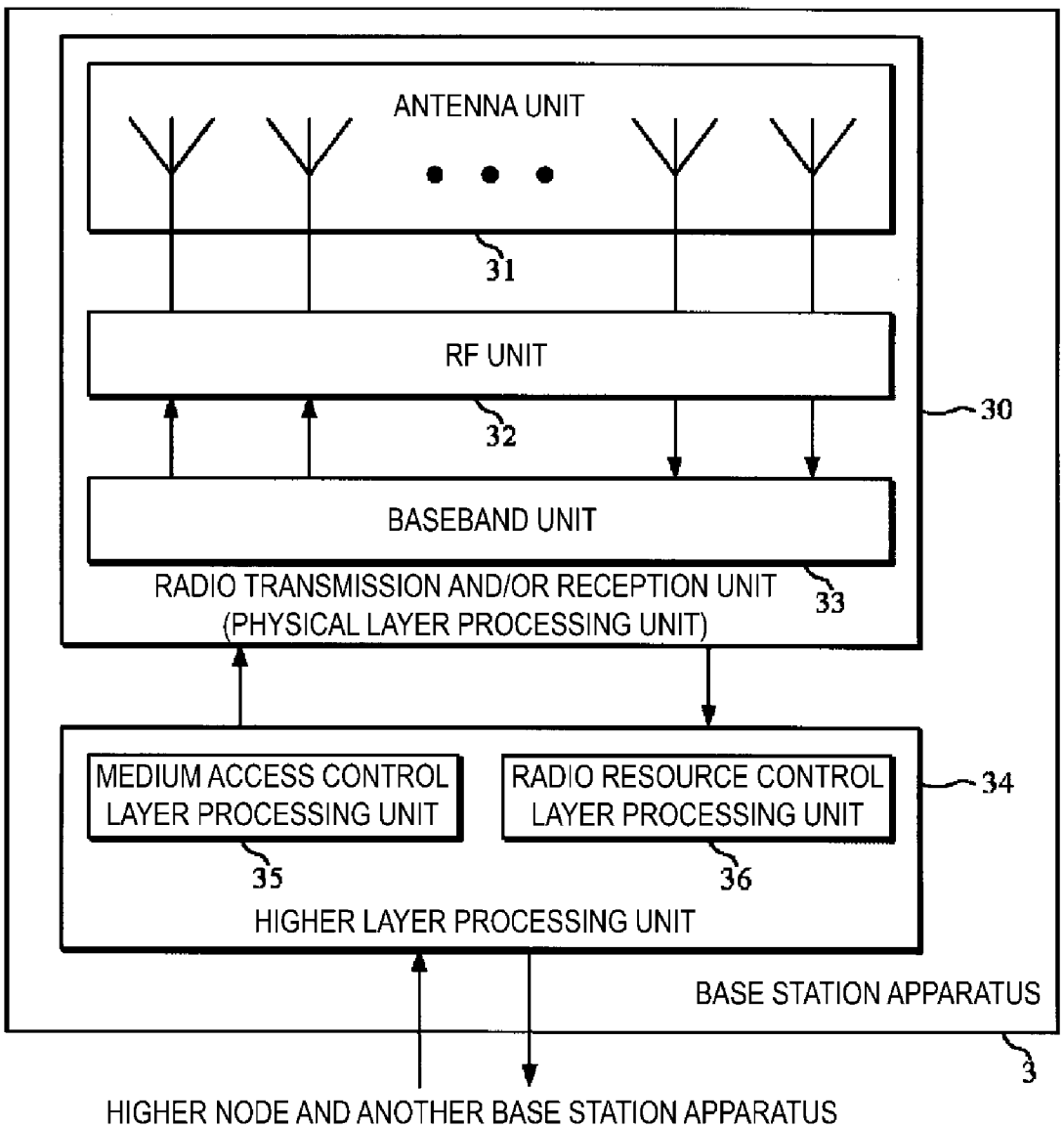

ANTENNA UNIT
31
RF UNIT
32
30
BASEBAND UNIT
RADIO TRANSMISSION AND/OR RECEPTION UNIT
(PHYSICAL LAYER PROCESSING UNIT)
33
MEDIUM ACCESS CONTROL
LAYER PROCESSING UNIT
RADIO RESOURCE CONTROL
LAYER PROCESSING UNIT
34
35
36
HIGHER LAYER PROCESSING UNIT
BASE STATION APPARATUS
3
HIGHER NODE AND ANOTHER BASE STATION APPARATUS

FIG. 5

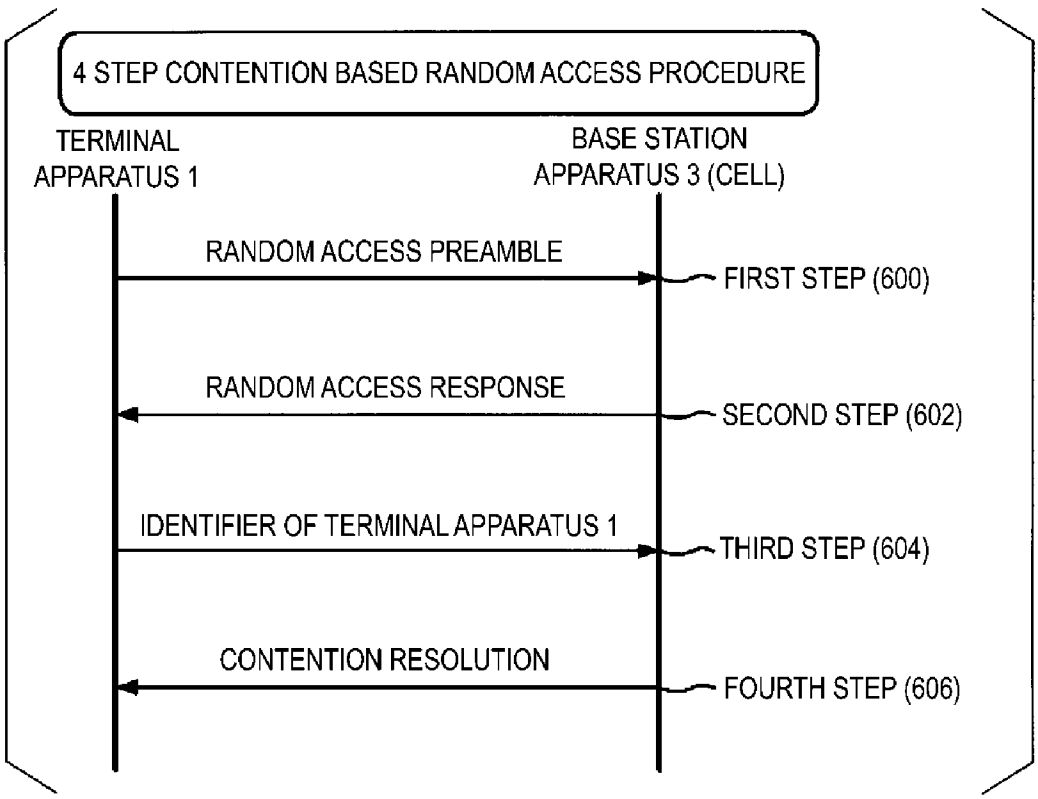


FIG. 6

DAINGEAN_0002632

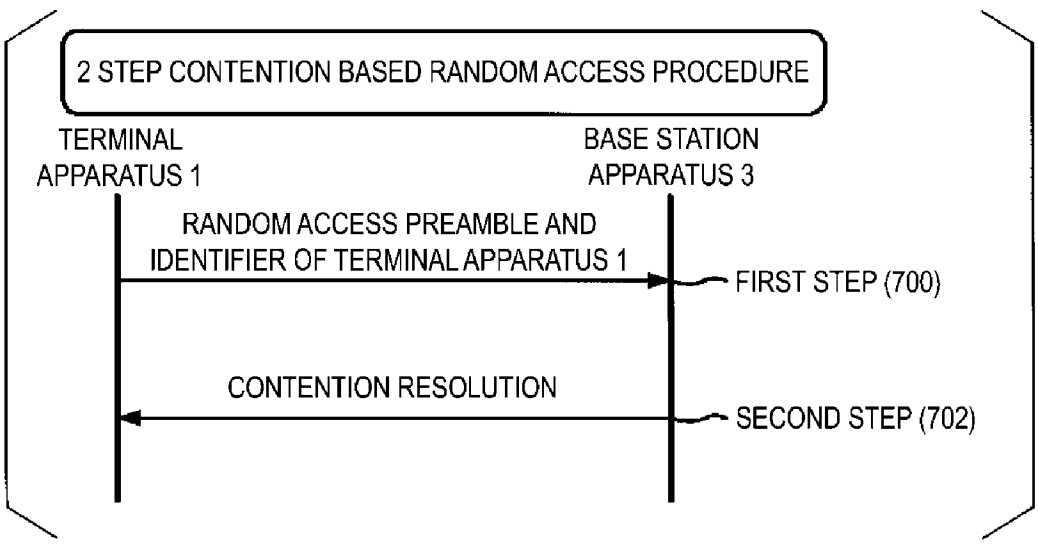


FIG. 7

DAINGEAN_0002633

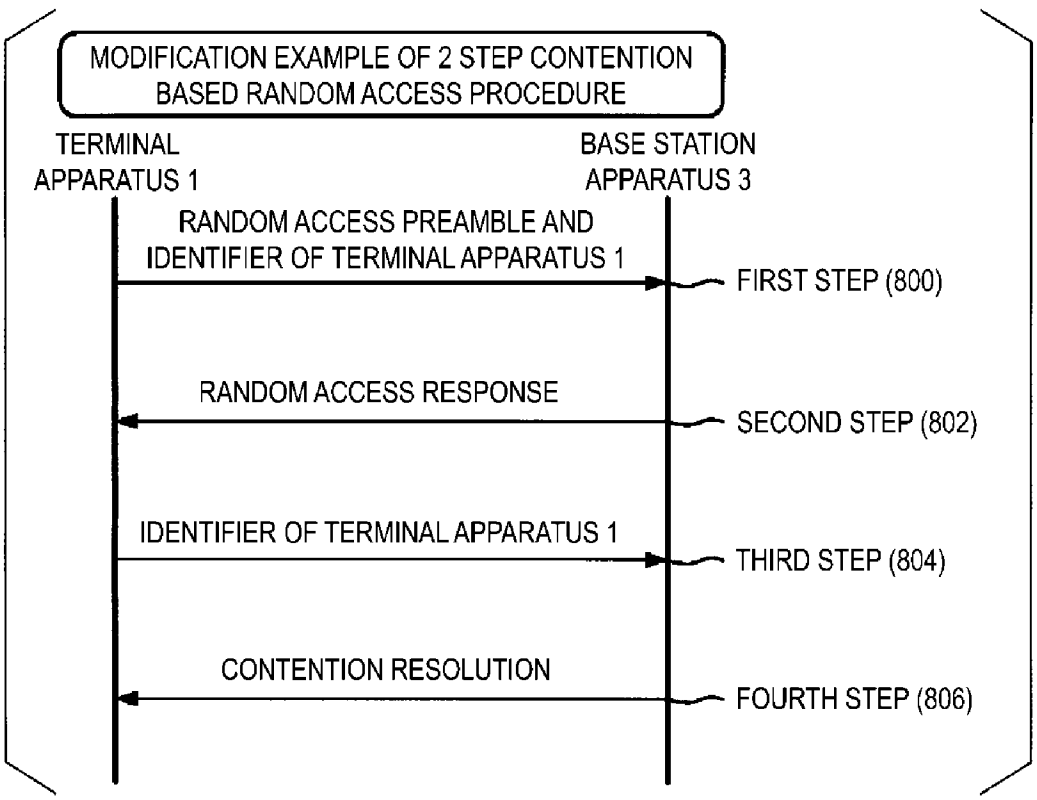


FIG. 8

DAINGEAN_0002634

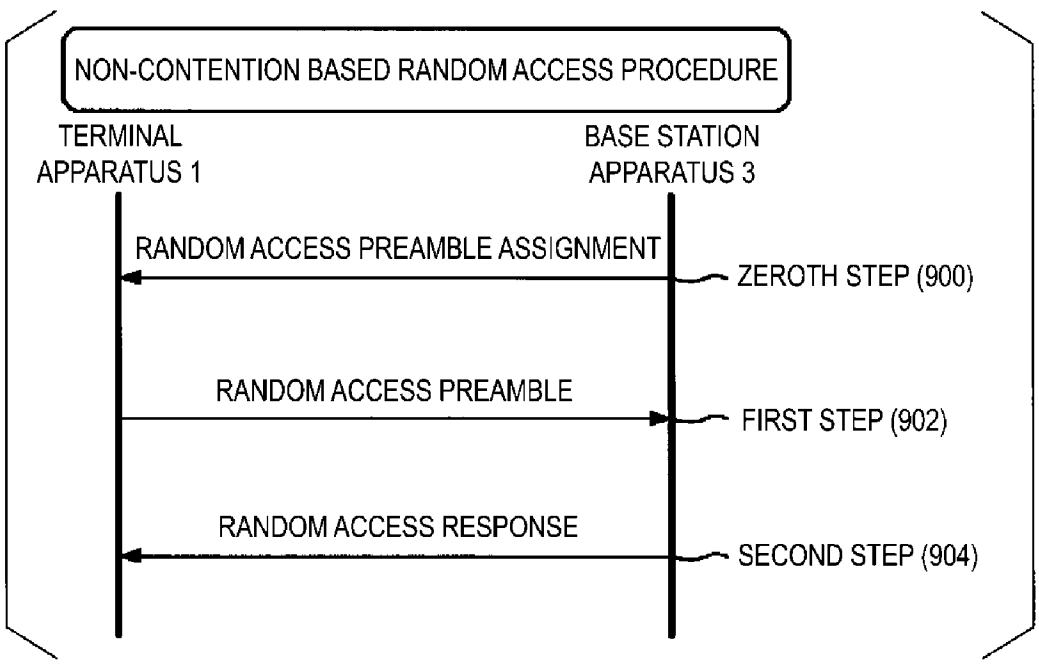


FIG. 9

DAINGEAN_0002635

EVENT	4 STEP CONTENTION BASED RANDOM ACCESS PROCEDURE	2 STEP CONTENTION BASED RANDOM ACCESS PROCEDURE	NON-CONTENTION BASED RANDOM ACCESS PROCEDURE
(i) INITIAL ACCESS	ENABLED	ENABLED	*DISABLED*
(ii) RRC CONNECTION REESTABLISHMENT	ENABLED	ENABLED	*DISABLED*
(iii) HANDOVER	ENABLED	ENABLED	ENABLED
(iv) DOWNLINK DATA ARRIVAL	ENABLED	*DISABLED*	ENABLED
(v) UPLINK DATA ARRIVAL	ENABLED	ENABLED	*DISABLED*
(vi) TIME ADJUSTMENT FOR STAG	*DISABLED*	*DISABLED*	ENABLED

10

FIG. 10

DAINGEAN_0002636

EVENT	4 STEP CONTENTION BASED RANDOM ACCESS PROCEDURE	2 STEP CONTENTION BASED RANDOM ACCESS PROCEDURE	NON-CONTENTION BASED RANDOM ACCESS PROCEDURE
(A) IN A CASE THAT RANDOM ACCESS PROCEDURE IS INITIATED BY RRC	ENABLED	ENABLED	ENABLED
(B) IN A CASE THAT RANDOM ACCESS PROCEDURE IS INITIATED BY MAC ITSELF	ENABLED	ENABLED	*DISABLED*
(C) IN A CASE THAT RANDOM ACCESS PROCEDURE IN PRIMARY CELL IS INITIATED BASED ON PDCCH ORDER	ENABLED	*DISABLED*	ENABLED
(D) IN A CASE THAT RANDOM ACCESS PROCEDURE IN SECONDARY CELL IS INITIATED BASED ON PDCCH ORDER	*DISABLED*	*DISABLED*	ENABLED

11

FIG. 11

DAINGEAN_0002637

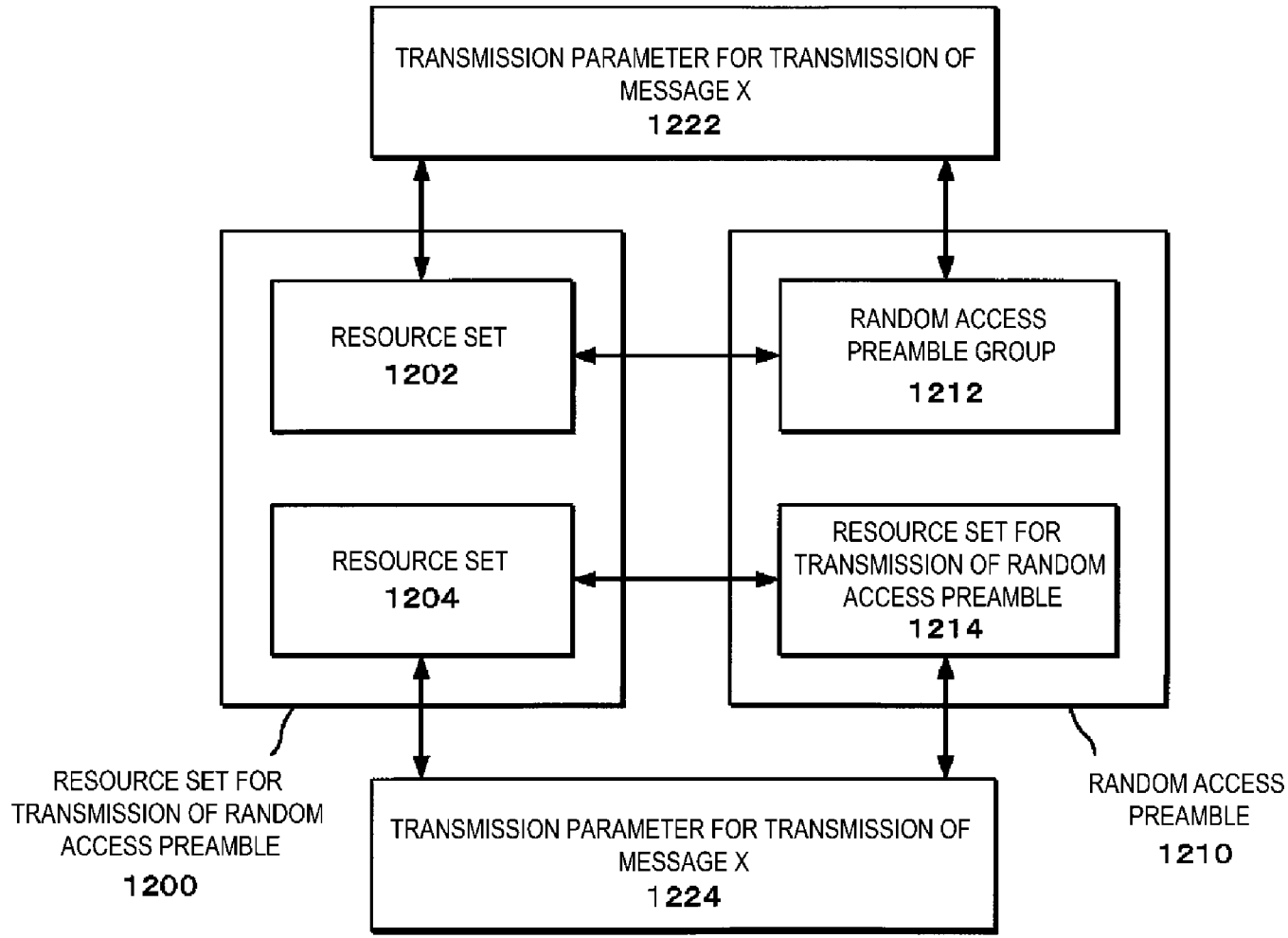


FIG. 12

DAINGEAN_0002638

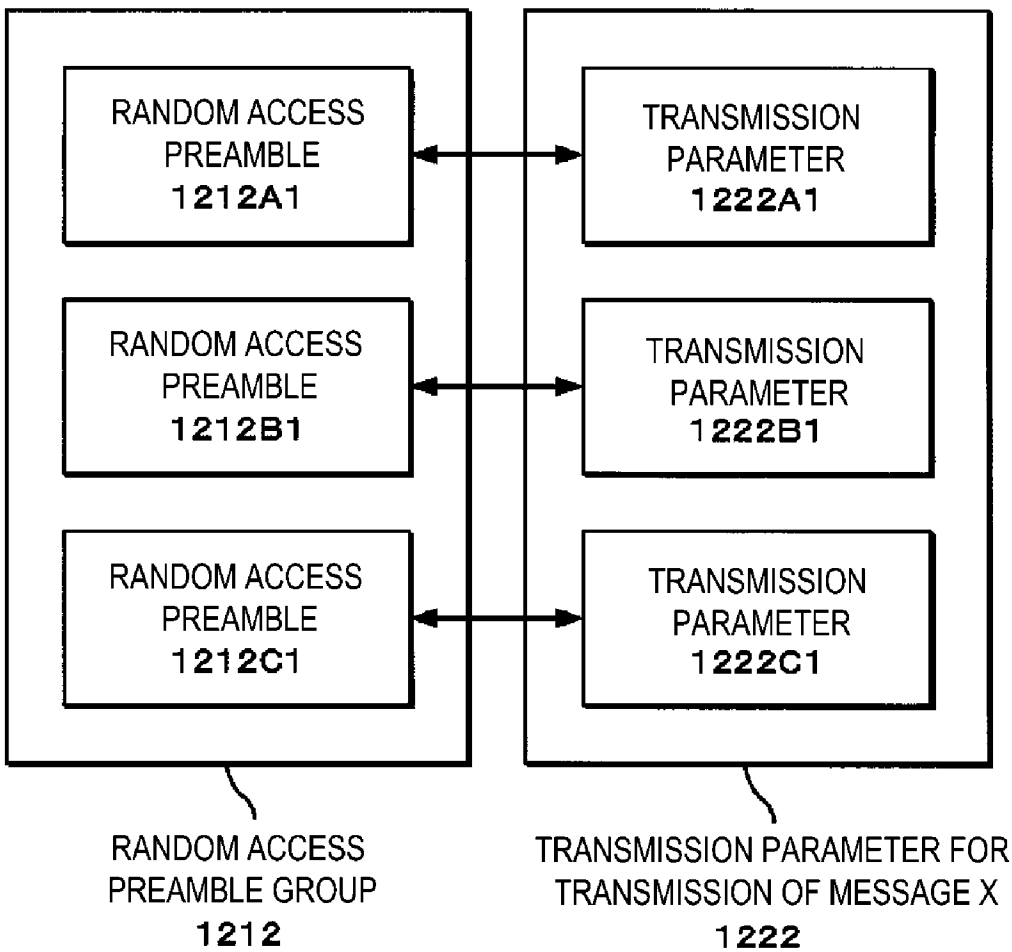


FIG. 13

DAINGEAN_0002639

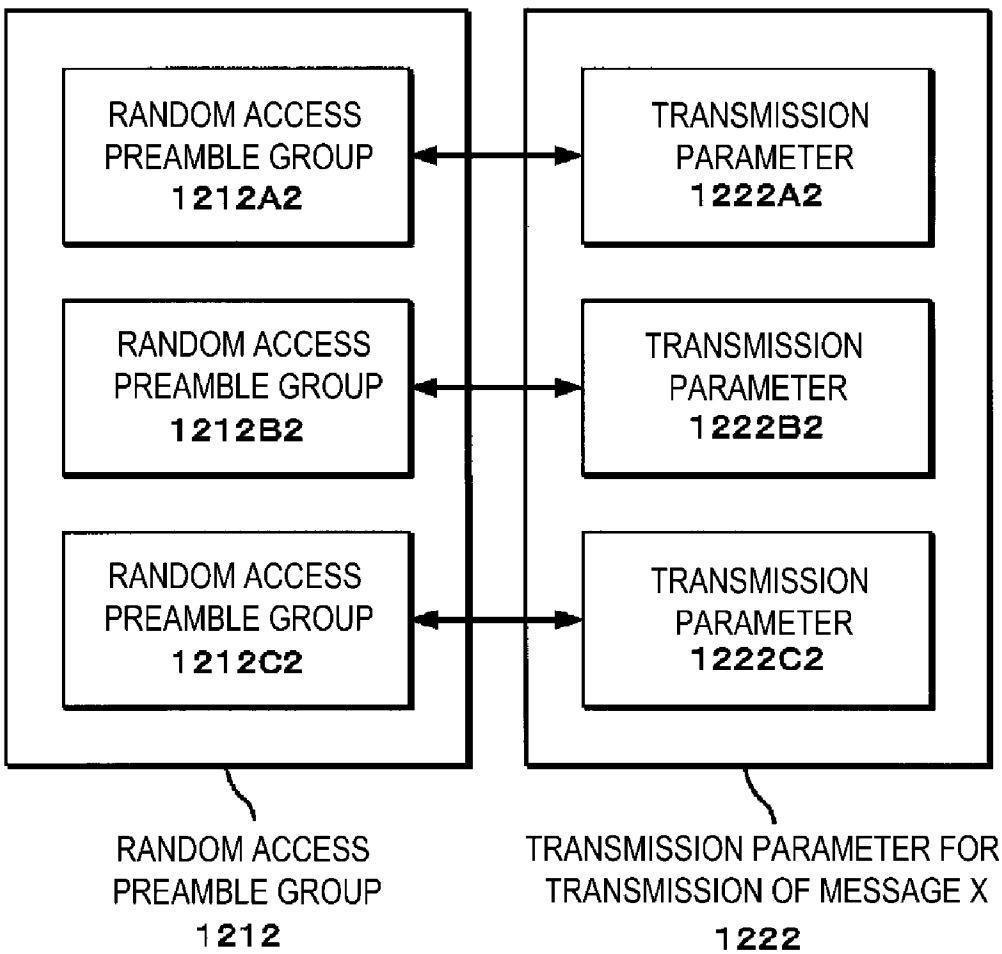

RANDOM ACCESS PREAMBLE GROUP 1212A2
RANDOM ACCESS PREAMBLE GROUP 1212B2
RANDOM ACCESS PREAMBLE GROUP 1212C2
TRANSMISSION PARAMETER 1222A2
TRANSMISSION PARAMETER 1222B2
TRANSMISSION PARAMETER 1222C2
RANDOM ACCESS PREAMBLE GROUP 1212
TRANSMISSION PARAMETER FOR TRANSMISSION OF MESSAGE X 1222

FIG. 14

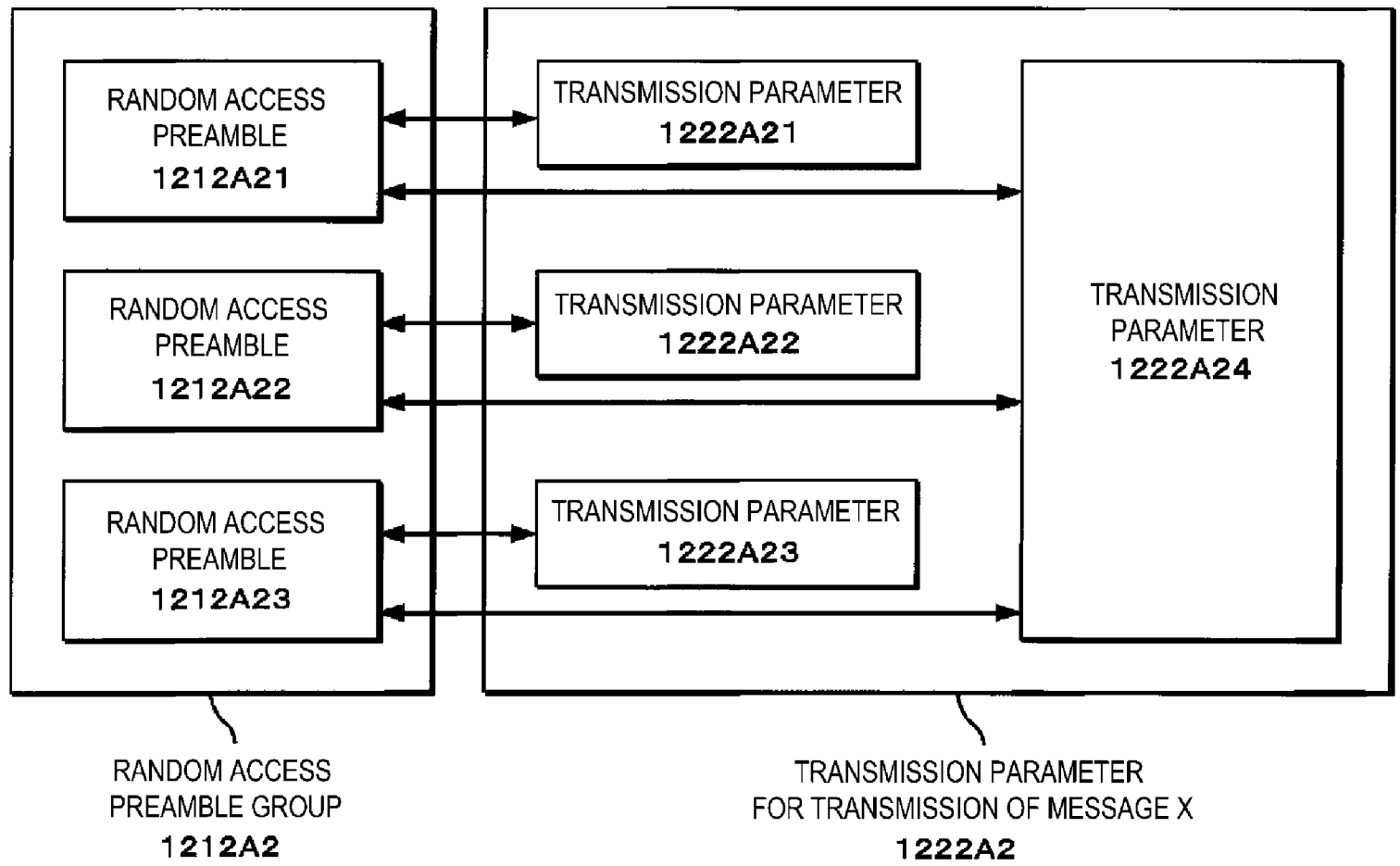


FIG. 15

DAINGEAN_0002641

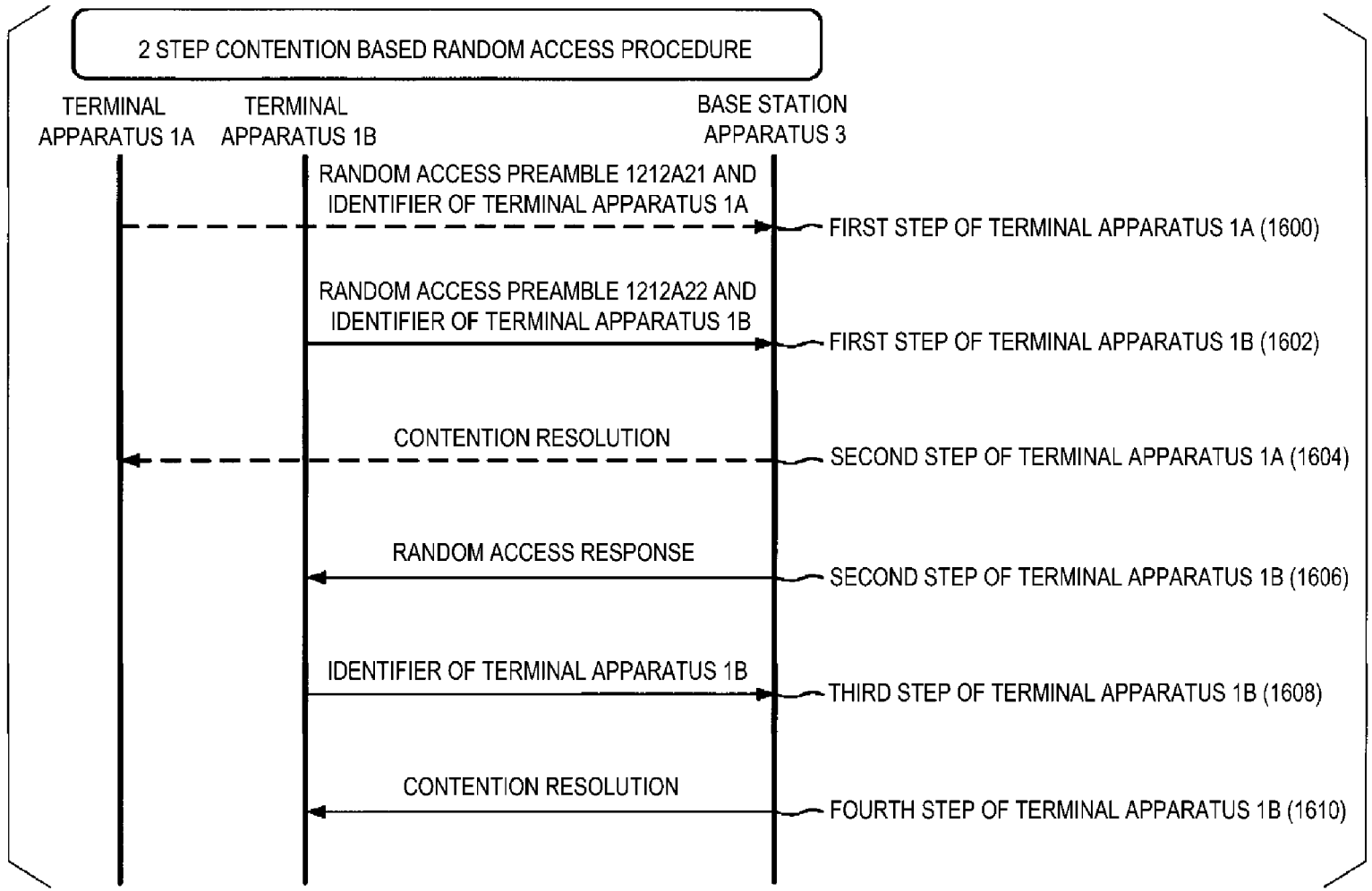


FIG. 16

DAINGEAN_0002642

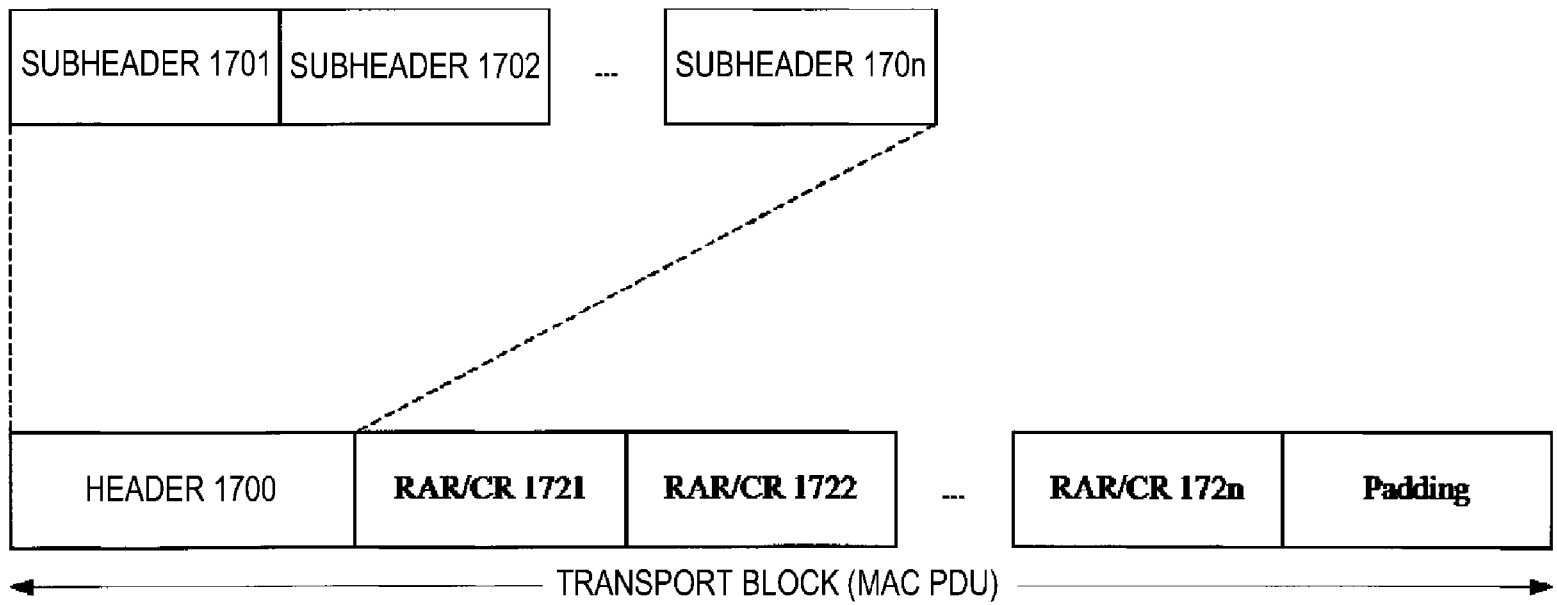


FIG. 17

DAINGEAN_0002643

RESOURCE SET FOR TRANSMISSION OF RANDOM ACCESS PREAMBLE	RANDOM ACCESS PREAMBLE INDEX	4 STEP CONTENTION BASED RANDOM ACCESS PROCEDURE	2 STEP CONTENTION BASED RANDOM ACCESS PROCEDURE
RESOURCE SET 1202	0 to 5	-	-
	6 to 20	GROUP 1212A2	GROUP 1212A2
	21 to 41	GROUP 1212B2	GROUP 1212B2
	42 to 63	GROUP 1212C2	GROUP 1212C2

FIG. 18

DAINGEAN_0002644

RESOURCE SET FOR TRANSMISSION OF RANDOM ACCESS PREAMBLE	RANDOM ACCESS PREAMBLE INDEX	4 STEP CONTENTION BASED RANDOM ACCESS PROCEDURE	2 STEP CONTENTION BASED RANDOM ACCESS PROCEDURE
RESOURCE SET 1202	0 to 5	-	-
	6 to 20	GROUP 1212A2'	GROUP 1212A2
	21 to 41		GROUP 1212B2
	42 to 63	GROUP 1212B2'	

FIG. 19

DAINGEAN_0002645

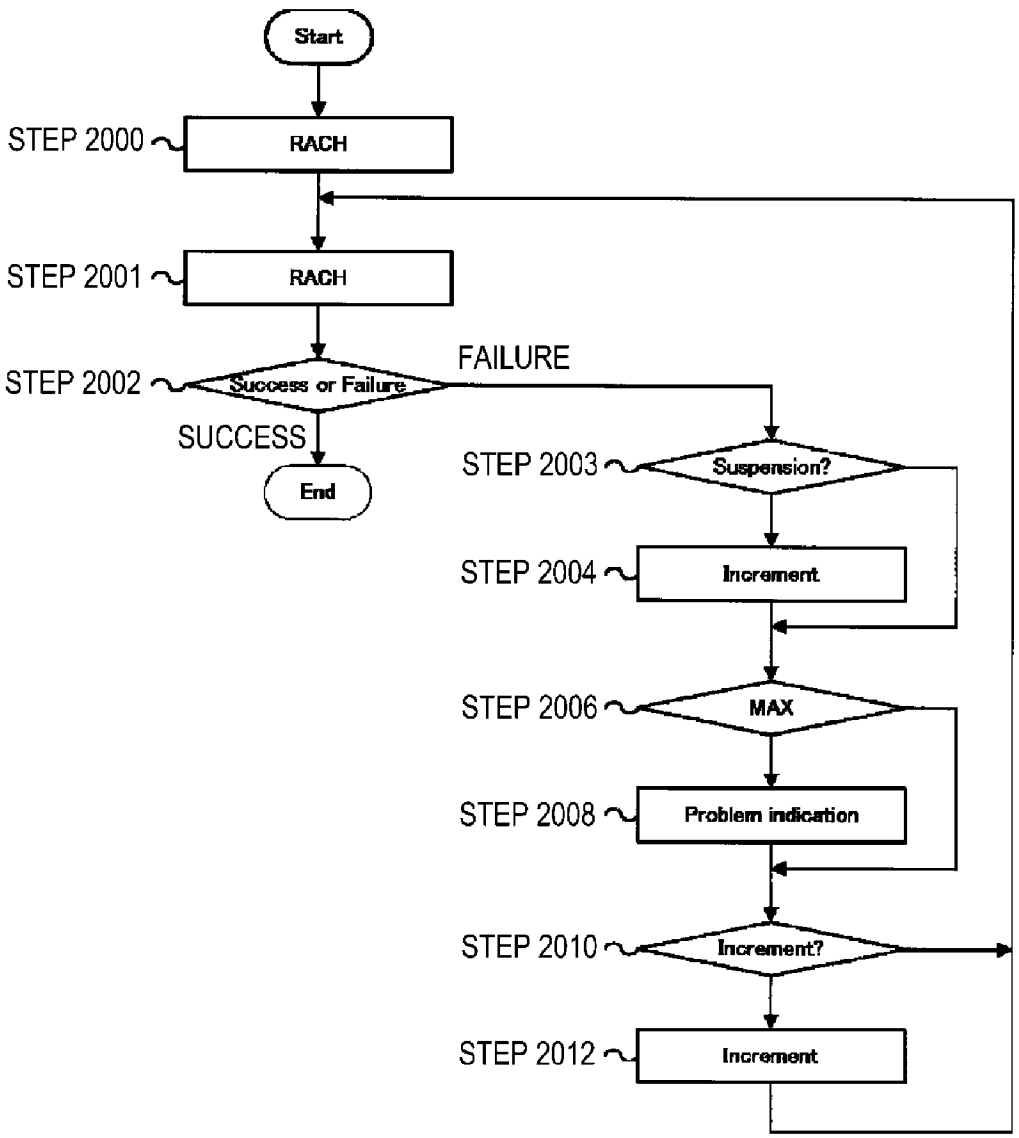


FIG. 20

DAINGEAN_0002646

Attorney Docket No. .

COMBINED DECLARATION/ASSIGNMENT FOR UTILITY OR DESIGN APPLICATION

Title	TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT

As a below named INVENTOR/ASSIGNOR, I hereby declare that:

This declaration ☐ The attached application, or

is directed to: ☒ United States application or PCT international application number PCT/JP2018/005323 filed on February 15, 2018.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56.

WHEREAS, (1) Sharp Kabushiki Kaisha; (2) FG INNOVATION COMPANY LIMITED (hereinafter referred to as "ASSIGNEE") having places of business at: (1) 1, Takumi-cho, Sakai-ku, Sakai City, Osaka 590-8522, Japan; (2) Flat 2623, 26/F Tuen Mun Central Square, 22 Hoi Wing Road, Tuen Mun, New Territories, HONG KONG, China, is desirous of acquiring the entire right, title, and interest in, to, and under said invention and any Letters Patent that may be granted therefore in the United States and in any and all foreign countries;

NOW, THEREFORE, TO ALL WHOM IT MAY CONCERN: Be it known that in consideration of the payment by ASSIGNEE to ASSIGNOR of the sum of One Dollar ($1.00), the receipt of which is hereby acknowledged, and for other good and valuable consideration, ASSIGNOR hereby sells, assigns, and transfers to ASSIGNEE the full and exclusive right, title, and interest to the said invention and all Letters Patent of the United States to be obtained therefore on said application or any continuation, division, renewal, substitute, or reissue thereof for the full term or terms for which the same may be granted; and all Letters Patent and applications therefore through the world, including all the rights accruing by virtue of the International Convention for the Protection of Industrial Property or other relevant International Treaties and Arrangements.

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I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

LEGAL NAME OF FIRST INVENTOR/ASSIGNOR

Inventor: Shoichi SUZUKI Date: July 31, 2019

Signature: Shoichi Suzuki

LEGAL NAME OF SECOND INVENTOR/ASSIGNOR	
Inventor: Wataru OUCHI	Date: July 31, 2019
Signature: Wataru Ouchi	
LEGAL NAME OF THIRD INVENTOR/ASSIGNOR	
Inventor: Tomoki YOSHIMURA	Date: July 31, 2019
Signature: Tomoki Yoshimura	
LEGAL NAME OF FOURTH INVENTOR/ASSIGNOR	
Inventor: Liqing LIU	Date: July 31, 2019
Signature: Liqing LIU	
LEGAL NAME OF FIFTH INVENTOR/ASSIGNOR	
Inventor:	Date:
Signature:	
LEGAL NAME OF SIXTH INVENTOR/ASSIGNOR	
Inventor:	Date:
Signature:	
LEGAL NAME OF SEVENTH INVENTOR/ASSIGNOR	
Inventor:	Date:
Signature:	
LEGAL NAME OF EIGHTH INVENTOR/ASSIGNOR	
Inventor:	Date:
Signature:	

Docket Number
70404.4566/sg

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Shoichi SUZUKI et al. Application No.: Currently unknown Filing or 371(c) Date: Concurrently herewith Title: TERMINAL APPARATUS, BASE STATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT	

EXPRESS REQUEST TO BEGIN NATIONAL EXAMINATION PROCEDURES

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

This is an express request to begin national examination procedures under 35 U.S.C. § 371(f). As required by 35 U.S.C. § 371(c), this submission includes a copy of the International Application as filed, unless a copy of the International Application has already been communicated by the International Bureau; an English language translation of the International Application as filed if the International Application was filed in a language other than English; an oath or declaration of the inventor(s); and the national fee.

Respectfully submitted,

Dated: August 8, 2019

/Joseph R. Keating #37,368/
Attorney for Applicant

KEATING & BENNETT, LLP
1800 Alexander Bell Drive, Suite 200
Reston, VA 20191
Telephone: (571) 313-7440
Facsimile: (571) 313-7421

Joseph R. Keating
Registration No. 37,368

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First Named Inventor	Shoichi SUZUKI
Art Unit	
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	Application Number	
	Filing Date	
	First Named Inventor	Shoichi SUZUKI
	Art Unit	
	Examiner Name	
	Attorney Docket Number	70404.4566/sg

	1	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 13)", 3GPP TS 36.211 V13.0.0, December 2015, pp. 1-142.	
	2	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding (Release 13)", 3GPP TS 36.212 V13.0.0, December 2015, pp. 1-121.	
	3	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 13)", 3GPP TS 36.213 V13.0.0, December 2015, pp. 1-326.	
	4	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification (Release 13)", 3GPP TS 36.321 V13.0.0, December 2015, pp. 1-82.	
	5	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification (Release 13)", 3GPP TS 36.331 V13.0.0, December 2015, pp. 1-507.	
	6	NOKIA, "Motivation for new SI proposal: Enhancements to initial access and scheduling for low-latency LTE", RP-162295, RAN#74, December 5-8, 2016, pp. 1-5.	

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	Application Number	
	Filing Date	
	First Named Inventor	Shoichi SUZUKI
	Art Unit	
	Examiner Name	
	Attorney Docket Number	70404.4566/sg

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Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

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See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

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Signature	/Joseph R. Keating #37,368/	Date (YYYY-MM-DD)	2019-08-08
Name/Print	Joseph R. Keating	Registration Number	37,368

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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3GPP TS 36.211 V13.0.0 (2015-12)

Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Evolved Universal Terrestrial Radio Access (E-UTRA);
Physical channels and modulation
(Release 13)





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Keywords
UMTS, radio, layer 1

3GPP

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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

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

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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.

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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".

[9] 3GPP TS 36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) Protocol specification"

[10] 3GPP TS 36.304, "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode"

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

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$a_{k,l}^{(p)}$	Value of resource element (k,l) [for antenna port p]
D	Matrix for supporting cyclic delay diversity
D_{RA}	Density of random access opportunities per radio frame
f_0	Carrier frequency
f_{RA}	PRACH resource frequency index within the considered time-domain location
$M_{\text{sc}}^{\text{PSBCH}}$	Bandwidth for PSBCH transmission, expressed as a number of subcarriers
$M_{\text{RB}}^{\text{PSBCH}}$	Bandwidth for PSBCH transmission, expressed as a number of resource blocks
$M_{\text{sc}}^{\text{PSCCH}}$	Bandwidth for PSCCH transmission, expressed as a number of subcarriers
$M_{\text{RB}}^{\text{PSCCH}}$	Bandwidth for PSCCH transmission, expressed as a number of resource blocks
$M_{\text{sc}}^{\text{PSDCH}}$	Bandwidth for PSDCH transmission, expressed as a number of subcarriers
$M_{\text{RB}}^{\text{PSDCH}}$	Bandwidth for PSDCH transmission, expressed as a number of resource blocks
$M_{\text{sc}}^{\text{PSSCH}}$	Scheduled bandwidth for PSSCH transmission, expressed as a number of subcarriers
$M_{\text{RB}}^{\text{PSSCH}}$	Scheduled bandwidth for PSSCH transmission, expressed as a number of resource blocks
$M_{\text{sc}}^{\text{PUSCH}}$	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_{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
$N_{\text{ID}}^{\text{SL}}$	Physical layer sidelink synchronization 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 $N_{\text{sc}}^{\text{RB}}$
$N_{\text{RB}}^{\text{SL}}$	Sidelink 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
$N_{\text{symb}}^{\text{SL}}$	Number of SC-FDMA symbols in a sidelink slot
$N_{\text{sc}}^{\text{RB}}$	Resource block size in the frequency domain, expressed as a number of subcarriers
N_{sb}	Number of sub-bands for PUSCH frequency-hopping with predefined hopping pattern

N_{RB}^{sb}	Size of each sub-band for PUSCH frequency-hopping with predefined hopping pattern, expressed as a number of resource blocks
N_{SP}	Number of downlink to uplink switch points within the radio frame
N_{RS}^{PUCCH}	Number of reference symbols per slot for PUCCH
N_{TA}	Timing offset between uplink and downlink radio frames at the UE, expressed in units of T_s
$N_{TA\ offset}$	Fixed timing advance offset, expressed in units of T_s
$N_{TA,SL}$	Timing offset between sidelink and timing reference frames at the UE, expressed in units of T_s
$n_{PUCCH}^{(1,\tilde{p})}$	Resource index for PUCCH formats 1/1a/1b
$n_{PUCCH}^{(2,\tilde{p})}$	Resource index for PUCCH formats 2/2a/2b
$n_{PUCCH}^{(3,\tilde{p})}$	Resource index for PUCCH formats 3
n_{PDCCH}	Number of PDCCHs present in a subframe
n_{PRB}	Physical resource block number
n_{PRB}^{RA}	First physical resource block occupied by PRACH resource considered
$n_{PRB\ offset}^{RA}$	First physical resource block available for PRACH
n_{VRB}	Virtual resource block number
n_{RNTI}	Radio network temporary identifier
n_{ID}^{SA}	Sidelink group destination identity
n_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, 6 for 64QAM and 8 for 256QAM 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
β_{PRACH}	Amplitude scaling for PRACH
β_{PUCCH}	Amplitude scaling for PUCCH
β_{PUSCH}	Amplitude scaling for PUSCH
β_{SRS}	Amplitude scaling for sounding reference symbols
Δf	Subcarrier spacing
Δf_{RA}	Subcarrier spacing for the random access preamble
υ	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

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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
PSBCH	Physical Sidelink Broadcast CHannel
PSCCH	Physical Sidelink Control CHannel
PSDCH	Physical Sidelink Discovery CHannel
PSSCH	Physical Sidelink Shared CHannel
PUCCH	Physical Uplink Control CHannel
PUSCH	Physical Uplink Shared CHannel
REG	Resource-Element Group
SCG	Secondary Cell 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, uplink and sidelink transmissions are organized into radio frames with $T_f = 307200 \times T_s = 10\text{ ms}$ duration. Three radio frame structures are supported:

- Type 1, applicable to FDD only,
- Type 2, applicable to TDD only,
- Type 3, applicable to LAA secondary cell operation only.

NOTE: LAA secondary cell operation only applies to frame structure type 3.

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, different frame structures can be used in the different serving cells.

4.1 Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD only. 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.

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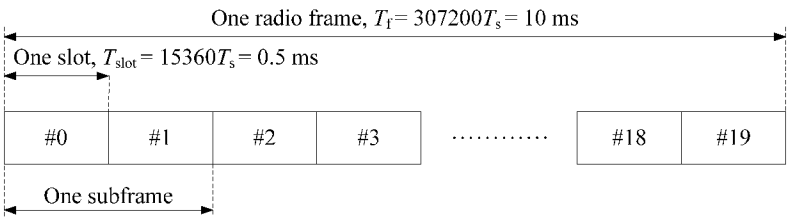


Figure 4.1-1: Frame structure type 1

4.2 Frame structure type 2

Frame structure type 2 is applicable to TDD only. Each radio frame of length $T_f = 307200 \cdot T_s = 10$ ms consists of two half-frames of length $153600 \cdot T_s = 5$ ms each. Each half-frame consists of five subframes of length $30720 \cdot T_s = 1$ ms. Each subframe i is defined as two slots, $2i$ and $2i+1$, of length $T_{slot} = 15360 \cdot T_s = 0.5$ ms each.

The uplink-downlink configuration in a cell may vary between frames and controls in which subframes uplink or downlink transmissions may take place in the current frame. The uplink-downlink configuration in the current frame is obtained according to Section 13 in [4].

The supported uplink-downlink configurations are listed in Table 4.2-2 where, for each subframe in a radio frame, "D" denotes a downlink subframe reserved for downlink transmissions, "U" denotes an uplink subframe 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 $30720 \cdot T_s = 1$ ms.

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 cells using frame structure type 2 have an overlap of at least $1456 \cdot T_s$.

In case multiple cells with different uplink-downlink configurations in the current radio frame 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.

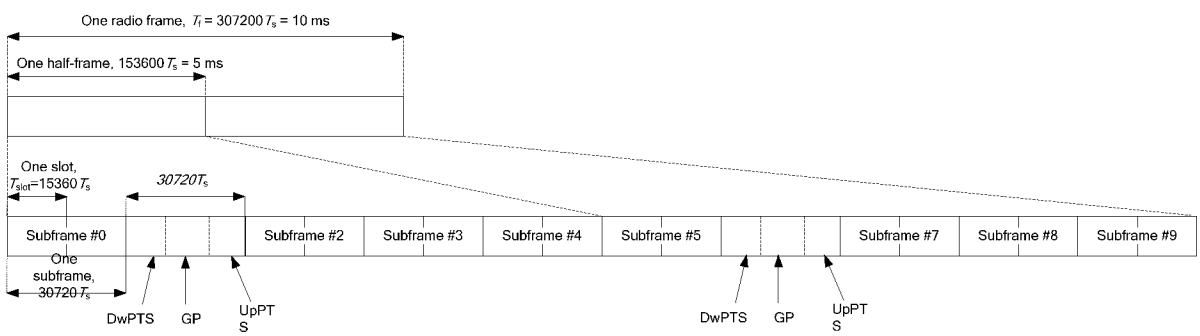


Figure 4.2-1: Frame structure type 2 (for 5 ms switch-point periodicity)

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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

4.3 Frame structure type 3

Frame structure type 3 is applicable to LAA secondary cell operation with normal cyclic prefix only. Each radio frame is $T_f = 307200 \cdot T_s = 10$ ms long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5$ ms, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe i consists of slots $2i$ and $2i+1$.

The 10 subframes within a radio frame are available for downlink transmissions. Downlink transmissions occupy one or more consecutive subframes, starting anywhere within a subframe and ending with the last subframe either fully occupied or following one of the DwPTS durations in Table 4.2-1.

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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.

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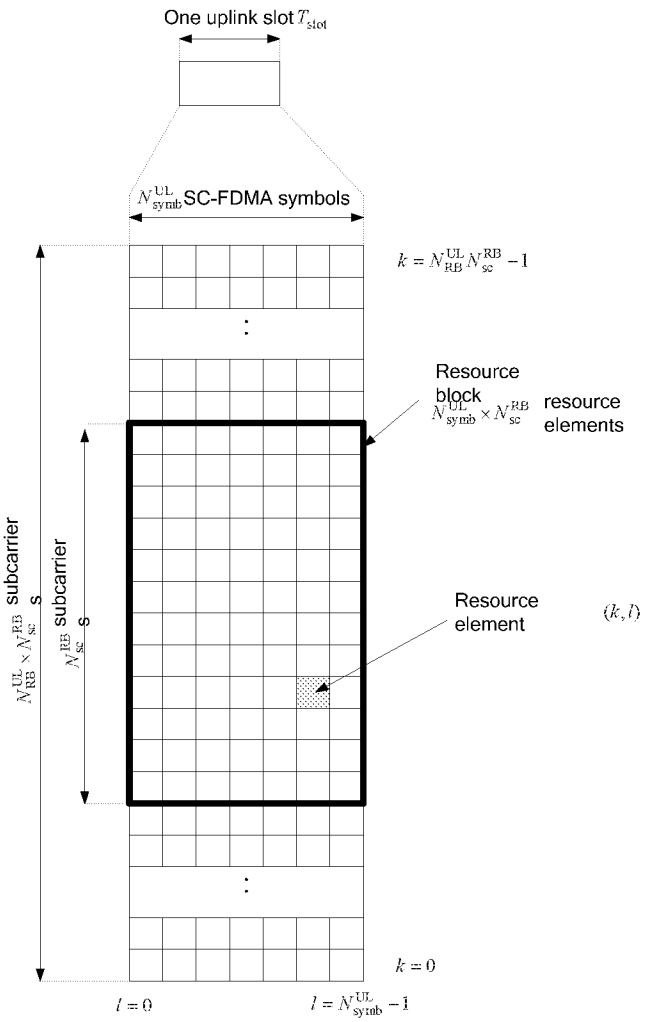


Figure 5.2.1-1: Uplink resource grid

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 $k = 0,...,N_{RB}^{UL}N_{sc}^{RB} - 1$ and $l = 0,...,N_{symb}^{UL} - 1$ 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_{symb}^{UL} consecutive SC-FDMA symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{UL} and N_{sc}^{RB} are given by Table 5.2.3-1.
A physical resource block in the uplink thus consists of $N_{symb}^{UL} \times N_{sc}^{RB}$ 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_{sc}^{RB}	N_{symb}^{UL}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

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

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

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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

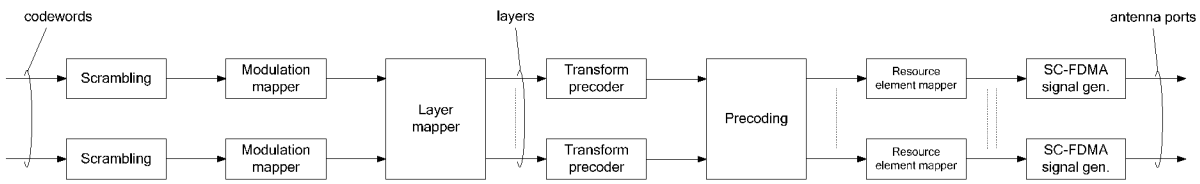


Figure 5.3-1: Overview of uplink physical channel processing

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 $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$ 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

$i = i + 1$

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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_{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 $\tilde{b}^{(q)}(0),\ldots,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued symbols $d^{(q)}(0),\ldots,d^{(q)}(M_{\text{symb}}^{(q)} - 1)$. 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

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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 $x(i)=\left[x^{(0)}(i) \ \ldots \ x^{(\upsilon-1)}(i)\right]^T$, $i=0,1,...,M_{\text{symb}}^{\text{layer}}-1$ where υ 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 υ 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	$x^{(0)}(i)=d^{(0)}(2i)$ $x^{(1)}(i)=d^{(0)}(2i+1)$ $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}/2$
2	2	$x^{(0)}(i)=d^{(0)}(i)$ $x^{(1)}(i)=d^{(1)}(i)$ $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}=M_{\text{symb}}^{(1)}$
3	2	$x^{(0)}(i)=d^{(0)}(i)$ $x^{(1)}(i)=d^{(1)}(2i)$ $x^{(2)}(i)=d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}=M_{\text{symb}}^{(1)}/2$
4	2	$x^{(0)}(i)=d^{(0)}(2i)$ $x^{(1)}(i)=d^{(0)}(2i+1)$ $x^{(2)}(i)=d^{(1)}(2i)$ $x^{(3)}(i)=d^{(1)}(2i+1)$ $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}/2=M_{\text{symb}}^{(1)}/2$

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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 $\left[y^{(0)}(i)\ \ ...\ \ y^{(\upsilon-1)}(i)\right]^T$, $i=0,1,...,M_{\text{symb}}^{\text{layer}}-1$ from the transform precoder and generates a block of vectors $\left[z^{(0)}(i)\ \ ...\ \ z^{(P-1)}(i)\right]^T$, $i=0,1,...,M_{\text{symb}}^{\text{ap}}-1$ 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.

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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 $z^{(\tilde{p})}(0),\ldots,z^{(\tilde{p})}(M^{\text{ap}}_{\text{symb}}-1)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} in order to conform to the transmit power P_{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 in the same serving cell, 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 in the same serving cell, 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_{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_s is given by the scheduling grant together with a predefined pattern according to

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

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

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

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

where n_{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_{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".

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

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

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

where $f_{hop}(-1) = 0$ 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_s as defined in [8]. The pseudo-random sequence generator shall be initialised with $c_{init} = N_{ID}^{cell}$ for frame structure type 1 and $c_{init} = 2^9 \cdot (n_f \bmod 4) + N_{ID}^{cell}$ for frame structure type 2 at the start of each frame.

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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_{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
4	QPSK	
5	QPSK	

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

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

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

The physical resources used for PUCCH depends on two parameters, $N_{RB}^{(2)}$ and $N_{cs}^{(1)}$, given by higher layers. The variable $N_{RB}^{(2)} \geq 0$ 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 $N_{cs}^{(1)}$ 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 $N_{cs}^{(1)}$ is an integer multiple of Δ_{shift}^{PUCCH} within the range of $\{0, 1, \ldots, 7\}$, where Δ_{shift}^{PUCCH} is provided by higher layers. No mixed resource block is present if $N_{cs}^{(1)} = 0$. 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, 3, 4, and 5 are represented by the non-negative indices $n_{PUCCH}^{(1,\tilde{p})}$, $n_{PUCCH}^{(2,\tilde{p})} < N_{RB}^{(2)} N_{sc}^{RB} + \left\lceil \frac{N_{cs}^{(1)}}{8} \right\rceil \cdot (N_{sc}^{RB} - N_{cs}^{(1)} - 2)$, $n_{PUCCH}^{(3,\tilde{p})}$, $n_{PUCCH}^{(4)}$ and $n_{PUCCH}^{(5)}$, 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 $b(0),\ldots,b(M_{bit}-1)$ 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 $N_{seq}^{PUCCH} = 12$ sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ for each of the P antenna ports used for PUCCH transmission according to

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

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 $y^{(\tilde{p})}(0),\ldots, y^{(\tilde{p})}(N_{\text{seq}}^{\text{PUCCH}} - 1)$ 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

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

where

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

and

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

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 $n'_{\tilde{p}}(n_s)$ 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 $n_{\text{oc}}^{(\tilde{p})}(n_s)$ and the cyclic shift $\alpha_{\tilde{p}}(n_s, l)$ are determined according to

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

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

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

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

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

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for $n_s \bmod 2 = 0$ and by

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

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* Δ_{shift}^{PUCCH} is provided by higher layers.

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

PUCCH format	$b(0),\ldots,b(M_{bit}-1)$	$d(0)$
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	$\left[1 \quad e^{j4\pi/3} \quad e^{j2\pi/3}\right]$

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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_{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

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

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

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

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.

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

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

5.4.2A PUCCH format 3

The block of bits $b(0),\ldots,b(M_{\text{bit}}-1)$ shall be scrambled with a UE-specific scrambling sequence, resulting in a block of scrambled bits $\tilde{b}(0),\ldots,\tilde{b}(M_{\text{bit}}-1)$ 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_{RNTI} is the C-RNTI.

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

The complex-valued symbols $d(0),\ldots,d(M_{\text{symb}}-1)$ shall be block-wise spread with the orthogonal sequences $w_{n_{\text{oc},0}^{(\tilde{p})}}(i)$ and $w_{n_{\text{oc},1}^{(\tilde{p})}}(i)$ 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

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

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

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

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

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 $w_{n_{\text{oc},0}^{(\tilde{p})}}(i)$ and $w_{n_{\text{oc},1}^{(\tilde{p})}}(i)$ 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.

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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_{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	$\left[1 \quad e^{j8\pi/5} \quad e^{j6\pi/5} \quad e^{j4\pi/5} \quad e^{j2\pi/5}\right]$	-

5.4.2B PUCCH format 4

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_{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 $M_{\text{symb}} = M_{\text{bit}}/2$.

The block of complex-valued symbols $d(0),...,d(M_{\text{symb}}-1)$ is divided into $M_{\text{symb}}/M_{\text{sc}}^{\text{PUCCH4}}$ sets, each corresponding to one SC-FDMA symbol. Transform precoding shall be applied according to

$$z^{(\tilde{p})}(l \cdot M_{\text{sc}}^{\text{PUCCH4}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUCCH4}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUCCH4}}-1} d(l \cdot M_{\text{sc}}^{\text{PUCCH4}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUCCH4}}}}$$
$$k = 0,...,M_{\text{sc}}^{\text{PUCCH4}} - 1$$
$$l = 0,...,M_{\text{symb}}/M_{\text{sc}}^{\text{PUCCH4}} - 1$$

where $\tilde{p} = 0$, resulting in a block of complex-valued symbols $z^{(\tilde{p})}(0),...,z^{(\tilde{p})}(M_{\text{symb}}-1)$. The variable $M_{\text{sc}}^{\text{PUCCH4}} = M_{\text{RB}}^{\text{PUCCH4}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUCCH4}}$ represents the bandwidth of the PUCCH format 4 in terms of resource blocks, shall fulfil

$$M_{\text{RB}}^{\text{PUCCH4}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5} \le N_{\text{RB}}^{\text{UL}}$$

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

5.4.2C PUCCH format 5

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_{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 $M_{\text{symb}} = M_{\text{bit}}/2$.

The complex-valued symbols $d(0),...,d(M_{\text{symb}}-1)$ shall be divided into $N_0^{\text{PUCCH}} + N_1^{\text{PUCCH}}$ sets, each corresponding to one SC-FDMA symbol. Block-wise spreading shall be applied according to

$$y_n(i) = w_{n_{oc}}(i) \cdot d\left(i \bmod N_{\text{sc}}^{\text{RB}}/N_{\text{SF}}^{\text{PUCCH}} + n \cdot N_{\text{sc}}^{\text{RB}}/N_{\text{SF}}^{\text{PUCCH}}\right)$$
$$n = 0,...,N_0^{\text{PUCCH}} + N_1^{\text{PUCCH}} - 1$$
$$i = 0,1,...,N_{\text{sc}}^{\text{RB}} - 1$$

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where $N_{SF}^{PUCCH}=2$, N_0^{PUCCH} and N_1^{PUCCH} are given by Table 5.4.2C-1, and $w_{n_{oc}}(i)$ is given by Table 5.4.2C-2 with n_{oc} provided by higher layers.

The block-wise spread complex-valued symbols shall be transform precoded according to

$$z^{(\tilde{p})}(n\cdot N_{sc}^{RB}+k)=\frac{1}{\sqrt{N_{sc}^{RB}}}\sum_{i=0}^{N_{sc}^{RB}-1}y_n(i)e^{-j\frac{2\pi ik}{N_{sc}^{RB}}}$$
$$k=0,\ldots,N_{sc}^{RB}-1$$
$$n=0,\ldots,N_0^{PUCCH}+N_1^{PUCCH}-1$$

where $\tilde{p}=0$, resulting in a block of complex-valued symbols $z^{(\tilde{p})}(0),\ldots,z^{(\tilde{p})}\left(\left(N_0^{PUCCH}+N_1^{PUCCH}\right)N_{sc}^{RB}-1\right)$.

Table 5.4.2C-1: The quantities N_0^{PUCCH} and N_1^{PUCCH}

Subframe type	Normal cyclic prefix		Extended cyclic prefix	
	N_0^{PUCCH}	N_1^{PUCCH}	N_0^{PUCCH}	N_1^{PUCCH}
Normal subframe	6	6	5	5
Shortened subframe	6	5	5	4

Table 5.4.2C-2: Orthogonal sequences $w_{n_{oc}}(i)$

n_{oc}	Orthogonal sequences $\left[w_{n_{oc}}(0)\ \cdots\ w_{n_{oc}}\left(N_{sc}^{RB}-1\right)\right]$
0	[+1 +1 +1 +1 +1 +1 +1 +1 +1 +1 +1 +1]
1	[+1 +1 +1 +1 +1 +1 −1 −1 −1 −1 −1 −1]

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 β_{PUCCH} in order to conform to the transmit power P_{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 or more resource block in each of the two slots in a subframe. Within the physical resource block(s) 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.

Except for PUCCH format 4, the physical resource blocks to be used for transmission of PUCCH in slot n_s are given by

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

where the variable m depends on the PUCCH format.

- Formats 1, 1a and 1b:

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

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

- Formats 2, 2a and 2b:

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

- Format 3:

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

- Format 5:

$$m = n_{PUCCH}^{(5)}$$

For PUCCH format 4, the physical resource blocks to be used for transmission of PUCCH in slot n_s are given by

$$n_{PRB} = \begin{cases} m & \text{if } n_s \bmod 2 = 0 \\ N_{RB}^{UL} - 1 - m & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m = n_{PUCCH}^{(4)}, n_{PUCCH}^{(4)} + 1, \ldots, n_{PUCCH}^{(4)} + M_{RB}^{PUCCH4} - 1$$

where M_{RB}^{PUCCH4} is obtained from [4].

Mapping of modulation symbols for the physical uplink control channel for PUCCH formats 1 – 3 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.

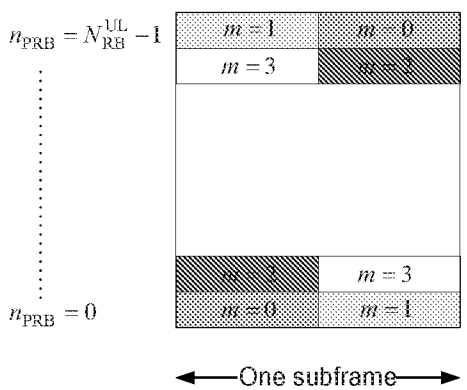


Figure 5.4.3-1: Mapping to physical resource blocks for PUCCH formats 1 – 3

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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 α 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 α.

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 qth 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 $N_{\text{ZC}}^{\text{RS}} < M_{\text{sc}}^{\text{RS}}$.

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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	$\varphi(0),\ldots,\varphi(11)$											
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

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

u	$\varphi(0),\ldots,\varphi(23)$																							
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 $\Delta_{ss} \in \{0,1,\ldots,29\}$ 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.

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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 Δ_{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 α_λ in a slot n_{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_{init} at the beginning of each radio frame. The quantity c_{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

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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 β_{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 $r_{\text{PUCCH}}^{(\tilde{p})}(\cdot)$ for PUCCH formats 1, 1a, 1b, 2, 2a, 2b, and 3 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

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

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

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

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

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

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

$$\alpha_{\tilde{p}}(n_{\text{s}},l)=2\pi\cdot n_{\text{cs}}^{(\tilde{p})}(n_{\text{s}},l)/N_{\text{sc}}^{\text{RB}}$$
$$n_{\text{cs}}^{(\tilde{p})}(n_{\text{s}},l)=\left(n_{\text{cs}}^{\text{cell}}(n_{\text{s}},l)+n'_{\tilde{p}}(n_{\text{s}})\right)\bmod N_{\text{sc}}^{\text{RB}}$$

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where $n'_{\tilde{p}}(n_s)$ is given by Table 5.5.2.2.1-4 and $n^{(\tilde{p})}_{oc,0}$ and $n^{(\tilde{p})}_{oc,1}$ 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^{PUCCH}_{RS} and the sequence $\bar{w}(n)$ 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^{PUCCH}_{RS}

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 $\left[\bar{w}^{(\tilde{p})}(0) \quad \cdots \quad \bar{w}^{(\tilde{p})}(N^{PUCCH}_{RS}-1)\right]$ for PUCCH formats 1, 1a and 1b

Sequence index $\bar{n}^{(\tilde{p})}_{oc}(n_s)$	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 $\left[\bar{w}^{(\tilde{p})}(0) \quad \cdots \quad \bar{w}^{(\tilde{p})}(N^{PUCCH}_{RS}-1)\right]$ 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 $n^{(\tilde{p})}_{oc}$ and $n'_{\tilde{p}}(n_s)$ for PUCCH format 3.

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

The PUCCH demodulation reference signal sequence $r^{(\tilde{p})}_{PUCCH}(\cdot)$ for PUCCH formats 4 and 5 is defined by

$$r^{(\tilde{p})}_{PUCCH}\left(m \cdot M^{RS}_{sc} + n\right) = r^{(\alpha)}_{u,v}(n)$$

where

$$\tilde{p} = 0$$
$$m = 0,1$$
$$n = 0,\ldots,M^{RS}_{sc}-1$$

and

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$$M_{sc}^{RS} = \begin{cases} M_{sc}^{PUCCH4} & \text{for PUCCH format 4} \\ N_{sc}^{RB} & \text{for PUCCH format 5} \end{cases}$$

Subclause 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),\ldots,r_{u,v}^{(\alpha_\lambda)}(M_{sc}^{RS}-1)$.

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

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

where the values of $n_{DMRS}^{(1)}$ and $n_{PN}(n_s)$ are given by Subclause 5.5.2.1.1 and

$$n_{DMRS}^{(2)} = \begin{cases} 0 & \text{PUCCH format 4} \\ 0 & \text{PUCCH format 5 with } n_{oc} = 0 \\ 6 & \text{PUCCH format 5 with } n_{oc} = 1 \end{cases}$$

with n_{oc} obtained as described in clause 5.4.2C.

5.5.2.2.2 Mapping to physical resources

The sequence $r_{PUCCH}^{(\tilde{p})}(\cdot)$ shall be multiplied with the amplitude scaling factor β_{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
4,5	3	2

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5.5.3 Sounding reference signal

5.5.3.1 Sequence generation

The sounding reference signal sequence $r_{\mathrm{SRS}}^{(\tilde{p})}(n) = r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ 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

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

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

$$\tilde{p} \in \{0,1,\ldots,N_{\mathrm{ap}}-1\}$$

where $n_{\mathrm{SRS}}^{\mathrm{cs}} = \{0,1,\ldots,n_{\mathrm{SRS}}^{\mathrm{cs,max}}\}$ 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_{ap} is the number of antenna ports used for sounding reference signal transmission. The parameter $n_{\mathrm{SRS}}^{\mathrm{cs,max}} = 8$ if $K_{\mathrm{TC}} = 2$ for all sounding reference signal configurations, otherwise $n_{\mathrm{SRS}}^{\mathrm{cs,max}} = 12$.

5.5.3.2 Mapping to physical resources

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

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

where N_{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 parameter K_{TC} is given by the higher-layer parameter [Number-of-combs] if configured, otherwise $K_{\mathrm{TC}} = 2$. 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 $b = B_{\mathrm{SRS}}$ and $M_{\mathrm{sc},b}^{\mathrm{RS}}$ is the length of the sounding reference signal sequence defined as

$$M_{\mathrm{sc},b}^{\mathrm{RS}} = m_{\mathrm{SRS},b} N_{\mathrm{sc}}^{\mathrm{RB}} / K_{\mathrm{TC}}$$

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

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

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 $k_{\mathrm{TC}}^{(p)} \in \{0,1,\ldots,K_{\mathrm{TC}} - 1\}$ 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, $k_{\mathrm{TC}}^{(p)} \in \{0,1,\ldots,K_{\mathrm{TC}} - 1\}$ 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_{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 $n_b = \lfloor 4n_{\mathrm{RRC}}/m_{\mathrm{SRS},b} \rfloor \bmod N_b$ where the parameter n_{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_{SRS} is UE-specific periodicity of SRS transmission defined in clause 8.2 of 3GPP TS 36.213 [4], T_{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_{offset} for a certain configuration of SRS subframe offset.

The sounding reference signal shall be transmitted in the last symbol of the uplink subframe.

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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_{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_{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_{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_{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 Δ_{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, a sounding reference signal is transmitted only in uplink 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 Δ_{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 Δ_{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

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5.6 SC-FDMA baseband signal generation

This clause applies to all uplink physical signals and uplink 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

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

for $0 \le t < (N_{\mathrm{CP},l} + N) \times T_s$ 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 $\sum_{l'=0}^{l-1} (N_{\mathrm{CP},l'} + N) T_s$ 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 $l = 0$ 144 for $l = 1,2,\ldots,6$
Extended cyclic prefix	512 for $l = 0,1,\ldots,5$

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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.

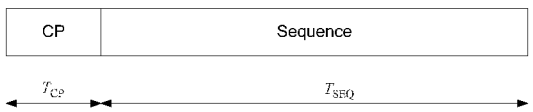


Figure 5.7.1-1: Random access preamble format

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 $0 \le n_{PRBoffset}^{RA} \le N_{RB}^{UL} - 6$.

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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_{RA} and version index, r_{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 $153600 \cdot T_s$.

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_{RA}	Version r_{RA}	PRACH configuration Index	Preamble Format	Density Per 10 ms D_{RA}	Version r_{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_{RA}. Each quadruple of the format $(f_{RA}, t_{RA}^{(0)}, t_{RA}^{(1)}, t_{RA}^{(2)})$ indicates the location of a specific random access resource, where f_{RA} is a frequency resource index within the considered time instance, $t_{RA}^{(0)} = 0,1,2$ indicates whether the resource is reoccurring in all radio frames, in even radio frames, or in odd radio frames, respectively, $t_{RA}^{(1)} = 0,1$ indicates whether the random access resource is located in first half frame or in second half frame, respectively, and where $t_{RA}^{(2)}$ 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 $t_{RA}^{(2)}$ 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 $N_{TA} = 0$ and the random access preamble format 4 shall start $4832 \cdot T_s$ before the end of the UpPTS at the UE, where the UpPTS is referenced to the UE's uplink frame timing assuming $N_{TA} = 0$.

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_{RA} without overlap in time. For preamble format 0-3, the frequency multiplexing shall be done according to

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

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_{f} is the system frame number and where N_{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.

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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) (0,0,1,2)	(0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0)	(0,0,0,1) (0,0,0,2)	(0,0,0,0) (0,0,0,1)	(0,0,0,0) (1,0,0,0)	(0,0,0,2) (0,0,1,1)
7	(0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0)	N/A	(0,0,0,0) (0,0,0,2)	N/A	N/A	(0,0,0,1) (0,0,1,0)
8	(0,0,0,0) (0,0,1,0)	N/A	N/A	(0,0,0,0) (0,0,0,1)	N/A	N/A	(0,0,0,0) (0,0,1,1)
9	(0,0,0,1) (0,0,0,2) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0)	(0,0,0,1) (0,0,0,2) (0,0,1,1)
10	(0,0,0,0) (0,0,1,0) (0,0,1,1)	(0,0,0,1) (0,0,1,0) (0,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,1,0)	N/A	(0,0,0,0) (0,0,0,1) (1,0,0,0)	N/A	(0,0,0,0) (0,0,0,2) (0,0,1,0)
11	N/A	(0,0,0,0) (0,0,0,1) (0,0,1,0)	N/A	N/A	N/A	N/A	(0,0,0,1) (0,0,1,0) (0,0,1,1)
12	(0,0,0,1) (0,0,0,2) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)	(0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1)
13	(0,0,0,0) (0,0,0,2) (0,0,1,0) (0,0,1,2)	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,1)	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,1)
14	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1)	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0)	N/A	N/A	(0,0,0,0) (0,0,0,2) (0,0,1,0) (0,0,1,1)
15	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,1) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1) (2,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1)
16	(0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,1,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1) (2,0,0,0)	N/A	N/A
17	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,0)	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0) (1,0,0,1)	N/A	N/A	N/A
18	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,1) (1,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0) (2,0,1,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0) (1,0,0,1) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1) (2,0,0,0) (2,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0) (5,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (1,0,0,2)
19	N/A	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,0) (1,0,1,0)	N/A	N/A	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (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) (0,0,1,1)	(0,0,0,0) (0,0,1,0)	N/A	(0,0,0,1) (1,0,0,1)	(0,0,0,0) (1,0,0,0)	N/A	(0,0,0,1) (0,0,1,0)
26 / 36	(0,0,0,1) (0,0,1,1) (1,0,0,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1)

27 / 37	(0,0,0,1) (0,0,1,1) (1,0,0,1) (1,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1) (3,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1) (1,0,1,0)
28 / 38	(0,0,0,1) (0,0,1,1) (1,0,0,1) (1,0,1,1) (2,0,0,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1) (3,0,0,1) (4,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1) (1,0,1,0) (2,0,0,1)
29 /39	(0,0,0,1) (0,0,1,1) (1,0,0,1) (1,0,1,1) (2,0,0,1) (2,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0) (2,0,1,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1) (3,0,0,1) (4,0,0,1) (5,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0) (5,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1) (1,0,1,0) (2,0,0,1) (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) (0,0,1,0)	N/A	N/A	(0,0,0,0) (1,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0)
46	(0,0,0,0) (0,0,1,0) (1,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0)
47	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0) (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,*) (0,0,1,*)	(0,0,0,*) (0,0,1,*)	(0,0,0,*) (0,0,1,*)	(0,0,0,*) (1,0,0,*)	(0,0,0,*) (1,0,0,*)	(0,0,0,*) (1,0,0,*)	(0,0,0,*) (0,0,1,*)
54	(0,0,0,*) (0,0,1,*) (1,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*)
55	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)
56	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)
57	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*) (5,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*) (5,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*) (5,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (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							

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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 uth root Zadoff-Chu sequence is defined by

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

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

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

where the cyclic shift is given by

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

and N_{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 $1/T_{SEQ}$ and is given by

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

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

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

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

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

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 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, 72 767, 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

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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

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

where $0 \le t < T_{\text{SEQ}} + T_{\text{CP}}$, β_{PRACH} is an amplitude scaling factor in order to conform to the transmit power P_{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 Δf_{RA}, the subcarrier spacing for the random access preamble, and the variable φ, 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	Δf_{RA}	φ
0 – 3	1250 Hz	7
4	7500 Hz	2

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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].

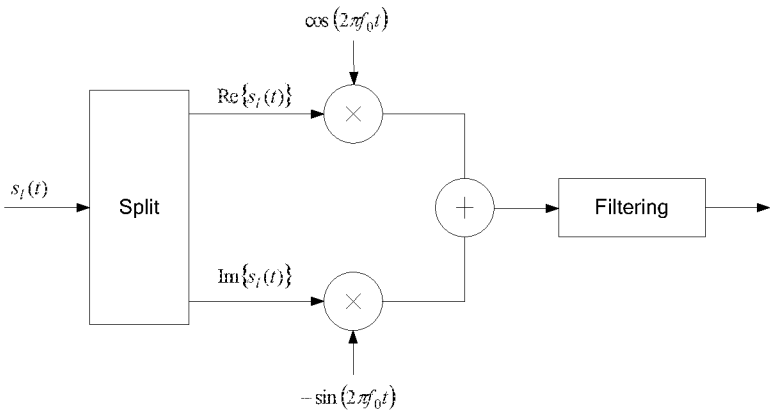


Figure 5.8-1: Uplink modulation

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.

MBSFN configuration shall not be applied to downlink subframes with PDSCH or PDCCH transmissions starting in the second slot.

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
- Discovery signal

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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 $N_{RB}^{DL}N_{sc}^{RB}$ subcarriers and N_{symb}^{DL} OFDM symbols. The resource grid structure is illustrated in Figure 6.2.2-1. The quantity N_{RB}^{DL} depends on the downlink transmission bandwidth configured in the cell and shall fulfil

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

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

The set of allowed values for N_{RB}^{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. For MBSFN reference signals, positioning reference signals, UE-specific reference signals associated with PDSCH and demodulation reference signals associated with EPDCCH, there are limits given below within which the channel can be inferred from one symbol to another symbol on the same antenna port. 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 $p = 4$. The channel over which a symbol on antenna port $p = 4$ is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only if the two symbols correspond to subframes of the same MBSFN area.
- UE-specific reference signals associated with PDSCH are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$, or one or several of $p \in \{7,8,9,10,11,12,13,14\}$. The channel over which a symbol on one of these antenna ports is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only if the two symbols are within the same subframe and in the same PRG when PRB bundling is used or in the same PRB pair when PRB bundling is not used.
- Demodulation reference signals associated with EPDCCH are transmitted on one or several of $p \in \{107,108,109,110\}$. The channel over which a symbol on one of these antenna ports is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only if the two symbols are in the same PRB pair.
- Positioning reference signals are transmitted on antenna port $p = 6$. The channel over which a symbol on antenna port $p = 6$ is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only within one positioning reference signal occasion consisting of N_{PRS} consecutive downlink subframes, where N_{PRS} is configured by higher layers.
- CSI reference signals support a configuration of one, two, four, eight, twelve, or 16 antenna ports and are transmitted on antenna ports $p = 15$, $p = 15,16$, $p = 15,...,18$, $p = 15,...,22$, $p = 15,...,26$ and $p = 15,...,30$, 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.

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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 $k=0,\ldots,N_{\mathrm{RB}}^{\mathrm{DL}}N_{\mathrm{sc}}^{\mathrm{RB}}-1$ and $l=0,\ldots,N_{\mathrm{symb}}^{\mathrm{DL}}-1$ 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.

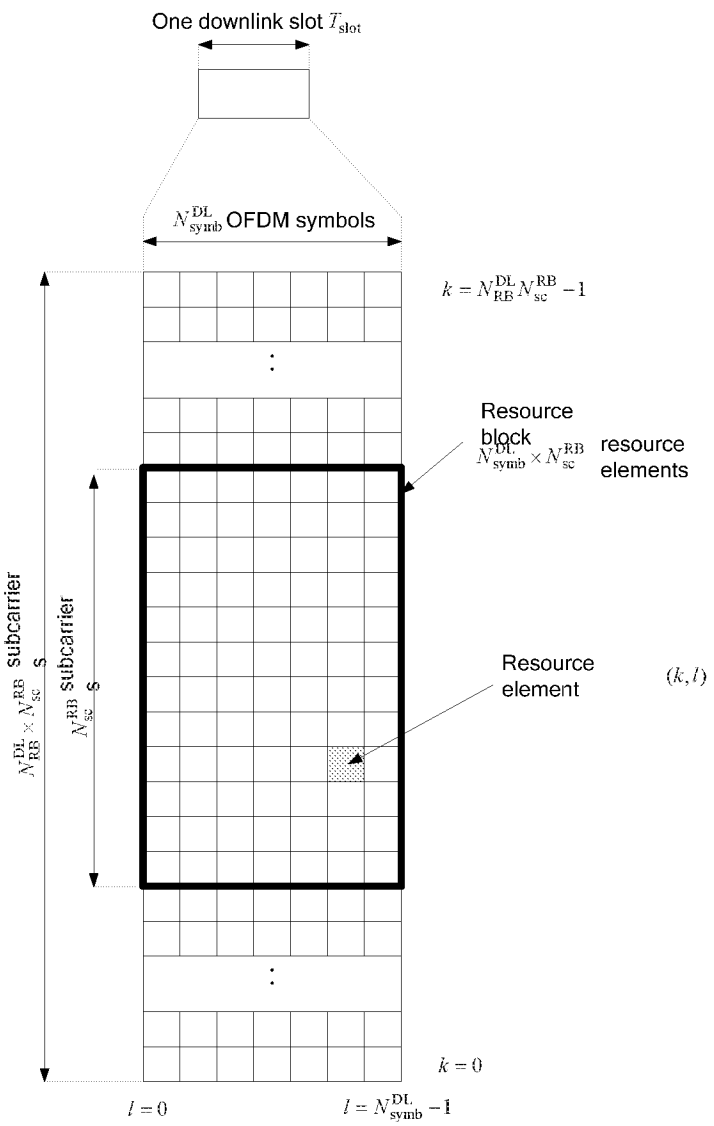


Figure 6.2.2-1: Downlink resource grid

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_{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_{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_{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_{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.

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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;

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

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;

$$n_{PRB}(n_s) = \begin{cases} \tilde{n}_{PRB}(n_s), & \tilde{n}_{PRB}(n_s) < \tilde{N}_{VRB}^{DL}/2 \\ \tilde{n}_{PRB}(n_s) + N_{gap} - \tilde{N}_{VRB}^{DL}/2, & \tilde{n}_{PRB}(n_s) \ge \tilde{N}_{VRB}^{DL}/2 \end{cases}.$$

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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 $k_0 = n_{\mathrm{PRB}} \cdot N_{\mathrm{sc}}^{\mathrm{RB}}$, $0 \le n_{\mathrm{PRB}} < N_{\mathrm{RB}}^{\mathrm{DL}}$.

- In the first OFDM symbol of the first slot in a subframe the two resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=0)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 5$ and $k = k_0 + 6, k_0 + 7, \ldots, k_0 + 11$, 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_{PRB} consist of resource elements $(k,l=1)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 3$, $k = k_0 + 4, k_0 + 5, \ldots, k_0 + 7$ and $k = k_0 + 8, k_0 + 9, \ldots, k_0 + 11$, 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_{PRB} consist of resource elements $(k,l=1)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 5$ and $k = k_0 + 6, k_0 + 7, \ldots, k_0 + 11$, respectively.
- In the third OFDM symbol of the first slot in a subframe, the three resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=2)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 3$, $k = k_0 + 4, k_0 + 5, \ldots, k_0 + 7$ and $k = k_0 + 8, k_0 + 9, \ldots, k_0 + 11$, 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_{PRB} consist of resource elements $(k,l=3)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 3$, $k = k_0 + 4, k_0 + 5, \ldots, k_0 + 7$ and $k = k_0 + 8, k_0 + 9, \ldots, k_0 + 11$, 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_{PRB} consist of resource elements $(k,l=3)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 5$ and $k = k_0 + 6, k_0 + 7, \ldots, k_0 + 11$, 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.

For frame structure type 3, if the higher layer parameter *subframeStartPosition* indicates 's07' and the downlink transmission starts in the second slot of a subframe, the above definition applies to the second slot of that subframe instead of the first slot.

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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.

For frame structure type 3, if the higher layer parameter *subframeStartPosition* indicates 's07' and the downlink transmission starts in the second slot of a subframe, the above definition applies to the second slot of that subframe instead of the first slot.

6.2.5 Guard period for half-duplex FDD operation

For type A 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.

For type B half-duplex FDD operation, guard periods, each referred to as a half-duplex guard subframe, are created by the UE by

- not receiving a downlink subframe immediately preceding an uplink subframe from the same UE, and
- not receiving a downlink subframe immediately following 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.

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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

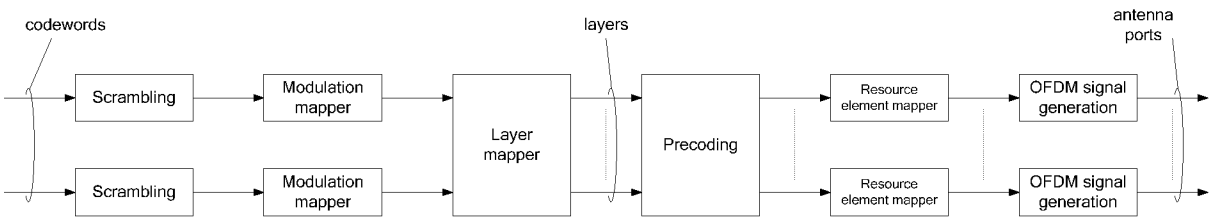


Figure 6.3-1: Overview of physical channel processing

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_{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_{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, 256QAM
PMCH	QPSK, 16QAM, 64QAM, 256QAM

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 $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(q)}-1)$ 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 υ 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 υ 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	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2$
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$
3	1	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3$
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}/2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/4$
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2 = M_{\text{symb}}^{(1)}/2$
5	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(3i)$ $x^{(3)}(i) = d^{(1)}(3i+1)$ $x^{(4)}(i) = d^{(1)}(3i+2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2 = M_{\text{symb}}^{(1)}/3$
6	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(3i)$ $x^{(4)}(i) = d^{(1)}(3i+1)$ $x^{(5)}(i) = d^{(1)}(3i+2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3 = M_{\text{symb}}^{(1)}/3$
7	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(4i)$ $x^{(4)}(i) = d^{(1)}(4i+1)$ $x^{(5)}(i) = d^{(1)}(4i+2)$ $x^{(6)}(i) = d^{(1)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3 = M_{\text{symb}}^{(1)}/4$

8	2	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$ $x^{(4)}(i) = d^{(1)}(4i)$ $x^{(5)}(i) = d^{(1)}(4i+1)$ $x^{(6)}(i) = d^{(1)}(4i+2)$ $x^{(7)}(i) = d^{(1)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/4 = M_{\text{symb}}^{(1)}/4$

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 υ 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 $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}} - 1$	
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = \begin{cases} M_{\text{symb}}^{(0)}/4 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 = 0 \\ \left(M_{\text{symb}}^{(0)} + 2\right)/4 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 \neq 0 \end{cases}$ 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 $x(i) = \left[x^{(0)}(i) \quad \ldots \quad x^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}} - 1$ from the layer mapping and generates a block of vectors $y(i) = \left[\ldots \quad y^{(p)}(i) \quad \ldots\right]^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$ 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 $p \in \{0,4,5,7,8,11,13\}$ is the number of the single antenna port used for transmission of the physical channel and $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

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 υ.

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 $\left[x^{(0)}(i) \quad \ldots \quad x^{(\upsilon-1)}(i)\right]^T$ on the physical downlink shared channel as follows. A different precoder is used every υ vectors, where υ 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 υ	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 υ	
	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, $p \in \{0,1,2,3\}$, the precoding matrix W shall be selected from Table 6.3.4.2.3-2 or a subset thereof. 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 except for *alternativeCodeBookEnabledFor4TX-r12 =TRUE* in which case the precoding matrix W shall be selected from Tables 7.2.4-0A, 7.2.4-0B, 7.2.4-0C, 7.2.4-0D in [4] 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 4×4 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 υ			
		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 $p = 7,8,\ldots,\upsilon+6$.

If no higher-layer parameter *Rel-13-DMRS-table* is present, or when the higher-layer parameter *Rel-13-DMRS-table* is set to 0, the precoding operation for transmission on υ antenna ports 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 $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

If the higher-layer parameter *Rel-13-DMRS-table* is set to 1, two codewords are enabled, and the field "Antenna port(s), scrambling identity and number of layers" given by DCI format 2C or 2D is 4 or 5, the precoding operation for transmission is defined by

$$\begin{bmatrix} y^{(11)}(i) \\ y^{(13)}(i) \end{bmatrix} = \begin{bmatrix} x^{(0)}(i) \\ x^{(1)}(i) \end{bmatrix}$$

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

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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 $y^{(p)}(0),...,y^{(p)}(M^{ap}_{symb}-1)$ 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.

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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 $p \in \{7,8,\ldots,\upsilon+6\}$, where υ 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) $p \in \{7,8,\ldots,\upsilon+6\}$, where υ 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:
  - zero-power 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, and
    - obtained by higher-layer configuration of up to five reserved CSI-RS resources as part of the discovery signal configuration following the procedure for zero-power CSI-RS in clause 6.10.5.2.
  - non-zero-power CSI reference signals for CSI reporting, where the positions of the non-zero-power CSI reference signals for CSI reporting are given by clause 6.10.5.2. 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.
- For frame structure type 1 and 2, 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].
- For frame structure type 3,
  - if the higher layer parameter *subframeStartPosition* indicates 's07' and the downlink transmission starts in the second slot of a subframe
    - the index l in the second 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],
  - otherwise
    - the index l in the first slot in a subframe fulfils $l \geq l_{\text{DataStart}}$ where $l_{\text{DataStart}}$ is given by clause 7.6.1.4 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:

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- 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 index l in the first slot in the MBSFN subframe fulfils $l \geq l_{\text{PMCHStart}}$ where $l_{\text{PMCHStart}}$ is equal to the value given by the higher layer parameter *non-MBSFNregionLength* [9].
- 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

The PBCH is not transmitted for frame structure type 3.

6.6.1 Scrambling

The block of bits $b(0),\ldots,b(M_{\text{bit}}-1)$, where M_{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 $\tilde{b}(0),\ldots,\tilde{b}(M_{\text{bit}}-1)$ according to

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

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 $\tilde{b}(0),\ldots,\tilde{b}(M_{\text{bit}}-1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),\ldots,d(M_{\text{symb}}-1)$. 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 $d(0),\ldots,d(M_{\text{symb}}-1)$ 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

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vectors $y(i) = \left[y^{(0)}(i) \quad \ldots \quad y^{(P-1)}(i) \right]^T$, $i = 0,\ldots,M_{\text{symb}} - 1$, where $y^{(p)}(i)$ represents the signal for antenna port p and where $p = 0,\ldots,P-1$ 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 $y^{(p)}(0),\ldots,y^{(p)}(M_{\text{symb}} - 1)$ for each antenna port is transmitted during 4 consecutive radio frames starting in each radio frame fulfilling $n_f \bmod 4 = 0$ 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

$$k = \frac{N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}}{2} - 36 + k', \qquad k' = 0,1,\ldots,71$$
$$l = 0,1,\ldots,3$$

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 $N_{\text{RB}}^{\text{DL}} > 10$	Number of OFDM symbols for PDCCH when $N_{\text{RB}}^{\text{DL}} \le 10$
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 UE may assume the PCFICH is transmitted when the number of OFDM symbols for PDCCH is greater than zero unless stated otherwise in [4, clause 12].

6.7.1 Scrambling

The block of bits $b(0),\ldots,b(31)$ transmitted in one subframe shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),\ldots,\tilde{b}(31)$ 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 $c_{\text{init}} = \left(\lfloor n_s/2 \rfloor + 1\right) \cdot \left(2N_{\text{ID}}^{\text{cell}} + 1\right) \cdot 2^9 + N_{\text{ID}}^{\text{cell}}$ 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 $M_{\text{symb}}^{(0)} = 16$ 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 or DwPTS 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.

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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_{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 $b^{(i)}(0),\ldots,b^{(i)}(M_{\text{bit}}^{(i)}-1)$ on each of the control channels to be transmitted in a subframe, where $M_{\text{bit}}^{(i)}$ 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 $b^{(0)}(0),\ldots,b^{(0)}(M_{\text{bit}}^{(0)}-1),b^{(1)}(0),\ldots,b^{(1)}(M_{\text{bit}}^{(1)}-1),\ldots,b^{(n_{\text{PDCCH}}-1)}(0),\ldots,b^{(n_{\text{PDCCH}}-1)}(M_{\text{bit}}^{(n_{\text{PDCCH}}-1)}-1)$, where n_{PDCCH} is the number of PDCCHs transmitted in the subframe.

The block of bits $b^{(0)}(0),\ldots,b^{(0)}(M_{\text{bit}}^{(0)}-1),b^{(1)}(0),\ldots,b^{(1)}(M_{\text{bit}}^{(1)}-1),\ldots,b^{(n_{\text{PDCCH}}-1)}(0),\ldots,b^{(n_{\text{PDCCH}}-1)}(M_{\text{bit}}^{(n_{\text{PDCCH}}-1)}-1)$ shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),\ldots,\tilde{b}(M_{\text{tot}}-1)$ 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 $c_{\text{init}}=\lfloor n_s/2\rfloor 2^9+N_{\text{ID}}^{\text{cell}}$ at the start of each subframe.

CCE number n corresponds to bits $b(72n),b(72n+1),\ldots,b(72n+71)$. 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 $\tilde{b}(0),\ldots,\tilde{b}(M_{\text{tot}}-1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),\ldots,d(M_{\text{symb}}-1)$. Table 6.8.3-1 specifies the modulation mappings applicable for the physical downlink control channel.

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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 $y(i)=\left[y^{(0)}(i) \ \ldots \ y^{(P-1)}(i)\right]^T$, $i=0,...,M_{\text{symb}}-1$ 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

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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

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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_{EPDCCH} for a particular UE and referenced in 3GPP TS 36.213 [4] is defined as the number of downlink resource elements (k,l) available for EPDCCH transmission 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
- for frame structure type 1 and 2, 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], and
- for frame structure type 3,
  - if the higher layer parameter *subframeStartPosition* indicates 's07' and the downlink transmission starts in the second slot of a subframe
    - the index l in the second slot in a subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l \geq l_{\text{EPDCCHStart}}$ is given by clause 7.1.6.4 of 3GPP TS 36.213 [4],
  - otherwise
    - the index l in the first slot in a subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l \geq l_{\text{EPDCCHStart}}$ is given by clause 7.6.1.4 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

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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:
  - zero-power 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 are provided by clause 9.1.4.3 in 3GPP TS 36.213 [4], and
    - obtained by higher-layer configuration of up to five reserved CSI-RS resources as part of the discovery signal configuration following the procedure for zero-power CSI-RS in clause 6.10.5.2.
  - non-zero-power CSI reference signals for CSI reporting with the configuration for non-zero power CSI reference signals for CSI reporting obtained as described in clause 6.10.5.2, and
- for frame structure type 1 and 2, 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], and
- for frame structure type 3,
  - if the higher layer parameter *subframeStartPosition* indicates 's07' and the downlink transmission starts in the second slot of a subframe
    - the index l in the second slot in a subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l \geq l_{\text{EPDCCHStart}}$ is given by clause 7.1.6.4 of 3GPP TS 36.213 [4],
  - otherwise
    - the index l in the first slot in a subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l \geq l_{\text{EPDCCHStart}}$ is given by clause 7.6.1.4 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_{RNTI} equals the C-RNTI, and $N_{\text{ECCE}}^{\text{EPDCCH}}$ is the number of ECCEs used for this EPDCCH.

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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.

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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 and type 3, the number of PHICH groups $N_{\text{PHICH}}^{\text{group}}$ is constant in all subframes and given by

$$N_{\text{PHICH}}^{\text{group}} = \begin{cases} \left\lceil N_g \left(N_{\text{RB}}^{\text{DL}} / 8 \right) \right\rceil & \text{for normal cyclic prefix} \\ 2 \cdot \left\lceil N_g \left(N_{\text{RB}}^{\text{DL}} / 8 \right) \right\rceil & \text{for extended cyclic prefix} \end{cases}$$

where $N_g \in \{1/6, 1/2, 1, 2\}$ 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 subframes and is given by $m_i \cdot N_{\text{PHICH}}^{\text{group}}$ where $N_{\text{PHICH}}^{\text{group}}$ is given by the expression above and m_i is given by Table 6.9-1 with the uplink-downlink configuration provided by the higher-layer parameter *subframeAssignment*. The index $n_{\text{PHICH}}^{\text{group}}$ in a 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	0	0	0	2	1	0	0	0
1	0	1	0	0	1	0	1	0	0	1
2	0	0	0	1	0	0	0	0	1	0
3	1	0	0	0	0	0	0	0	1	1
4	0	0	0	0	0	0	0	0	1	1
5	0	0	0	0	0	0	0	0	1	0
6	1	1	0	0	0	1	1	0	0	1

6.9.1 Modulation

The block of bits $b(0), \ldots, b(M_{\text{bit}} - 1)$ 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 $z(0), \ldots, z(M_{\text{s}} - 1)$, 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 $z(0), \ldots, z(M_{\text{s}} - 1)$ shall be symbol-wise multiplied with an orthogonal sequence and scrambled, resulting in a sequence of modulation symbols $d(0), \ldots, d(M_{\text{symb}} - 1)$ 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

$$i = 0,\ldots,M_{\text{symb}} - 1$$

$$M_{\text{symb}} = N_{\text{SF}}^{\text{PHICH}} \cdot M_{\text{s}}$$

$$N_{\text{SF}}^{\text{PHICH}} = \begin{cases} 4 & \text{normal cyclic prefix} \\ 2 & \text{extended cyclic prefix} \end{cases}$$

and $c(i)$ is a cell-specific scrambling sequence generated according to clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = (\lfloor n_{\text{s}}/2 \rfloor + 1) \cdot (2N_{\text{ID}}^{\text{cell}} + 1) \cdot 2^9 + N_{\text{ID}}^{\text{cell}}$ 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 $d(0),\ldots,d(M_{\text{symb}} - 1)$ should be first aligned with resource element group size, resulting in a block of symbols $d^{(0)}(0),\ldots,d^{(0)}(c \cdot M_{\text{symb}} - 1)$, where $c = 1$ for normal cyclic prefix; and $c = 2$ for extended cyclic prefix.

For normal cyclic prefix, $d^{(0)}(i) = d(i)$, for $i = 0,\ldots,M_{\text{symb}} - 1$.

For extended cyclic prefix,

$$\left[d^{(0)}(4i) \quad d^{(0)}(4i+1) \quad d^{(0)}(4i+2) \quad d^{(0)}(4i+3)\right]^T = \begin{cases} \left[d(2i) \quad d(2i+1) \quad 0 \quad 0\right]^T & n_{\text{PHICH}}^{\text{group}} \bmod 2 = 0 \\ \left[0 \quad 0 \quad d(2i) \quad d(2i+1)\right]^T & n_{\text{PHICH}}^{\text{group}} \bmod 2 = 1 \end{cases}$$

for $i = 0,\ldots,(M_{\text{symb}}/2) - 1$.

The block of symbols $d^{(0)}(0),\ldots,d^{(0)}(c \cdot M_{\text{symb}} - 1)$ shall be mapped to layers and precoded, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad \ldots \quad y^{(P-1)}(i)\right]^T$, $i = 0,\ldots,c \cdot M_{\text{symb}} - 1$, where $y^{(p)}(i)$ represents the signal for antenna port p, $p = 0,\ldots,P-1$ 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.

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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 $\bar{y}^{(p)}(0),\ldots,\bar{y}^{(p)}(M_{\text{symb}}^{(0)}-1)$ 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

$$m'=m=\begin{cases}0,1,\ldots,N_{\text{PHICH}}^{\text{group}}-1 & \text{for frame structure type 1}\\ 0,1,\ldots,m_i\cdot N_{\text{PHICH}}^{\text{group}}-1 & \text{for frame structure type 2}\end{cases},$$

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

$$m'=m/2$$

$$m=\begin{cases}0,2,\ldots,N_{\text{PHICH}}^{\text{group}}-2 & \text{for frame structure type 1}\\ 0,2,\ldots,m_i\cdot N_{\text{PHICH}}^{\text{group}}-2 & \text{for frame structure type 2}\end{cases}$$

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

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$$l_i' = \begin{cases} 0 & \text{normal PHICH duration, all subframes} \\ \left(\lfloor m'/2 \rfloor + i + 1\right) \bmod 2 & \text{extended PHICH duration, MBSFN subframes} \\ \left(\lfloor m'/2 \rfloor + i + 1\right) \bmod 2 & \text{extended PHICH duration, subframe 1 and 6 in frame structure type 2} \\ i & \text{otherwise} \end{cases}$$

8) Set the frequency-domain index k_i' to the resource-element group assigned the number $\overline{n}_i$ in step 3 above, where $\overline{n}_i$ is given by

$$\overline{n}_i = \begin{cases} \left(N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'}/n_1 \rfloor + m'\right) \bmod n_{l'} & i = 0 \\ \left(N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'}/n_1 \rfloor + m' + \lfloor n_{l'}/3 \rfloor\right) \bmod n_{l'} & i = 1 \\ \left(N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'}/n_1 \rfloor + m' + \lfloor 2n_{l'}/3 \rfloor\right) \bmod n_{l'} & i = 2 \end{cases}$$

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

$$\overline{n}_i = \begin{cases} \left(N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'}/n_0 \rfloor + m'\right) \bmod n_{l'} & i = 0 \\ \left(N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'}/n_0 \rfloor + m' + \lfloor n_{l'}/3 \rfloor\right) \bmod n_{l'} & i = 1 \\ \left(N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'}/n_0 \rfloor + m' + \lfloor 2n_{l'}/3 \rfloor\right) \bmod n_{l'} & i = 2 \end{cases}$$

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

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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)

The UE may assume cell-specific reference signals are, unless otherwise stated in [4, clause 12], transmitted in

- all downlink subframes for frame structure type 1,
- all downlink subframes and DwPTS for frame structure type 2,
- non-empty subframes for frame structure type 3

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

$$n_s' = \begin{cases} 10\lfloor n_s/10 \rfloor + n_s \bmod 2 & \text{for frame structure type 3 when the CRS is part of a DRS} \\ n_s & \text{otherwise} \end{cases}$$

$$N_{\text{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

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

$$k = 6m + (v + v_{\text{shift}}) \bmod 6$$

$$l = \begin{cases} 0, N_{\text{symb}}^{\text{DL}} - 3 & \text{if } p \in \{0,1\} \\ 1 & \text{if } p \in \{2,3\} \end{cases}$$

$$m = 0,1,\ldots,2 \cdot N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}$$

The variables v and v_{shift} define the position in the frequency domain for the different reference signals where v is given by

$$v = \begin{cases} 0 & \text{if } p = 0 \text{ and } l = 0 \\ 3 & \text{if } p = 0 \text{ and } l \neq 0 \\ 3 & \text{if } p = 1 \text{ and } l = 0 \\ 0 & \text{if } p = 1 \text{ and } l \neq 0 \\ 3(n_s \bmod 2) & \text{if } p = 2 \\ 3 + 3(n_s \bmod 2) & \text{if } p = 3 \end{cases}$$

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.

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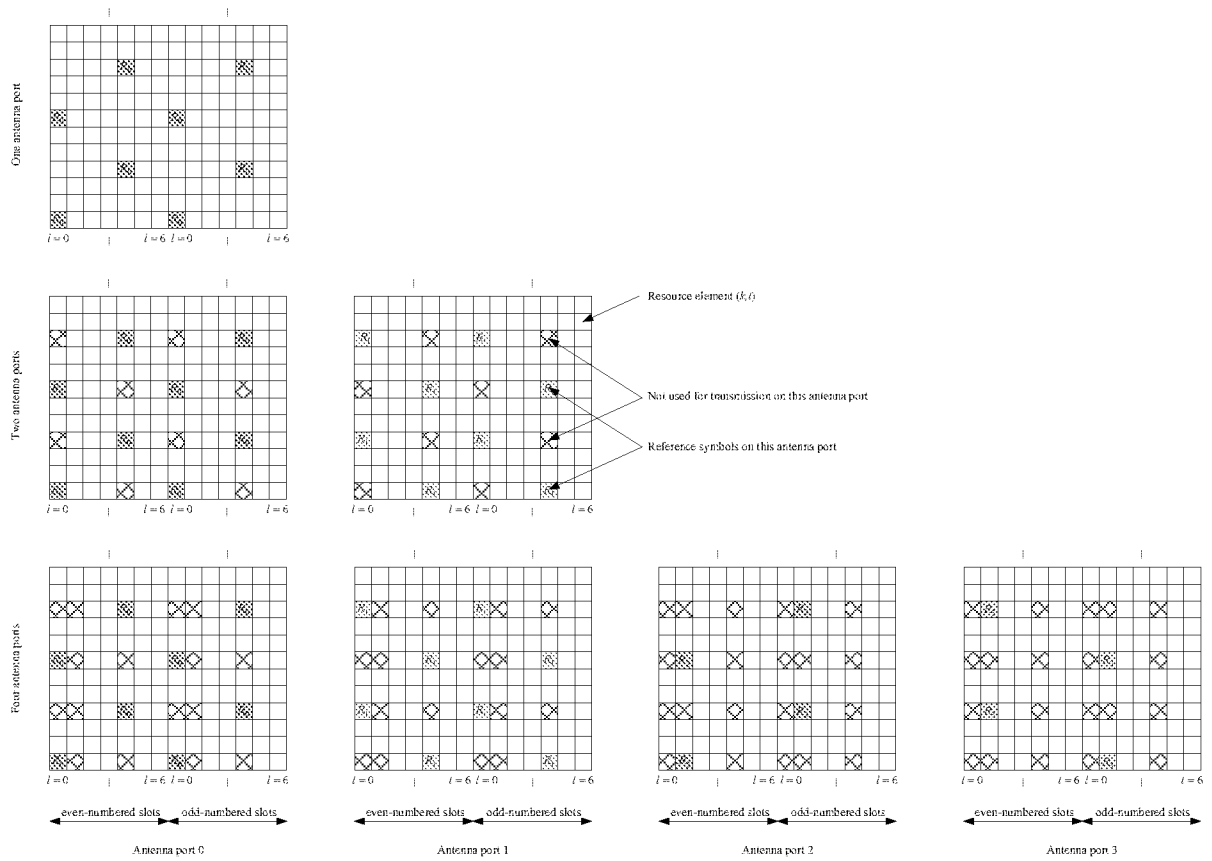


Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix)

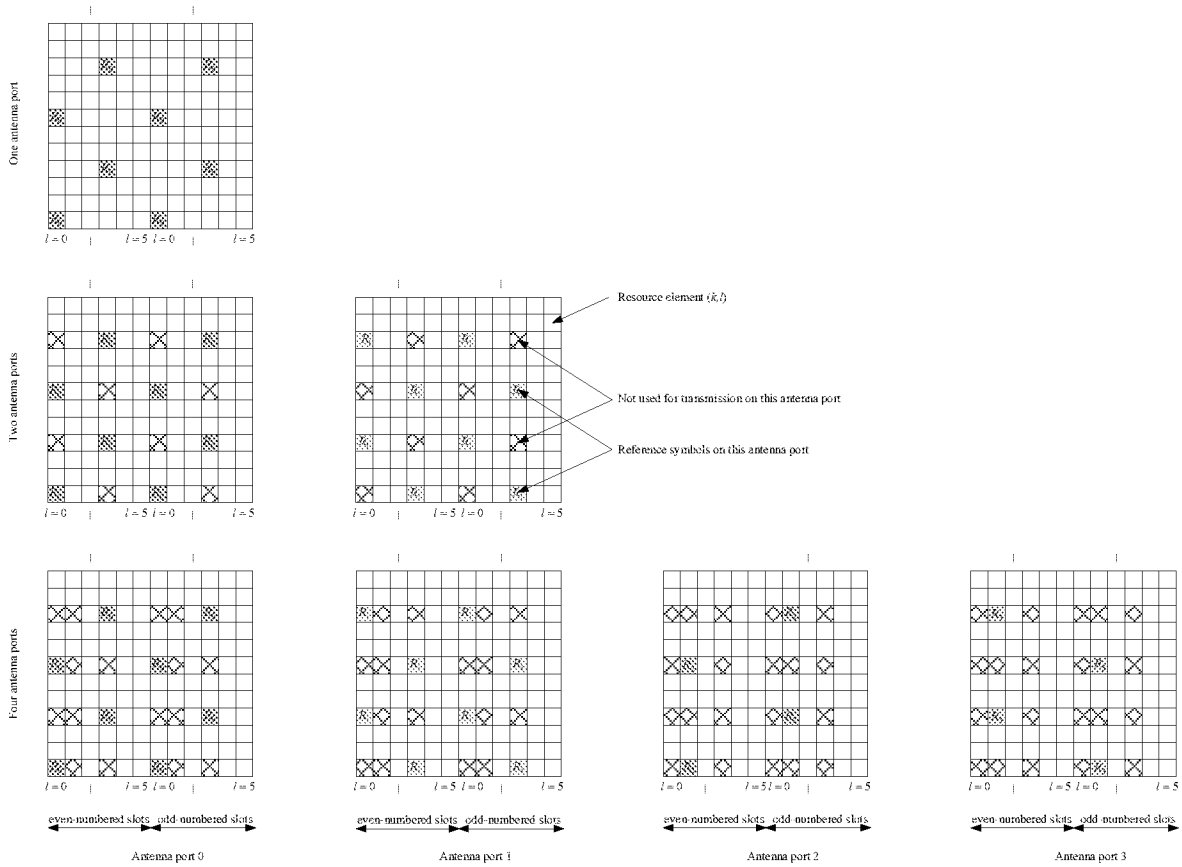


Figure 6.10.1.2-2. Mapping of downlink reference signals (extended cyclic prefix)

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 $\Delta f = 15\,\text{kHz}$. In case of $\Delta f = 7.5\,\text{kHz}$ 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.

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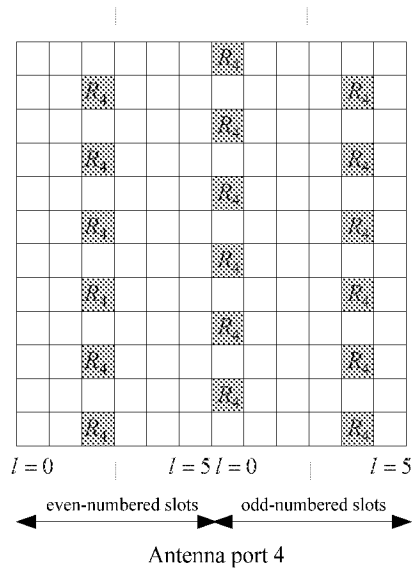


Figure 6.10.2.2-1: Mapping of MBSFN reference signals (extended cyclic prefix, $\Delta f = 15\,\text{kHz}$)

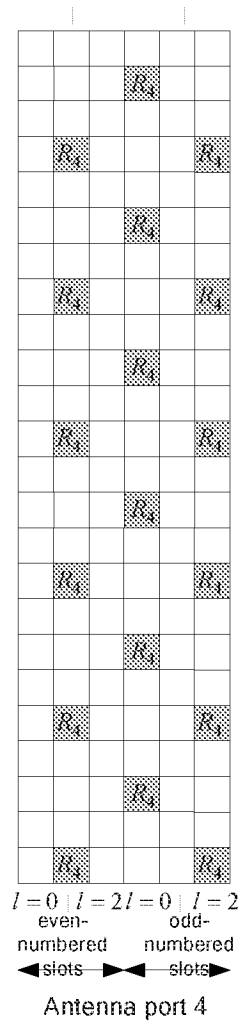


Figure 6.10.2.2-3: Mapping of MBSFN reference signals (extended cyclic prefix, $\Delta f = 7.5\,\text{kHz}$)

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 υ 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_{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_{SCID} is zero unless specified otherwise. For a PDSCH transmission on ports 7 or 8, n_{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_{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_{SCID} is given by Table 5.3.3.1.5C-1 in 3GPP TS 36.212 [3].

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Table 6.10.3.1-1: Mapping of scrambling identity field in DCI format 2B to n_{SCID} values for antenna ports 7 and 8

Scrambling identity field in DCI format 2B (3GPP TS 36.212 [3])	n_{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_{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_{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.

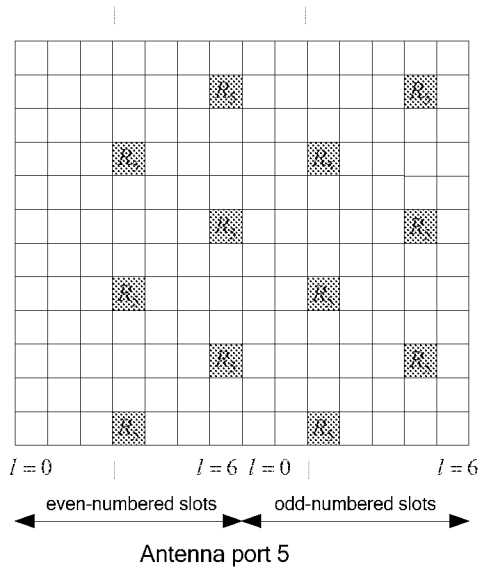


Figure 6.10.3.2-1: Mapping of UE-specific reference signals, antenna port 5 (normal cyclic prefix)

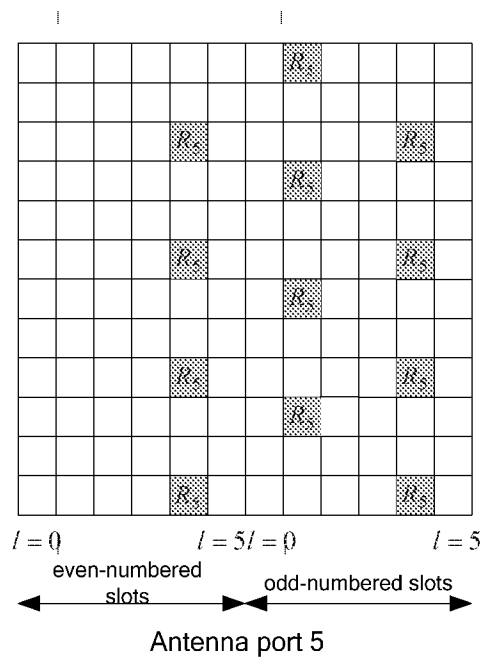


Figure 6.10.3.2-2: Mapping of UE-specific reference signals, antenna port 5 (extended cyclic prefix)

For antenna ports $p = 7$, $p = 8$ or $p = 7,8,\ldots,\upsilon + 6$, in a physical resource block with frequency-domain index n_{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

$$w_p(i) = \begin{cases} \overline{w}_p(i) & (m'+n_{\mathrm{PRB}}) \bmod 2 = 0 \\ \overline{w}_p(3-i) & (m'+n_{\mathrm{PRB}}) \bmod 2 = 1 \end{cases}$$

$$k = 5m' + N_{\mathrm{sc}}^{\mathrm{RB}} n_{\mathrm{PRB}} + k'$$

$$k' = \begin{cases} 1 & p \in \{7,8,11,13\} \\ 0 & p \in \{9,10,12,14\} \end{cases}$$

$$l = \begin{cases} l' \bmod 2 + 2 & \text{if in a special subframe with configuration 3, 4, 8 or 9 (see Table 4.2-1)} \\ l' \bmod 2 + 2 + 3\lfloor l'/2 \rfloor & \text{if in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ l' \bmod 2 + 5 & \text{if not in a special subframe} \end{cases}$$

$$l' = \begin{cases} 0,1,2,3 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \end{cases}$$

$$m' = 0,1,2$$

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	$[\overline{w}_p(0) \quad \overline{w}_p(1) \quad \overline{w}_p(2) \quad \overline{w}_p(3)]$
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

$$w_p(i) = \begin{cases} \overline{w}_p(i) & m' \bmod 2 = 0 \\ \overline{w}_p(1-i) & m' \bmod 2 = 1 \end{cases}$$

$$k = 3m' + N_{\mathrm{sc}}^{\mathrm{RB}} n_{\mathrm{PRB}} + k'$$

$$k' = \begin{cases} 1 & \text{if } n_s \bmod 2 = 0 \text{ and } p \in \{7,8\} \\ 2 & \text{if } n_s \bmod 2 = 1 \text{ and } p \in \{7,8\} \end{cases}$$

$$l = l' \bmod 2 + 4$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 3, 5 or 6 (see Table 4.2-1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in a special subframe} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in a special subframe} \end{cases}$$

$$m' = 0,1,2,3$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3.2-2.

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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.

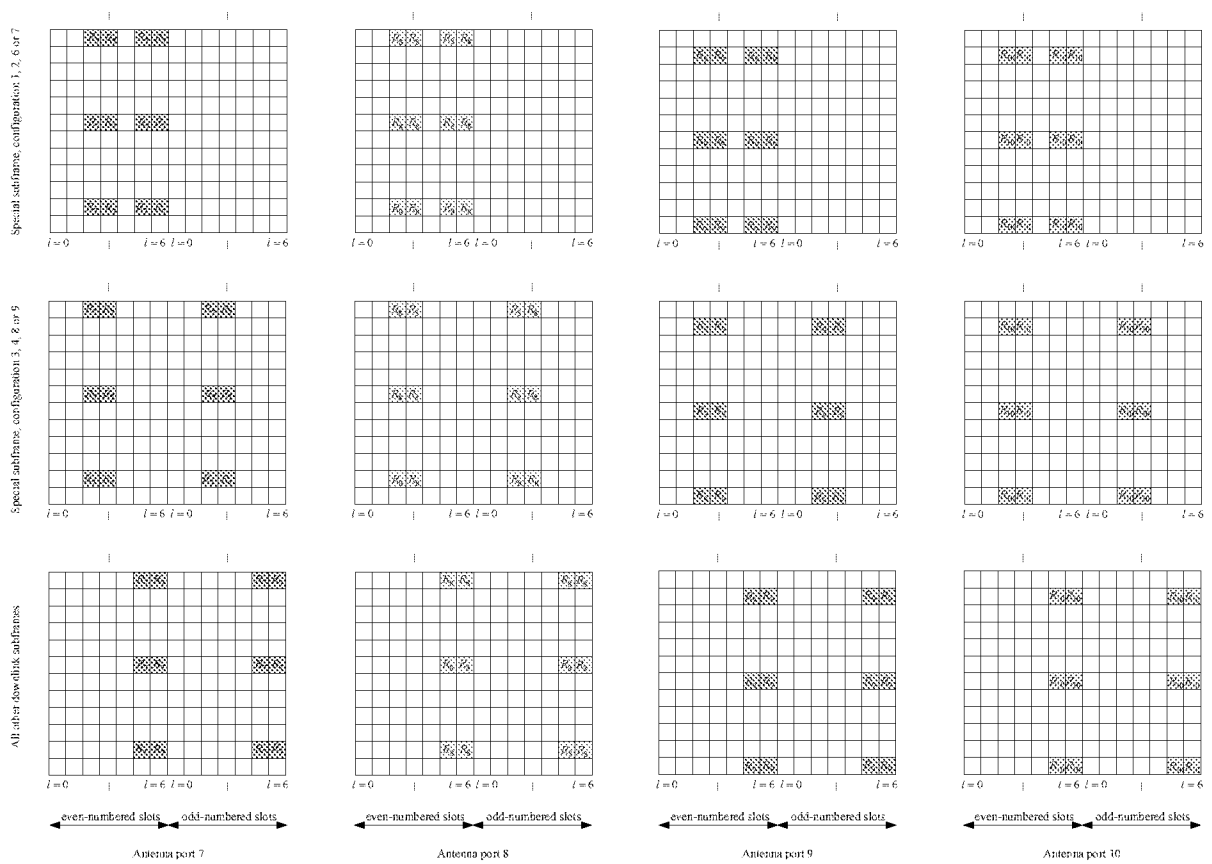


Figure 6.10.3.2-3: Mapping of UE-specific reference signals, antenna ports 7, 8, 9 and 10 (normal cyclic prefix)

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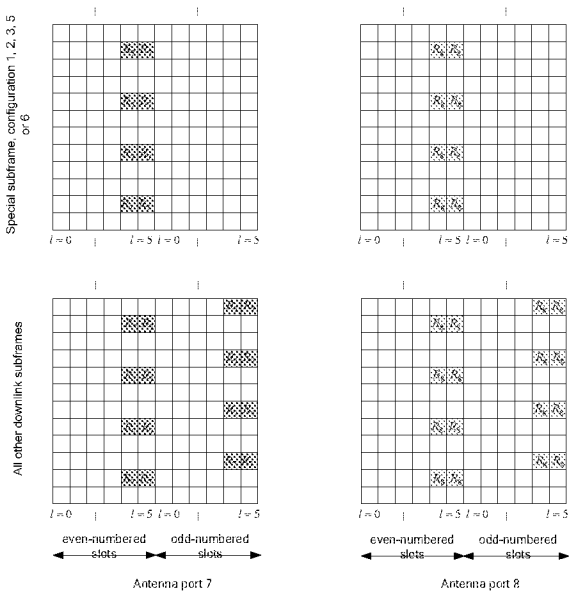


Figure 6.10.3.2-4: Mapping of UE-specific reference signals, antenna ports 7 and 8 (extended cyclic prefix)

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

$$c_{\text{init}} = \left(\lfloor n_s/2 \rfloor + 1\right)\cdot\left(2n_{\text{ID},i}^{\text{EPDCCH}}+1\right)\cdot 2^{16} + n_{\text{SCID}}^{\text{EPDCCH}}$$

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_{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

$$w_p(i) = \begin{cases} \overline{w}_p(i) & (m'+n_{\text{PRB}}) \bmod 2 = 0 \\ \overline{w}_p(3-i) & (m'+n_{\text{PRB}}) \bmod 2 = 1 \end{cases}$$

$$k = 5m' + N_{\text{sc}}^{\text{RB}} n_{\text{PRB}} + k'$$

$$k' = \begin{cases} 1 & p \in \{107,108\} \\ 0 & p \in \{109,110\} \end{cases}$$

$$l = \begin{cases} l' \bmod 2 + 2 & \text{if in a special subframe with configuration 3, 4, 8 or 9 (see Table 4.2-1)} \\ l' \bmod 2 + 2 + 3\lfloor l'/2 \rfloor & \text{if in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ l' \bmod 2 + 5 & \text{if not in a special subframe} \end{cases}$$

$$l' = \begin{cases} 0,1,2,3 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \end{cases}$$

$$m' = 0,1,2$$

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	$[+1 \quad +1 \quad +1 \quad +1]$
108	$[+1 \quad -1 \quad +1 \quad -1]$
109	$[+1 \quad +1 \quad +1 \quad +1]$
110	$[+1 \quad -1 \quad +1 \quad -1]$

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

$$w_p(i) = \begin{cases} \overline{w}_p(i) & m' \bmod 2 = 0 \\ \overline{w}_p(1-i) & m' \bmod 2 = 1 \end{cases}$$

$$k = 3m' + N_{\mathrm{sc}}^{\mathrm{RB}} n_{\mathrm{PRB}} + k'$$

$$k' = \begin{cases} 1 & \text{if } n_s \bmod 2 = 0 \text{ and } p \in \{107,108\} \\ 2 & \text{if } n_s \bmod 2 = 1 \text{ and } p \in \{107,108\} \end{cases}$$

$$l = l' \bmod 2 + 4$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 3, 5 or 6 (see Table 4.2-1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in a special subframe} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in a special subframe} \end{cases}$$

$$m' = 0,1,2,3$$

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	$[+1 \quad +1]$
108	$[-1 \quad +1]$

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

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right), \quad m = 0,1,\ldots,2N_{\text{RB}}^{\max,\text{DL}}-1$$

where n_s is the slot number within a radio frame, 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

$$N_{\text{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

6.10.4.2 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:

$$k = 6\left(m + N_{\text{RB}}^{\text{DL}} - N_{\text{RB}}^{\text{PRS}}\right) + \left(6 - l + v_{\text{shift}}\right) \bmod 6$$

$$l = \begin{cases} 3,5,6 & \text{if } n_s \bmod 2 = 0 \\ 1,2,3,5,6 & \text{if } n_s \bmod 2 = 1 \text{ and (1 or 2 PBCH antenna ports)} \\ 2,3,5,6 & \text{if } n_s \bmod 2 = 1 \text{ and (4 PBCH antenna ports)} \end{cases}$$

$$m = 0,1,\ldots,2\cdot N_{\text{RB}}^{\text{PRS}}-1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{PRS}}$$

Extended cyclic prefix:

$$k = 6\left(m + N_{\text{RB}}^{\text{DL}} - N_{\text{RB}}^{\text{PRS}}\right) + \left(5 - l + v_{\text{shift}}\right) \bmod 6$$

$$l = \begin{cases} 4,5 & \text{if } n_s \bmod 2 = 0 \\ 1,2,4,5 & \text{if } n_s \bmod 2 = 1 \text{ and (1 or 2 PBCH antenna ports)} \\ 2,4,5 & \text{if } n_s \bmod 2 = 1 \text{ and (4 PBCH antenna ports)} \end{cases}$$

$$m = 0,1,\ldots,2 \cdot N_{\text{RB}}^{\text{PRS}} - 1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{PRS}}$$

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 $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 6$.

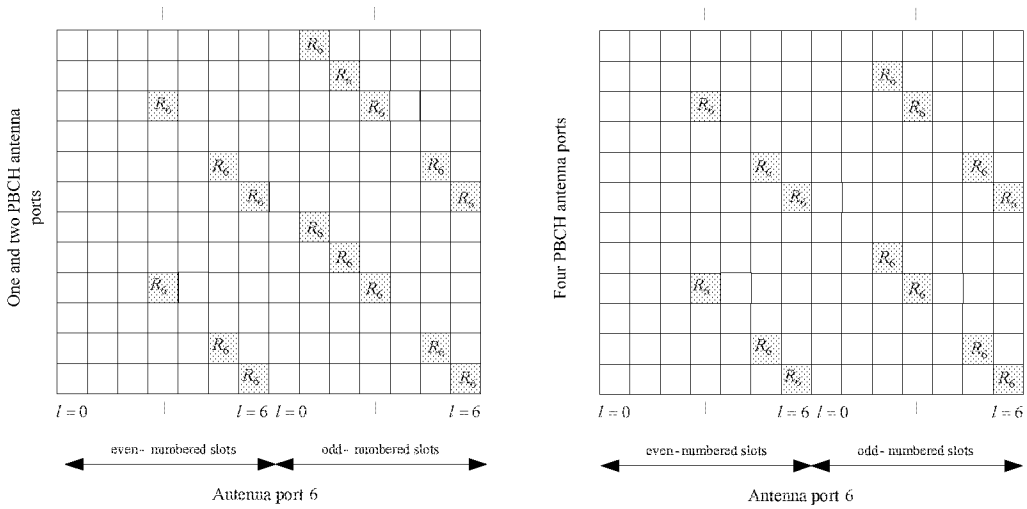


Figure 6.10.4.2-1: Mapping of positioning reference signals (normal cyclic prefix)

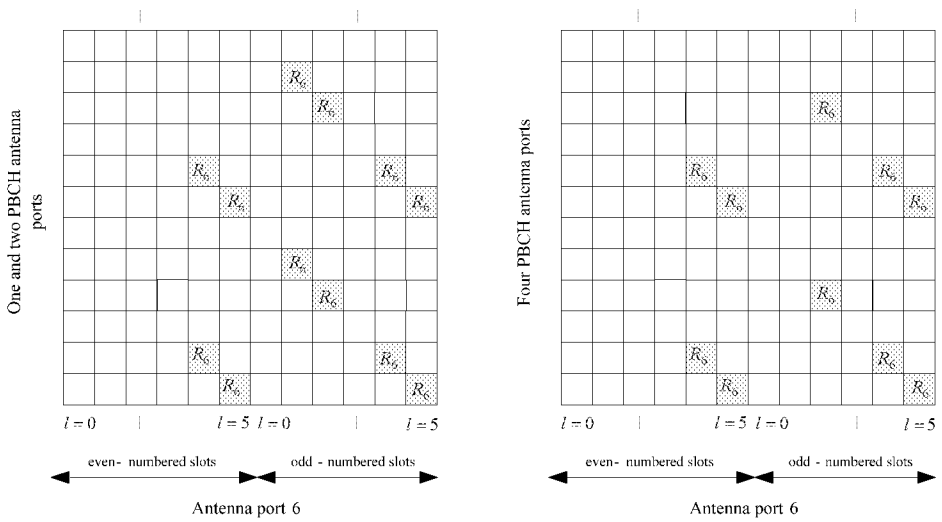


Figure 6.10.4.2-2: Mapping of positioning reference signals (extended cyclic prefix)

6.10.4.3 Positioning reference signal subframe configuration

The cell specific subframe configuration period T_{PRS} and the cell specific subframe offset Δ_{PRS} for the transmission of positioning reference signals are listed in Table 6.10.4.3-1. The PRS configuration index I_{PRS} is configured by higher layers. Positioning reference signals are transmitted only in configured DL subframes. Positioning reference

signals shall not be transmitted in DwPTS. Positioning reference signals shall be transmitted in N_{PRS} consecutive downlink subframes, where N_{PRS} is configured by higher layers.

The positioning reference signal instances, for the first subframe of the N_{PRS} downlink subframes, shall satisfy $(10 \times n_f + \lfloor n_s / 2 \rfloor - \Delta_{PRS}) \bmod T_{PRS} = 0$.

Table 6.10.4.3-1: Positioning reference signal subframe configuration

PRS configuration Index I_{PRS}	PRS periodicity T_{PRS} (subframes)	PRS subframe offset Δ_{PRS} (subframes)
0 – 159	160	I_{PRS}
160 – 479	320	$I_{PRS} - 160$
480 – 1119	640	$I_{PRS} - 480$
1120 – 2399	1280	$I_{PRS} - 1120$
2400-4095	Reserved	

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6.10.5 CSI reference signals

CSI reference signals are transmitted on one, two, four, eight, twelve, or 16 antenna ports using $p=15$, $p=15,16$, $p=15,...,18$, $p=15,...,22$, $p=15,...,26$ and $p=15,...,30$, respectively.

For CSI reference signals using more than eight antenna ports, $N_{\text{res}}^{\text{CSI}}>1$ CSI-RS resources in the same subframe, numbered from 0 to $N_{\text{res}}^{\text{CSI}}-1$, are aggregated to obtain $N_{\text{res}}^{\text{CSI}}N_{\text{ports}}^{\text{CSI}}$ antenna ports in total. Each CSI-RS resource in such an aggregation corresponds to $N_{\text{ports}}^{\text{CSI}}\in\{4,8\}$ antenna ports and one of the configurations in Table 6.10.5.3-1 or 6.10.5.2-1 for normal cyclic prefix. The supported configurations of aggregated CSI-RS resources are shown in Table 6.10.5-1.

CSI reference signals are defined for $\Delta f=15\,\text{kHz}$ only.

Table 6.10.5-1: Aggregation of CSI-RS resources.

Total number of antenna ports $N_{\text{res}}^{\text{CSI}}N_{\text{ports}}^{\text{CSI}}$	Number of antenna ports per resources $N_{\text{ports}}^{\text{CSI}}$	Number of CSI-RS resources $N_{\text{res}}^{\text{CSI}}$
12	4	3
16	8	2

6.10.5.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m)=\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right)+j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right),\quad m=0,1,...,N_{\text{RB}}^{\max,\text{DL}}-1$$

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 $c_{\text{init}}=2^{10}\cdot\left(7\cdot\left(n_s'+1\right)+l+1\right)\cdot\left(2\cdot N_{\text{ID}}^{\text{CSI}}+1\right)+2\cdot N_{\text{ID}}^{\text{CSI}}+N_{\text{CP}}$ at the start of each OFDM symbol where

$$n_s'=\begin{cases}10\lfloor n_s/10\rfloor+n_s \bmod 2 & \text{for frame structure type 3 when the CSI-RS is part of a DRS}\\ n_s & \text{otherwise}\end{cases}$$

$$N_{\text{CP}}=\begin{cases}1 & \text{for normal CP}\\ 0 & \text{for extended CP}\end{cases}$$

The quantity $N_{\text{ID}}^{\text{CSI}}$ equals $N_{\text{ID}}^{\text{cell}}$ 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. The mapping depends on the higher-layer parameter *CDMType*.

For the case of *CDMType* not equal to CDM4:

$$a_{k,l}^{(p')}=w_{l''}\cdot r_{l,n_s}(m')$$

where

$$k = k' + 12m + \begin{cases} -0 & \text{for } p' \in \{15,16\}, \text{ normal cyclic prefix} \\ -6 & \text{for } p' \in \{17,18\}, \text{ normal cyclic prefix} \\ -1 & \text{for } p' \in \{19,20\}, \text{ normal cyclic prefix} \\ -7 & \text{for } p' \in \{21,22\}, \text{ normal cyclic prefix} \\ -0 & \text{for } p' \in \{15,16\}, \text{ extended cyclic prefix} \\ -3 & \text{for } p' \in \{17,18\}, \text{ extended cyclic prefix} \\ -6 & \text{for } p' \in \{19,20\}, \text{ extended cyclic prefix} \\ -9 & \text{for } p' \in \{21,22\}, \text{ extended cyclic prefix} \end{cases}$$

$$l = l' + \begin{cases} l'' & \text{CSI reference signal configurations 0 - 19, normal cyclic prefix} \\ 2l'' & \text{CSI reference signal configurations 20 - 31, normal cyclic prefix} \\ l'' & \text{CSI reference signal configurations 0 - 27, extended cyclic prefix} \end{cases}$$

$$w_{l''} = \begin{cases} 1 & p' \in \{15,17,19,21\} \\ (-1)^{l''} & p' \in \{16,18,20,22\} \end{cases}$$

$$l'' = 0,1$$

$$m = 0,1,\ldots, N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + \left\lfloor \frac{N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}}{2} \right\rfloor$$

For the case of *CDMType* equal to *CDM4*:

$$a_{k,l}^{(p')} = w_{p'}(i) \cdot r_{l,n_s}(m')$$

where

$$k = k' + 12m - \begin{cases} k'' & \text{for } p' \in \{15,16,19,20\}, \text{ normal cyclic prefix, } N_{\text{ports}}^{\text{CSI}} = 8 \\ k''+6 & \text{for } p' \in \{17,18,21,22\}, \text{ normal cyclic prefix, } N_{\text{ports}}^{\text{CSI}} = 8 \\ 6k'' & \text{for } p' \in \{15,16,17,18\}, \text{ normal cyclic prefix, } N_{\text{ports}}^{\text{CSI}} = 4 \end{cases}$$

$$l = l' + \begin{cases} l'' & \text{CSI reference signal configurations 0 - 19, normal cyclic prefix} \\ 2l'' & \text{CSI reference signal configurations 20 - 31, normal cyclic prefix} \end{cases}$$

$$l'' = 0,1$$

$$k'' = 0,1$$

$$i = 2k'' + l''$$

$$m = 0,1,\ldots, N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + \left\lfloor \frac{N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}}{2} \right\rfloor$$

and where $w_{p'}(i)$ is given by Table 6.10.5.2-0.

Table 6.10.5.2-0: The sequence $w_{p'}(i)$ for *CDM4*.

p'		
$N_{\text{ports}}^{\text{CSI}} = 4$	$N_{\text{ports}}^{\text{CSI}} = 8$	$\left[w_{p'}(0) \quad w_{p'}(1) \quad w_{p'}(2) \quad w_{p'}(3)\right]$
15	15,17	$\left[1 \quad 1 \quad 1 \quad 1\right]$
16	16,18	$\left[1 \quad -1 \quad 1 \quad -1\right]$
17	19,21	$\left[1 \quad 1 \quad -1 \quad -1\right]$
18	20,22	$\left[1 \quad -1 \quad -1 \quad 1\right]$

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.

The relation between the antenna port number p and the quantity p' depends on the number of CSI-RS antenna ports:

- for CSI reference signals using up to eight antenna ports, $p = p'$
- for CSI reference signals using more than eight antenna ports when the higher-layer parameter *CDMType* equals *CDM2*

$$p = \begin{cases} p' + \dfrac{N_{\text{ports}}^{\text{CSI}}}{2} i & \text{for } p' \in \left\{15,\ldots,15 + N_{\text{ports}}^{\text{CSI}}/2 - 1\right\} \\ p' + \dfrac{N_{\text{ports}}^{\text{CSI}}}{2}\left(i + N_{\text{res}}^{\text{CSI}} - 1\right) & \text{for } p' \in \left\{15 + N_{\text{ports}}^{\text{CSI}}/2,\ldots,15 + N_{\text{ports}}^{\text{CSI}} - 1\right\} \end{cases}$$

  where $i \in \left\{0,1,\ldots,N_{\text{res}}^{\text{CSI}} - 1\right\}$ is the CSI-RS resource number.

- for CSI reference signals using more than eight antenna ports the higher-layer parameter *CDMType* equals *CDM4*, antenna port number $p = iN_{\text{ports}}^{\text{CSI}} + p'$ where $p' \in \left\{15,16,..,15 + N_{\text{ports}}^{\text{CSI}} - 1\right\}$ for CSI-RS resource number $i \in \left\{0,1,\ldots,N_{\text{res}}^{\text{CSI}} - 1\right\}$.

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 CSI reporting 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, and
- zero or more configurations valid across the system downlink bandwidth as part of the discovery signals for which the UE shall assume non-zero transmission power for the CSI-RS.

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 DwPTS for special subframe configuration 0, 5 and 9 for normal cyclic prefix and special subframe configuration 0, 4 and 7 for extended cyclic prefix, in case of frame structure type 2,
- in subframes where PDSCH/EPDCCH transmission starts in the second slot of a subframe for frame structure type 3,
- in subframes where PDSCH/EPDCCH transmission ends prior to the end of a subframe for frame structure type 3,
- in an empty subframe where there is no PDSCH or discovery signal transmission for frame structure type 3,
- 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 if higher layer parameter *CDMType* is not configured, or is configured to *CDM2*.

Resource elements (k,l) used for transmission of CSI reference signals on any of the antenna ports in the set S, where $S=\{15,16,17,18\}$, $S=\{19,20,21,22\}$ or $S=\{23,24,25,26\}$ for CSI reference signals on 12 ports or $S=\{15,16,19,20\}$, $S=\{17,18,21,22\}$, $S=\{23,24,27,28\}$ or $S=\{25,26,29,30\}$ for CSI reference signals on 16 ports shall not be used for transmission of PDSCH on any antenna port in the same slot if higher layer parameter *CDMType* is configured to *CDM4*.

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-RS config.	Number of CSI reference signals configured											
	1 or 2				4				8			
	Normal subframe		Special subframe		Normal subframe		Special subframe		Normal subframe		Special subframe	
	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'
0	(9,5)	0	(9,5)	0	(9,5)	0	(9,5)	0	(9,5)	0	(9,5)	0
1	(11,2)	1	(11,5)	0	(11,2)	1	(11,5)	0	(11,2)	1	(11,5)	0
2	(9,2)	1	(9,2)	1	(9,2)	1	(9,2)	1	(9,2)	1	(9,2)	1
3	(7,2)	1	(7,5)	0	(7,2)	1	(7,5)	0	(7,2)	1	(7,5)	0
4	(9,5)	1			(9,5)	1			(9,5)	1		
5	(8,5)	0	(8,5)	0	(8,5)	0	(8,5)	0				
6	(10,2)	1	(10,5)	0	(10,2)	1	(10,5)	0				
7	(8,2)	1	(8,2)	1	(8,2)	1	(8,2)	1				
8	(6,2)	1	(6,5)	0	(6,2)	1	(6,5)	0				
9	(8,5)	1			(8,5)	1						
10	(3,5)	0	(3,5)	0								
11	(2,5)	0	(2,5)	0								
12	(5,2)	1	(5,5)	0								
13	(4,2)	1	(4,5)	0								
14	(3,2)	1	(3,2)	1								
15	(2,2)	1	(2,2)	1								
16	(1,2)	1	(1,5)	0								
17	(0,2)	1	(0,5)	0								
18	(3,5)	1										
19	(2,5)	1										
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										

Note: $n_s' = n_s \bmod 2$. Configurations 0 – 19 for normal subframes are available for frame structure types 1, 2 and 3. Configurations 20 – 31 and configurations for special subframes are available for frame structure type 2 only.

Table 6.10.5.2-2: Mapping from CSI reference signal configuration to (k',l') for extended cyclic prefix.

CSI-RS config.	Number of CSI reference signals configured											
	1 or 2				4				8			
	Normal subframe		Special subframe		Normal subframe		Special subframe		Normal Subframe		Special subframe	
	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'
0	(11,4)	0	(11,4)	0	(11,4)	0	(11,4)	0	(11,4)	0	(11,4)	0
1	(9,4)	0	(9,4)	0	(9,4)	0	(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	(5,4)	0	(5,4)	0				
5	(3,4)	0	(3,4)	0	(3,4)	0	(3,4)	0				
6	(4,4)	1			(4,4)	1						
7	(3,4)	1			(3,4)	1						
8	(8,4)	0	(8,4)	0								
9	(6,4)	0	(6,4)	0								
10	(2,4)	0	(2,4)	0								
11	(0,4)	0	(0,4)	0								
12	(7,4)	1										
13	(6,4)	1										
14	(1,4)	1										
15	(0,4)	1										
16	(11,1)	1	(11,1)	1	(11,1)	1	(11,1)	1	(11,1)	1	(11,1)	1
17	(10,1)	1	(10,1)	1	(10,1)	1	(10,1)	1	(10,1)	1	(10,1)	1
18	(9,1)	1	(9,1)	1	(9,1)	1	(9,1)	1	(9,1)	1	(9,1)	1
19	(5,1)	1	(5,1)	1	(5,1)	1	(5,1)	1				
20	(4,1)	1	(4,1)	1	(4,1)	1	(4,1)	1				
21	(3,1)	1	(3,1)	1	(3,1)	1	(3,1)	1				
22	(8,1)	1	(8,1)	1								
23	(7,1)	1	(7,1)	1								
24	(6,1)	1	(6,1)	1								
25	(2,1)	1	(2,1)	1								
26	(1,1)	1	(1,1)	1								
27	(0,1)	1	(0,1)	1								

Note: $n_s' = n_s \bmod 2$. Configurations 0 – 15 for normal subframes are available for both frame structure type 1 and type 2. Configurations 16 – 27 and configurations for special subframes are available for frame structure type 2 only.

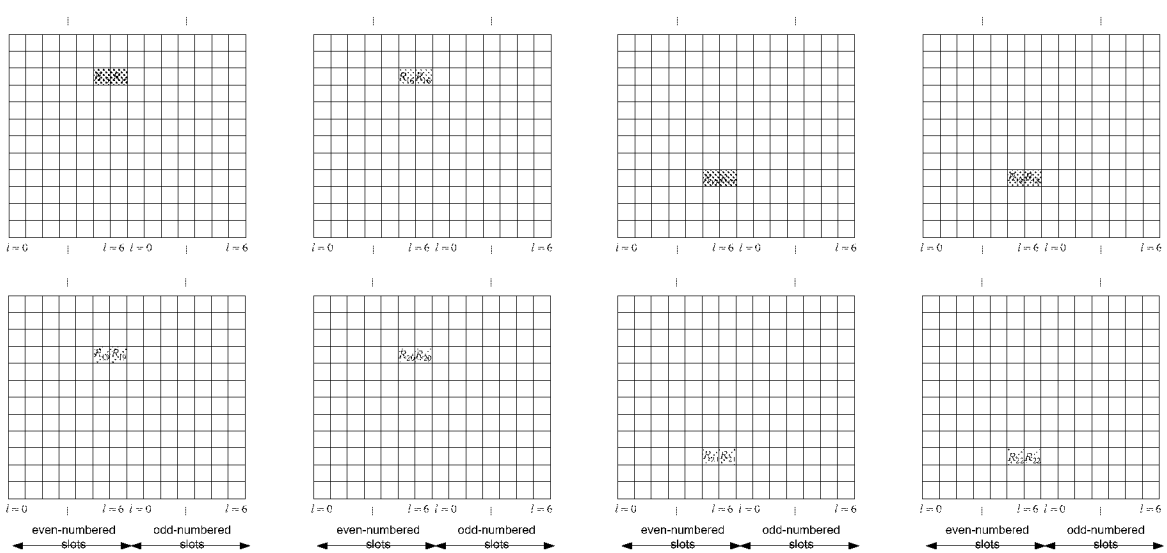


Figure 6.10.5.2-1: Mapping of CSI reference signals (CSI configuration 0, normal cyclic prefix)

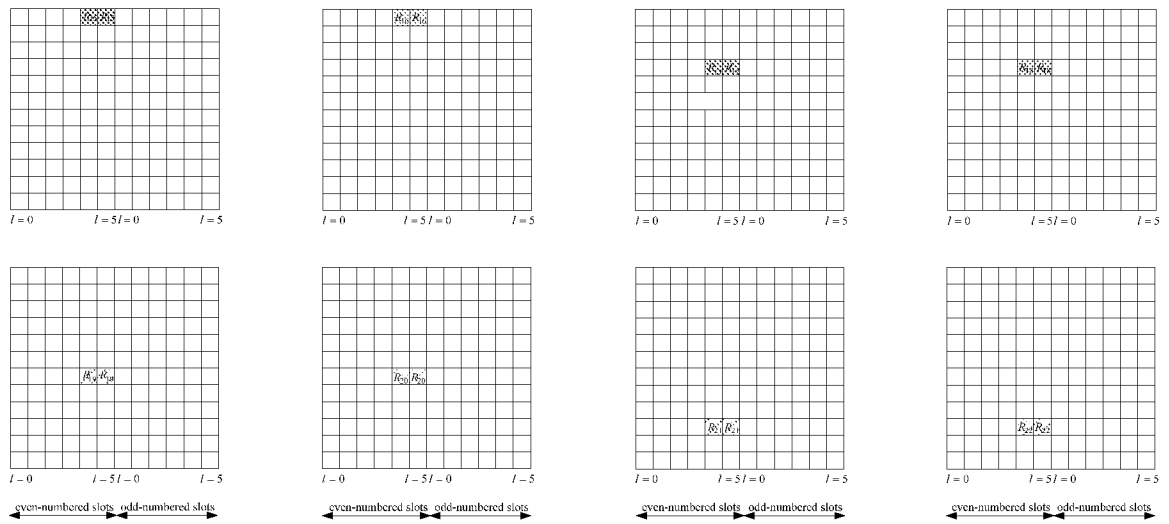


Figure 6.10.5.2-2: Mapping of CSI reference signals (CSI configuration 0, extended cyclic prefix)

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 $(10n_f + \lfloor n_s/2 \rfloor - \Delta_{\text{CSI-RS}}) \bmod T_{\text{CSI-RS}} = 0$.

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 (PSS)

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

$$d_u(n) = \begin{cases} e^{-j\frac{\pi un(n+1)}{63}} & n = 0,1,\ldots,30 \\ e^{-j\frac{\pi u(n+1)(n+2)}{63}} & n = 31,32,\ldots,61 \end{cases}$$

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

$$a_{k,l} = d(n), \qquad n = 0,\ldots,61$$
$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$

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

$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$
$$n = -5,-4,\ldots,-1,62,63,\ldots 66$$

are reserved and not used for transmission of the primary synchronization signal.

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For frame structure type 3, the primary synchronization signal shall be mapped according to frame structure type 1 with the following exceptions:

- the primary synchronization signal shall be transmitted only if the corresponding subframe is non-empty and at least 12 OFDM symbols are transmitted,
- a primary synchronization signal being part of a discovery signal shall be transmitted in the last OFDM symbol of the first slot of a discovery signal occasion.

6.11.2 Secondary synchronization signal (SSS)

6.11.2.1 Sequence generation

The sequence $d(0),\ldots,d(61)$ 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 subframes according to

$$d(2n) = \begin{cases} s_0^{(m_0)}(n)c_0(n) & \text{in subframes } 0, 1, 2, 3, 4 \\ s_1^{(m_1)}(n)c_0(n) & \text{in subframes } 5, 6, 7, 8, 9 \end{cases}$$
$$d(2n+1) = \begin{cases} s_1^{(m_1)}(n)c_1(n)z_1^{(m_0)}(n) & \text{in subframes } 0, 1, 2, 3, 4 \\ s_0^{(m_0)}(n)c_1(n)z_1^{(m_1)}(n) & \text{in subframes } 5, 6, 7, 8, 9 \end{cases}$$

where $0 \le n \le 30$. The indices m_0 and m_1 are derived from the physical-layer cell-identity group $N_{\mathrm{ID}}^{(1)}$ according to

$$m_0 = m' \bmod 31$$
$$m_1 = (m_0 + \lfloor m'/31 \rfloor + 1) \bmod 31$$
$$m' = N_{\mathrm{ID}}^{(1)} + q(q+1)/2, \quad q = \left\lfloor \frac{N_{\mathrm{ID}}^{(1)} + q'(q'+1)/2}{30} \right\rfloor, \quad q' = \lfloor N_{\mathrm{ID}}^{(1)}/30 \rfloor$$

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 $x(0) = 0$, $x(1) = 0$, $x(2) = 0$, $x(3) = 0$, $x(4) = 1$.

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

$$c_0(n) = \tilde{c}((n + N_{\mathrm{ID}}^{(2)}) \bmod 31)$$
$$c_1(n) = \tilde{c}((n + N_{\mathrm{ID}}^{(2)} + 3) \bmod 31)$$

where $N_{ID}^{(2)} \in \{0,1,2\}$ is the physical-layer identity within the physical-layer cell identity group $N_{ID}^{(1)}$ and $\tilde{c}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i}+5) = \left(x(\bar{i}+3) + x(\bar{i})\right) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1$.

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 $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1$.

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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 3 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

$$a_{k,l} = d(n), \qquad n = 0,\ldots,61$$

$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$

$$l = \begin{cases} N_{\mathrm{symb}}^{\mathrm{DL}} - 2 & \text{in slots 0 and 10} \quad \text{for frame structure type 1} \\ N_{\mathrm{symb}}^{\mathrm{DL}} - 1 & \text{in slots 1 and 11} \quad \text{for frame structure type 2} \\ N_{\mathrm{symb}}^{\mathrm{DL}} - 2 & \text{in slots where the PSS is transmitted} \quad \text{for frame structure type 3} \end{cases}$$

Resource elements (k,l) where

$$k = n - 31 + \frac{N_{RB}^{DL} N_{sc}^{RB}}{2}$$

$$l = \begin{cases} N_{symb}^{DL} - 2 & \text{in slots 0 and 10} \quad \text{for frame structure type 1} \\ N_{symb}^{DL} - 1 & \text{in slots 1 and 11} \quad \text{for frame structure type 2} \\ N_{symb}^{DL} - 2 & \text{in slots where the PSS is transmitted} \quad \text{for frame structure type 3} \end{cases}$$

$$n = -5,-4,...,-1,62,63,...66$$

are reserved and not used for transmission of the secondary synchronization signal.

6.11A Discovery signal

A discovery signal occasion for a cell consists of a period with a duration of

- one to five consecutive subframes for frame structure type 1
- two to five consecutive subframes for frame structure type 2
- 12 OFDM symbols within one non-empty subframe for frame structure type 3

where the UE in the downlink subframes may assume presence of a discovery signal consisting of

- cell-specific reference signals on antenna port 0 in all downlink subframes and in DwPTS of all special subframes in the period,
- primary synchronization signal in the first subframe of the period for frame structure types 1 and 3 or the second subframe of the period for frame structure type 2,
- secondary synchronization signal in the first subframe of the period, and
- non-zero-power CSI reference signals in zero or more subframes in the period. The configuration of non-zero-power CSI reference signals part of the discovery signal is obtained as described in clause 6.10.5.2

For frame structures 1 and 2 the UE may assume a discovery signal occasion once every *dmtc-Periodicity*.

For frame structure type 3, the UE may assume a discovery signal occasion may occur in any subframe within the discovery signals measurement timing configuration in clause 5.5.2.10 of [9].

For frame structure type 3, simultaneous transmission of a discovery signal and PDSCH/PDCCH/EPDCCH may occur in subframes 0 and 5 only.

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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 $l = 0$ 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].

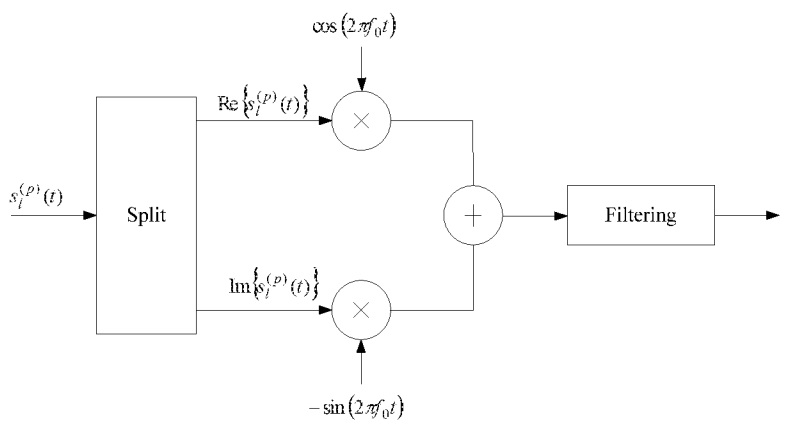


Figure 6.13-1: Downlink modulation

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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 $x=I+jQ$ 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 $x=I+jQ$ 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	$-1/\sqrt{2}$	$-1/\sqrt{2}$

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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	$-7/\sqrt{42}$	$-7/\sqrt{42}$

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7.1.5 256QAM

In case of 256QAM modulation, octuplets of bits, $b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5),b(i+6),b(i+7)$, are mapped to complex-valued modulation symbols $x=(I+jQ)/\sqrt{170}$ according to Table 7.1.5-1.

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Table 7.1.5-1: 256QAM modulation mapping

$b(i)...b(i+7)$	I	Q	$b(i)...b(i+7)$	I	Q	$b(i)...b(i+7)$	I	Q	$b(i)...b(i+7)$	I	Q
00000000	5	5	01000000	5	-5	10000000	-5	5	11000000	-5	-5
00000001	5	7	01000001	5	-7	10000001	-5	7	11000001	-5	-7
00000010	7	5	01000010	7	-5	10000010	-7	5	11000010	-7	-5
00000011	7	7	01000011	7	-7	10000011	-7	7	11000011	-7	-7
00000100	5	3	01000100	5	-3	10000100	-5	3	11000100	-5	-3
00000101	5	1	01000101	5	-1	10000101	-5	1	11000101	-5	-1
00000110	7	3	01000110	7	-3	10000110	-7	3	11000110	-7	-3
00000111	7	1	01000111	7	-1	10000111	-7	1	11000111	-7	-1
00001000	3	5	01001000	3	-5	10001000	-3	5	11001000	-3	-5
00001001	3	7	01001001	3	-7	10001001	-3	7	11001001	-3	-7
00001010	1	5	01001010	1	-5	10001010	-1	5	11001010	-1	-5
00001011	1	7	01001011	1	-7	10001011	-1	7	11001011	-1	-7
00001100	3	3	01001100	3	-3	10001100	-3	3	11001100	-3	-3
00001101	3	1	01001101	3	-1	10001101	-3	1	11001101	-3	-1
00001110	1	3	01001110	1	-3	10001110	-1	3	11001110	-1	-3
00001111	1	1	01001111	1	-1	10001111	-1	1	11001111	-1	-1
00010000	5	11	01010000	5	-11	10010000	-5	11	11010000	-5	-11
00010001	5	9	01010001	5	-9	10010001	-5	9	11010001	-5	-9
00010010	7	11	01010010	7	-11	10010010	-7	11	11010010	-7	-11
00010011	7	9	01010011	7	-9	10010011	-7	9	11010011	-7	-9
00010100	5	13	01010100	5	-13	10010100	-5	13	11010100	-5	-13
00010101	5	15	01010101	5	-15	10010101	-5	15	11010101	-5	-15
00010110	7	13	01010110	7	-13	10010110	-7	13	11010110	-7	-13
00010111	7	15	01010111	7	-15	10010111	-7	15	11010111	-7	-15
00011000	3	11	01011000	3	-11	10011000	-3	11	11011000	-3	-11
00011001	3	9	01011001	3	-9	10011001	-3	9	11011001	-3	-9
00011010	1	11	01011010	1	-11	10011010	-1	11	11011010	-1	-11
00011011	1	9	01011011	1	-9	10011011	-1	9	11011011	-1	-9
00011100	3	13	01011100	3	-13	10011100	-3	13	11011100	-3	-13
00011101	3	15	01011101	3	-15	10011101	-3	15	11011101	-3	-15
00011110	1	13	01011110	1	-13	10011110	-1	13	11011110	-1	-13
00011111	1	15	01011111	1	-15	10011111	-1	15	11011111	-1	-15
00100000	11	5	01100000	11	-5	10100000	-11	5	11100000	-11	-5
00100001	11	7	01100001	11	-7	10100001	-11	7	11100001	-11	-7
00100010	9	5	01100010	9	-5	10100010	-9	5	11100010	-9	-5
00100011	9	7	01100011	9	-7	10100011	-9	7	11100011	-9	-7
00100100	11	3	01100100	11	-3	10100100	-11	3	11100100	-11	-3
00100101	11	1	01100101	11	-1	10100101	-11	1	11100101	-11	-1
00100110	9	3	01100110	9	-3	10100110	-9	3	11100110	-9	-3
00100111	9	1	01100111	9	-1	10100111	-9	1	11100111	-9	-1
00101000	13	5	01101000	13	-5	10101000	-13	5	11101000	-13	-5
00101001	13	7	01101001	13	-7	10101001	-13	7	11101001	-13	-7
00101010	15	5	01101010	15	-5	10101010	-15	5	11101010	-15	-5
00101011	15	7	01101011	15	-7	10101011	-15	7	11101011	-15	-7
00101100	13	3	01101100	13	-3	10101100	-13	3	11101100	-13	-3
00101101	13	1	01101101	13	-1	10101101	-13	1	11101101	-13	-1
00101110	15	3	01101110	15	-3	10101110	-15	3	11101110	-15	-3
00101111	15	1	01101111	15	-1	10101111	-15	1	11101111	-15	-1
00110000	11	11	01110000	11	-11	10110000	-11	11	11110000	-11	-11
00110001	11	9	01110001	11	-9	10110001	-11	9	11110001	-11	-9
00110010	9	11	01110010	9	-11	10110010	-9	11	11110010	-9	-11
00110011	9	9	01110011	9	-9	10110011	-9	9	11110011	-9	-9
00110100	11	13	01110100	11	-13	10110100	-11	13	11110100	-11	-13
00110101	11	15	01110101	11	-15	10110101	-11	15	11110101	-11	-15
00110110	9	13	01110110	9	-13	10110110	-9	13	11110110	-9	-13
00110111	9	15	01110111	9	-15	10110111	-9	15	11110111	-9	-15
00111000	13	11	01111000	13	-11	10111000	-13	11	11111000	-13	-11
00111001	13	9	01111001	13	-9	10111001	-13	9	11111001	-13	-9
00111010	15	11	01111010	15	-11	10111010	-15	11	11111010	-15	-11
00111011	15	9	01111011	15	-9	10111011	-15	9	11111011	-15	-9
00111100	13	13	01111100	13	-13	10111100	-13	13	11111100	-13	-13
00111101	13	15	01111101	13	-15	10111101	-13	15	11111101	-13	-15

00111110	15	13	01111110	15	-13	10111110	-15	13	11111110	-15	-13
00111111	15	15	01111111	15	-15	10111111	-15	15	11111111	-15	-15

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_{PN}, where $n = 0,1,...,M_{PN}-1$, is defined by

$$c(n) = (x_1(n+N_C) + x_2(n+N_C)) \bmod 2$$
$$x_1(n+31) = (x_1(n+3) + x_1(n)) \bmod 2$$
$$x_2(n+31) = (x_2(n+3) + x_2(n+2) + x_2(n+1) + x_2(n)) \bmod 2$$

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 $c_{init} = \sum_{i=0}^{30} x_2(i) \cdot 2^i$ 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 $(N_{TA} + N_{TA\,offset}) \times T_s$ seconds before the start of the corresponding downlink radio frame at the UE, where $0 \le N_{TA} \le 4096$ if the UE is configured with a SCG and $0 \le N_{TA} \le 20512$ otherwise. For frame structure type 1 $N_{TA\,offset} = 0$ and for frame structure type 2 $N_{TA\,offset} = 624$ unless stated otherwise in [4]. 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.

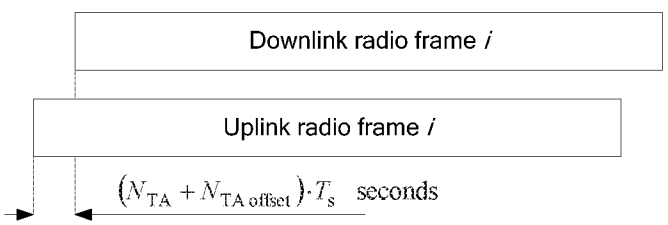


Figure 8.1-1: Uplink-downlink timing relation

9 Sidelink

9.1 Overview

A sidelink is used for ProSe direct communication and ProSe direct discovery between UEs.

9.1.1 Physical channels

A sidelink 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 sidelink physical channels are defined:

- Physical Sidelink Shared Channel, PSSCH
- Physical Sidelink Control Channel, PSCCH
- Physical Sidelink Discovery Channel, PSDCH
- Physical Sidelink Broadcast Channel, PSBCH

Generation of the baseband signal representing the different physical sidelink channels is illustrated in Figrue 5.3-1.

9.1.2 Physical signals

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

- Demodulation reference signal
- Synchronization signal

9.1.3 Handling of simultaneous sidelink and uplink/downlink transmissions

For a given carrier frequency, a UE shall not transmit a sidelink signal or channel overlapping partly or completely in time with an uplink transmission from the same UE.

For a given carrier frequency, no PSDCH, PSCCH, or PSSCH transmission shall occur from a UE in a sidelink subframe configured for synchronization purposes by the higher-layer parameters

- *syncOffsetIndicator1* or *syncOffsetIndicator2* in [9] if the UE has no serving cell fulfilling the S criterion according to [10, clause 5.2.3.2], or
- *syncOffsetIndicator* in *commSyncConfig* or *discSyncConfig* which includes *txParameters* in [9] if the UE has a serving cell fulfilling the S criterion according to [10, clause 5.2.3.2]. The UE may assume the same configuration in *commSyncConfig* and *discSyncConfig*.

For a given carrier frequency, with the exception of PSSCH transmissions with transmission mode 1 and same sidelink cyclic prefix as PUSCH, no sidelink transmissions shall occur in sidelink subframe n from a UE if uplink SRS is transmitted from the same UE in uplink subframe n.

In case of a UE capable of transmission on multiple carriers, sidelink transmission may only occur on a single carrier frequency at a given time.

A UE with limited transmission capabilities shall at a given time first prioritize uplink transmissions, followed by sidelink communication transmissions (PSSS, SSSS, PSBCH, PSSCH, PSCCH) and last sidelink discovery transmissions (PSDCH).

A UE with limited reception capabilities shall at a given time first prioritize downlink reception, followed by sidelink communication reception, sidelink discovery reception on carriers configured by the eNodeB, and last sidelink discovery reception on carriers not configured by the eNodeB.

9.2 Slot structure and physical resources

Sidelink transmissions are organized into radio frames with a duration of T_f, each consisting of 20 slots of duration T_{slot}. A sidelink subframe consists of two consecutive slots, starting with an even-numbered slot.

9.2.1 Resource grid

A transmitted physical channel or signal in a slot is described by a resource grid of $N_{RB}^{SL}N_{sc}^{RB}$ subcarriers and N_{symb}^{SL} SC-FDMA symbols. The sidelink bandwidth $N_{RB}^{SL} = N_{RB}^{UL}$ if the S criterion according to [10, clause 5.2.3.2] is fulfilled for a serving cell having the same uplink carrier frequency as the sidelink, otherwise a preconfigured value is used [9].

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The sidelink cyclic prefix is configured independently for type 1 discovery, type 2B discovery, sidelink transmission mode 1, sidelink transmission mode 2, control signalling, and PSBCH and synchronization signals. Configuration is per resource pool for discovery, sidelink transmission mode 2, and control signalling. The PSBCH and synchronization signals always use the same cyclic prefix.

The resource grid is illustrated in Figure 5.2.1-1.

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 are shown in Table 9.2.1-1.

Table 9.2.1-1: Antenna ports used for different physical channels and signals

Physical channel or signal	Antenna port number
PSSCH	1000
PSCCH	1000
PSDCH	1000
PSBCH	1010
Synchronization signals	1020

9.2.2 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 $k=0,...,N_{\text{RB}}^{\text{SL}}N_{\text{sc}}^{\text{RB}}-1$ and $l=0,...,N_{\text{symb}}^{\text{SL}}-1$ 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.

9.2.3 Resource blocks

A physical resource block is defined as $N_{\text{symb}}^{\text{SL}}$ consecutive SC-FDMA symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{SL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 9.2.3-1. A physical resource block in the sidelink thus consists of $N_{\text{symb}}^{\text{SL}}\times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Table 9.2.3-1: Resource block parameters

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

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

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

9.2.4 Resource pool

The subframe pools and resource block pools are defined in [4].

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For PSSCH, the number of the current slot in the subframe pool $n_{ss}^{PSSCH} = 2n_{ssf}^{PSSCH} + i$, where $i \in \{0,1\}$ is the number of the current slot within the current sidelink subframe $n_{ssf}^{PSSCH} = j \bmod 10$ with j equal to the subscript of l_j^{PSSCH}, defined in clauses 14.1.4 and 14.2.3 of [4] for sidelink transmission modes 1 and 2, respectively

9.2.5 Guard period

The last SC-FDMA symbol in a sidelink subframe serves as a guard period and shall not be used for sidelink transmission.

9.3 Physical Sidelink Shared Channel

9.3.1 Scrambling

The block of bits $b(0),...,b(M_{bit}-1)$, where M_{bit} is the number of bits transmitted on the physical sidelink shared channel in one subframe shall be scrambled according to clause 5.3.1.

The scrambling sequence generator shall be initialised with $c_{init} = n_{ID}^{SA} \cdot 2^{14} + n_{ssf}^{PSSCH} \cdot 2^9 + 510$ at the start of every PSSCH subframe where n_{ID}^{SA} is destination identity obtained from the sidelink control channel.

9.3.2 Modulation

Modulation shall be done according to clause 5.3.2. Table 9.3.2-1 specifies the modulation mappings applicable for the physical sidelink shared channel.

Table 9.3.2-1: PSSCH modulation schemes

Physical channel	Modulation schemes
PSSCH	QPSK, 16QAM

9.3.3 Layer mapping

Layer mapping shall be done according to clause 5.3.2A assuming a single antenna port, $\upsilon = 1$.

9.3.4 Transform precoding

Transform precoding shall be done according to clause 5.3.3 with M_{RB}^{PUSCH} and M_{sc}^{PUSCH} replaced by M_{RB}^{PSSCH} and M_{sc}^{PSSCH}, respectively.

9.3.5 Precoding

Precoding shall be done according to clause 5.3.3A assuming a single antenna port, $\upsilon = 1$.

9.3.6 Mapping to physical resources

The block of complex-valued symbols $z(0),...,z(M_{symb}^{ap}-1)$ shall be multiplied with the amplitude scaling factor β_{PSSCH} in order to conform to the transmit power P_{PSSCH} specified in [4], and mapped in sequence starting with $z(0)$ to physical resource blocks on antenna port p and assigned for transmission of PSSCH. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and not used for transmission of reference signals shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe. Resource elements in the last SC-FDFMA symbol within a subframe shall be counted in the mapping process but not transmitted.

If sidelink frequency hopping is disabled the set of physical resource blocks to be used for transmission is given by $n_{\text{PRB}} = n'_{\text{VRB}}$ where n'_{VRB} is obtained from [4, clause 14.1.1.2.1].

If sidelink frequency hopping with type 1 hopping is enabled, the set of physical resource blocks to be used for transmission is given by [4].

If sidelink frequency hopping with predefined hopping pattern is enabled, the set of physical resource blocks to be used for transmission is given by the sidelink control information together with a predefined pattern in clause 5.3.4 with the following exceptions:

- only inter-subframe hopping shall be used
- the number of subbands $N_{\text{sb}} \in \{1,2,4\}$ is given by higher layers as described in [4, clause 14.1.1.2]
- the quantity $N_{\text{RB}}^{\text{HO}} \in \{0,...,110\}$ is given by higher layers as described in [4, clause 14.1.1.2]
- the quantity $n_{\text{s}} = n_{\text{ss}}^{\text{PSSCH}}$ where $n_{\text{ss}}^{\text{PSSCH}}$ is given by clause 9.2.4
- the quantity CURRENT_TX_NB $= n_{\text{sst}}^{\text{PSSCH}}$
- the pseudo-random sequence generator is initialized at the start of each slot fulfilling $n_{\text{ss}}^{\text{PSSCH}} = 0$ with the initialization value $c_{\text{init}} \in \{0,1,...,503,510\}$ given by *hoppingParameter-r12* in [9]
- the quantity n_{VRB} shall be replaced by n'_{VRB}, given by [4, clause 14.1.1.2.1]
- for sidelink transmission mode 1
  - $N_{\text{RB}}^{\text{UL}} = N_{\text{RB}}^{\text{SL}}$
- for sidelink transmission mode 2
  - $N_{\text{RB}}^{\text{UL}} = M_{\text{RB}}^{\text{PSSCH\_RP}}$ where $M_{\text{RB}}^{\text{PSSCH\_RP}}$ is given by [4, clause 14.1.3]
  - the quantity n_{PRB} shall be replaced by n'_{PRB}, given by [4, clause 14.1.1.4]
  - the physical resource block to use for transmission $n_{\text{PRB}} = m_{n'_{\text{PRB}}}^{\text{PSSCH}}$ with m_j^{PSSCH} given by [4, clause 14.1.3]

9.4 Physical Sidelink Control Channel

9.4.1 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}}-1)$, where M_{bit} is the number of bits transmitted on the physical sidelink control channel in one subframe shall be scrambled according to clause 5.3.1.

The scrambling sequence generator shall be initialised with $c_{\text{init}} = 510$ at the start of every PSCCH subframe.

9.4.2 Modulation

Modulation shall be done according to clause 5.3.2. Table 9.4.2-1 specifies the modulation mappings applicable for the physical sidelink control channel.

Table 9.4.2-1: PSCCH modulation schemes

Physical channel	Modulation schemes
PSCCH	QPSK

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9.4.3 Layer mapping

Layer mapping shall be done according to clause 5.3.2A assuming a single antenna port, $\upsilon = 1$.

9.4.4 Transform precoding

Transform precoding shall be done according to clause 5.3.3 with $M_{\text{RB}}^{\text{PUSCH}}$ and $M_{\text{sc}}^{\text{PUSCH}}$ replaced by $M_{\text{RB}}^{\text{PSCCH}}$ and $M_{\text{sc}}^{\text{PSCCH}}$, respectively.

9.4.5 Precoding

Precoding shall be done according to clause 5.3.3A assuming a single antenna port, $\upsilon = 1$.

9.4.6 Mapping to physical resources

The block of complex-valued symbols $z(0),\ldots,z(M_{\text{symb}}^{\text{ap}}-1)$ shall be multiplied with the amplitude scaling factor β_{PSCCH} in order to conform to the transmit power P_{PSCCH} specified in [4], and mapped in sequence starting with $z(0)$ to physical resource blocks on antenna port p and assigned for transmission of PSCCH. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and not used for transmission of reference signals shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe. Resource elements in the last SC-FDFMA symbol within a subframe shall be counted in the mapping process but not transmitted.

9.5 Physical Sidelink Discovery Channel

9.5.1 Scrambling

The block of bits $b(0),\ldots,b(M_{\text{bit}}-1)$, where M_{bit} is the number of bits transmitted on the physical sidelink discovery channel in one subframe shall be scrambled according to clause 5.3.1.

The scrambling sequence generator shall be initialised with $c_{\text{init}} = 510$ at the start of each PSDCH subframe.

9.5.2 Modulation

Modulation shall be done according to clause 5.3.2. Table 9.5.2-1 specifies the modulation mappings applicable for the physical sidelink discovery channel.

Table 9.5.2-1: Sidelink modulation schemes

Physical channel	Modulation schemes
PSDCH	QPSK

9.5.3 Layer mapping

Layer mapping shall be done according to clause 5.3.2A assuming a single antenna port, $\upsilon = 1$.

9.5.4 Transform precoding

Transform precoding shall be done according to clause 5.3.3 with $M_{\text{RB}}^{\text{PUSCH}}$ and $M_{\text{sc}}^{\text{PUSCH}}$ replaced by $M_{\text{RB}}^{\text{PSDCH}}$ and $M_{\text{sc}}^{\text{PSDCH}}$, respectively.

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9.5.5 Precoding

Precoding shall be done according to clause 5.3.3A assuming a single antenna port, $\upsilon = 1$.

9.5.6 Mapping to physical resources

The block of complex-valued symbols $z(0),...,z(M_{\text{symb}}^{\text{ap}}-1)$ shall be multiplied with the amplitude scaling factor β_{PSDCH} in order to conform to the transmit power P_{PSDCH} specified in [4], and mapped in sequence starting with $z(0)$ to physical resource blocks on antenna port p and assigned for transmission of PSDCH. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and not used for transmission of reference signals shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe. Resource elements in the last SC-FDFMA symbol within a subframe shall be counted in the mapping process but not transmitted.

The set of physical resource blocks that shall be used are given by [4, clause 14.3.1].

9.6 Physical Sidelink Broadcast Channel

9.6.1 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}}-1)$, where M_{bit} is the number of bits transmitted on the physical sidelink broadcast channel in one subframe, shall be scrambled according to clause 5.3.1. The scrambling sequence generator shall be initialised at the start of every PSBCH subframe with $c_{\text{init}} = N_{\text{ID}}^{\text{SL}}$.

9.6.2 Modulation

Modulation shall be done according to clause 5.3.2. Table 9.6.2-1 specifies the modulation mappings applicable for the physical sidelink broadcast channel.

Table 9.6.2-1: PSBCH modulation schemes

Physical channel	Modulation schemes
PSBCH	QPSK

9.6.3 Layer mapping

Layer mapping shal be done according to clause 5.3.2A assuming a single antenna port, $\upsilon = 1$.

9.6.4 Transform precoding

Transform precoding shall be done according to clause 5.3.3 with $M_{\text{RB}}^{\text{PUSCH}}$ and $M_{\text{sc}}^{\text{PUSCH}}$ replaced by $M_{\text{RB}}^{\text{PSBCH}}$ and $M_{\text{sc}}^{\text{PSBCH}}$, respectively.

9.6.5 Precoding

Precoding shall be done according to clause 5.3.3A assuming a single antenna port, $\upsilon = 1$.

9.6.6 Mapping to physical resources

The block of complex-valued symbols $z(0),...,z(M_{\text{symb}}^{\text{ap}}-1)$ shall be multiplied with the amplitude scaling factor β_{PSBCH} in order to conform to the transmit power P_{PSBCH} specified in [4], and mapped in sequence starting with

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$z(0)$ to physical resource blocks on antenna port p. The PSBCH shall use the same set of resource blocks as the synchronization signal. The mapping to resource elements (k,l) corresponding to the physical resource blocks used for the PSBCH and not used for transmission of reference signals or synchronization signals shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe. The resource-element index k given by

$$k = k' - 36 + \frac{N_{\mathrm{RB}}^{\mathrm{SL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}, \quad k' = 0,1,\ldots,71$$

Resource elements in the last SC-FDMA symbol within a subframe should be counted in the mapping process but not transmitted.

9.7 Sidelink Synchronization Signals

A physical-layer sidelink synchronization identity is represented by $N_{\mathrm{ID}}^{\mathrm{SL}} \in \{0,1,\ldots,335\}$, divided into two sets id_net and id_oon consisting of identities $\{0,1,\ldots,167\}$ and $\{168,169,\ldots,335\}$, respectively.

9.7.1 Primary sidelink synchronization signal

The primary sidelink synchronization signal is transmitted in two adjacent SC-FDMA symbols in the same subframe.

9.7.1.1 Sequence generation

Each of the two sequences $d_i(0),\ldots,d_i(61), i = 1,2$ used for the primary sidelink synchronization signal in the two SC-FDMA symbols is given by clause 6.11.1.1 with root index $u = 26$ if $N_{\mathrm{ID}}^{\mathrm{SL}} \le 167$ and $u = 37$ otherwise.

9.7.1.2 Mapping to resource elements

The sequence $d_i(n)$ shall be multiplied with the amplitude scaling factor $\sqrt{72/62} \cdot \beta_{\mathrm{PSBCH}}$ and mapped to resource elements on antenna port 1020 in the first slot in the subframe according to

$$a_{k,l} = d_i(n), \qquad n = 0,\ldots,61$$

$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{SL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$

$$l = \begin{cases} 1,2 & \text{normal cyclic prefix} \\ 0,1 & \text{extended cyclic prefix} \end{cases}$$

9.7.2 Secondary sidelink synchronization signal

The secondary sidelink synchronization signal is transmitted in two adjacent SC-FDMA symbols in the same subframe.

9.7.2.1 Sequence generation

Each of the two sequences $d_i(0),\ldots,d_i(61), i = 1,2$ used for the secondary sidelink synchronization signal is given by clause 6.11.2.1 assuming subframe 0 with $N_{\mathrm{ID}}^{(1)} = N_{\mathrm{ID}}^{\mathrm{SL}} \bmod 168$ and $N_{\mathrm{ID}}^{(2)} = \left\lfloor N_{\mathrm{ID}}^{\mathrm{SL}} / 168 \right\rfloor$.

9.7.2.2 Mapping to resource elements

The sequence $d_i(n)$ shall be multiplied with the amplitude scaling factor β_{SSSS} in order to conform to the transmit power specified in clause 14.4 in 3GPP TS 36.213 [4] and mapped to resource elements on antenna port 1020 in the second slot in the subframe according to

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$$a_{k,l} = d_i(n), \qquad n = 0,\ldots,61$$
$$k = n - 31 + \frac{N_{RB}^{SL} N_{sc}^{RB}}{2}$$
$$l = \begin{cases} 4,5 & \text{normal cyclic prefix} \\ 3,4 & \text{extended cyclic prefix} \end{cases}$$

9.8 Demodulation reference signals

Demodulation reference signals associated with PSSCH, PSCCH, PSDCH, and PSBCH transmission shall be transmitted according to PUSCH in clause 5.5.2.1 with the following exceptions:

- The parameters in Tables 9.8-1 and 9.8-2 shall be used.
- The term PUSCH shall be replaced by PSSCH, PSCCH, PSDCH or PSBCH, depending on the physical channel to which the reference signal is associated.
- Antenna ports are given by Table 9.2-1.
- The set of physical resource blocks used in the mapping process shall be identical to the corresponding PSSCH/PSCCH/PSDCH/PSBCH transmission.
- The index k in the mapping process in clause 5.5.2.1.2 shall be identical to that for the corresponding PSSCH/PSCCH/PSDCH/PSBCH transmission.
- The pseudo-random sequence generator in clause 5.5.1.3 shall be initialized at the start of each slot fulfilling $n_{ss}^{PSSCH} = 0$

Table 9.8-1: Reference signal parameters for PSSCH and PSCCH.

Parameter in clause 5.5.2.1		PSSCH	PSCCH
Group hopping		enabled	disabled
	n_{ID}^{RS}	n_{ID}^{SA}	-
	n_s	n_{ss}^{PSSCH}	-
	f_{ss}	$n_{ID}^{SA} \bmod 30$	0
Sequence hopping		disabled	disabled
Cyclic shift	$n_{cs,\lambda}$	$\lfloor n_{ID}^{SA}/2 \rfloor \bmod 8$	0
Orthogonal sequence	$\left[w^{\lambda}(0) \quad w^{\lambda}(1)\right]$	$[+1 \quad +1]$ if $n_{ID}^{SA} \bmod 2 = 0$ $[+1 \quad -1]$ if $n_{ID}^{SA} \bmod 2 = 1$	$[+1 \quad +1]$
Reference signal length	M_{sc}^{RS}	M_{sc}^{PSSCH}	M_{sc}^{PSCCH}
Number of layers	υ	1	1
Number of antenna ports	P	1	1

Table 9.8-2: Reference signal parameters for PSDCH and PSBCH.

Parameter in clause 5.5.2.1		PSDCH	PSBCH
Group hopping		disabled	disabled
	f_{ss}	0	$\lfloor N_{ID}^{SL}/16 \rfloor \bmod 30$
Sequence hopping		disabled	disabled
Cyclic shift	$n_{cs,\lambda}$	0	$\lfloor N_{ID}^{SL}/2 \rfloor \bmod 8$
Orthogonal sequence	$\left[w^{\lambda}(0) \quad w^{\lambda}(1)\right]$	$[+1 \quad +1]$	$[+1 \quad +1]$ if $N_{ID}^{SL} \bmod 2 = 0$ $[+1 \quad -1]$ if $N_{ID}^{SL} \bmod 2 = 1$
Reference signal length	M_{sc}^{RS}	M_{sc}^{PSDCH}	M_{sc}^{PSBCH}
Number of layers	υ	1	1
Number of antenna ports	P	1	1

9.9 SC-FDMA baseband signal generation

The time-continuous signal $s_l^{(p)}(t)$ for antenna port p in SC-FDMA symbol l in a sidelink slot is defined by clause 5.6 with N_{RB}^{UL} replaced by N_{RB}^{SL}.

The cyclic prefix length for each sidelink channel or signal may differ from that configured for uplink transmissions.

9.10 Timing

Transmission of a sidelink radio frame number i from the UE shall start $(N_{TA,SL} + N_{TA\,offset}) \cdot T_s$ seconds before the start of the corresponding timing reference frame at the UE. The UE is not required to receive sidelink or downlink transmissions earlier than $624T_s$ after the end of a sidelink transmission.

For PSDCH transmission and sidelink synchronization signal transmission for PSDCH:

if the UE has a serving cell fulfilling the S criterion according to [10, clause 5.2.3.2]

- the timing of reference radio frame i equals that of downlink radio frame i of the cell c as given in Section 14.3.1 of [4] and
- $N_{TA\,offset}$ is given by clause 8.1,

otherwise

- the timing of reference radio frame i is implicitly obtained from [4] and
- $N_{TA\,offset} = 0$.

For all other sidelink transmissions:

if the UE has a serving cell fulfilling the S criterion according to [10, clause 5.2.3.2]

- the timing of reference radio frame i equals that of downlink radio frame i in the cell with the same uplink carrier frequency as the sidelink and
- $N_{TA\,offset}$ is given by clause 8.1,

otherwise

- the timing of reference radio frame i is implicitly obtained from [4] and
- $N_{TA\,offset} = 0$.

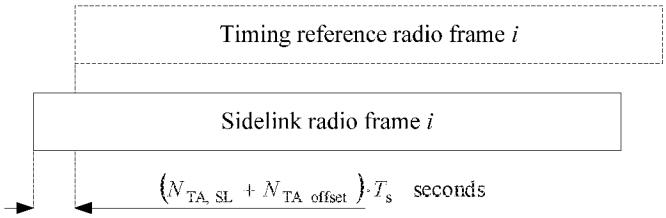


Figure 9.9-1: Sidelink timing relation.

The quantity $N_{TA,SL}$ differs between channels and signals according to

$$N_{TA,SL} = \begin{cases} N_{TA} & \text{for PSSCH in sidelink transmission mode 1} \\ 0 & \text{for all other cases} \end{cases}$$

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
2007-09-06	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

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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
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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

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Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
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
03/12/08	RP_42	RP-081074	105	1	Remaining Issues on SRS of TDD	8.4.0	8.5.0
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-090688	137	1	Clarification on DMRS sequence for PUSCH	8.7.0	8.8.0
15/09/09	RP_45	RP-090688	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	10.4.0	10.5.0

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Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
					for paging		
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
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
03/12/13	RP_62	RP-131896	184	3	Introduction of Rel 12 feature for Downlink MIMO Enhancement	11.5.0	12.0.0
03/03/14	RP_63	RP-140286	187	-	On PMCH starting symbol in an MBSFN subframe	12.0.0	12.1.0
10/06/14	RP_64	RP-140858	189	-	CR on antenna port definitions	12.1.0	12.2.0
10/06/14	RP_64	RP-140858	190	1	Clarification of downlink subframes	12.1.0	12.2.0
10/06/14	RP_64	RP-140862	191	-	Inclusion of eIMTA, TDD-FDD CA, and coverage enhancements	12.1.0	12.2.0
10/09/14	RP_65	RP-141485	192	-	Inclusion of low-cost MTC and 256QAM	12.2.0	12.3.0
10/09/14	RP_65	RP-141477	194	-	CR on port 5 UE-specific reference signal when PDSCH is overlapped with EPDCCH	12.2.0	12.3.0
08/12/14	RP_66	RP-142098	195	3	Clarification of PUSCH rate matching with SRS	12.3.0	12.4.0
08/12/14	RP_66	RP-142106	197	4	Inclusion of small-cell enhancements	12.3.0	12.4.0
09/03/15	RP_67	RP-150366	196	7	Inclusion of ProSe	12.4.0	12.5.0
09/03/15	RP_67	RP-150364	198	-	Correction on 256QAM applicability to PMCH	12.4.0	12.5.0
09/03/15	RP_67	RP-150364	199	-	Correction of discovery signal transmission	12.4.0	12.5.0
15/06/15	RP_68	RP-150935	201	-	Alignment of ProSe parameters	12.5.0	12.6.0
14/09/15	RP_69	RP-151465	203	-	Clarification on SRS BW configuration	12.6.0	12.7.0
07/12/15	RP_70	RP-152036	209	1	Modify max TA for dual connectivity	12.7.0	12.8.0
07/12/15	RP_70	RP-152025	206	2	Introduction of EB/FD-MIMO	12.8.0	13.0.0
07/12/15	RP_70	RP-152027	208	1	Introduction of Rel-13 eCA	12.8.0	13.0.0
07/12/15	RP_70	RP-152125	204	2	eD2D CR for 36.211	12.8.0	13.0.0
07/12/15	RP_70	RP-152258	205	4	Introduction of LAA	12.8.0	13.0.0

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Foreword

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1 Scope

The present document specifies the coding, multiplexing and mapping to physical channels for 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 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation".

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

[4] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".

[5] 3GPP TS36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification"

[6] 3GPP TS36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification"

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in [1].

Definition format

***<defined term>**: <definition>.*

3.2 Symbols

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

N_{RB}^{DL} Downlink bandwidth configuration, expressed in number of resource blocks [2]

N_{RB}^{UL} Uplink bandwidth configuration, expressed in number of resource blocks [2]

N_{RB}^{SL} Sidelink bandwidth configuration, expressed in number of resource blocks [2]

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N_{sc}^{RB}	Resource block size in the frequency domain, expressed as a number of subcarriers
N_{symb}^{PUSCH}	Number of SC-FDMA symbols carrying PUSCH in a subframe
$N_{symb}^{PUSCH-initial}$	Number of SC-FDMA symbols carrying PUSCH in the initial PUSCH transmission subframe
N_{symb}^{UL}	Number of SC-FDMA symbols in an uplink slot
N_{symb}^{SL}	Number of SC-FDMA symbols in a sidelink slot
N_{SRS}	Number of SC-FDMA symbols used for SRS transmission in a subframe (0 or 1).

3.3 Abbreviations

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

BCH	Broadcast channel
CFI	Control Format Indicator
CP	Cyclic Prefix
CSI	Channel State Information
DCI	Downlink Control Information
DL-SCH	Downlink Shared channel
EPDCCH	Enhanced Physical Downlink Control channel
FDD	Frequency Division Duplexing
HI	HARQ indicator
LAA	Licensed-Assisted Access
MCH	Multicast channel
PBCH	Physical Broadcast channel
PCFICH	Physical Control Format Indicator channel
PCH	Paging channel
PDCCH	Physical Downlink Control channel
PDSCH	Physical Downlink Shared channel
PHICH	Physical HARQ indicator channel
PMCH	Physical Multicast channel
PMI	Precoding Matrix Indicator
PRACH	Physical Random Access channel
PSBCH	Physical Sidelink Broadcast Channel
PSCCH	Physical Sidelink Control Channel
PSDCH	Physical Sidelink Discovery Channel
PSSCH	Physical Sidelink Shared Channel PUCCH Physical Uplink Control channel
PUSCH	Physical Uplink Shared channel
RACH	Random Access channel
RI	Rank Indication
SCI	Sidelink Control Information
SL-BCH	Sidelink Broadcast Channel
SL-DCH	Sidelink Discovery Channel
SL-SCH	Sidelink Shared Channel
SR	Scheduling Request
SRS	Sounding Reference Signal
TDD	Time Division Duplexing
TPMI	Transmitted Precoding Matrix Indicator
UCI	Uplink Control Information
UL-SCH	Uplink Shared channel

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4 Mapping to physical channels

4.1 Uplink

Table 4.1-1 specifies the mapping of the uplink transport channels to their corresponding physical channels. Table 4.1-2 specifies the mapping of the uplink control channel information to its corresponding physical channel.

Table 4.1-1

TrCH	Physical Channel
UL-SCH	PUSCH
RACH	PRACH

Table 4.1-2

Control information	Physical Channel
UCI	PUCCH, PUSCH

4.2 Downlink

Table 4.2-1 specifies the mapping of the downlink transport channels to their corresponding physical channels. Table 4.2-2 specifies the mapping of the downlink control channel information to its corresponding physical channel.

Table 4.2-1

TrCH	Physical Channel
DL-SCH	PDSCH
BCH	PBCH
PCH	PDSCH
MCH	PMCH

Table 4.2-2

Control information	Physical Channel
CFI	PCFICH
HI	PHICH
DCI	PDCCH, EPDCCH

4.3 Sidelink

Table 4.3-1 specifies the mapping of the sidelink transport channels to their corresponding physical channels. Table 4.3-2 specifies the mapping of the sidelink control information to its corresponding physical channel.

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Table 4.3-1

TrCH	Physical Channel
SL-SCH	PSSCH
SL-BCH	PSBCH
SL-DCH	PSDCH

Table 4.3-2

Control information	Physical Channel
SCI	PSCCH

5 Channel coding, multiplexing and interleaving

Data and control streams from/to MAC layer are encoded /decoded to offer transport and control services over the radio transmission link. Channel coding scheme is a combination of error detection, error correcting, rate matching, interleaving and transport channel or control information mapping onto/splitting from physical channels.

5.1 Generic procedures

This section contains coding procedures which are used for more than one transport channel or control information type.

5.1.1 CRC calculation

Denote the input bits to the CRC computation by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the size of the input sequence and L is the number of parity bits. The parity bits are generated by one of the following cyclic generator polynomials:

- $g_{CRC24A}(D) = [D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^7 + D^6 + D^5 + D^4 + D^3 + D + 1]$ and;
- $g_{CRC24B}(D) = [D^{24} + D^{23} + D^6 + D^5 + D + 1]$ for a CRC length $L = 24$ and;
- $g_{CRC16}(D) = [D^{16} + D^{12} + D^5 + 1]$ for a CRC length $L = 16$.
- $g_{CRC8}(D) = [D^8 + D^7 + D^4 + D^3 + D + 1]$ for a CRC length of $L = 8$.

The encoding is performed in a systematic form, which means that in GF(2), the polynomial:

$$a_0 D^{A+23} + a_1 D^{A+22} + ... + a_{A-1} D^{24} + p_0 D^{23} + p_1 D^{22} + ... + p_{22} D^1 + p_{23}$$

yields a remainder equal to 0 when divided by the corresponding length-24 CRC generator polynomial, $g_{CRC24A}(D)$ or $g_{CRC24B}(D)$, the polynomial:

$$a_0 D^{A+15} + a_1 D^{A+14} + ... + a_{A-1} D^{16} + p_0 D^{15} + p_1 D^{14} + ... + p_{14} D^1 + p_{15}$$

yields a remainder equal to 0 when divided by $g_{CRC16}(D)$, and the polynomial:

$$a_0 D^{A+7} + a_1 D^{A+6} + ... + a_{A-1} D^8 + p_0 D^7 + p_1 D^6 + ... + p_6 D^1 + p_7$$

yields a remainder equal to 0 when divided by $g_{CRC8}(D)$.

The bits after CRC attachment are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where $B = A + L$. The relation between a_k and b_k is:

$b_k = a_k$ for $k = 0, 1, 2, ..., A-1$

$b_k = p_{k-A}$ for $k = A, A+1, A+2, ..., A+L-1$.

5.1.2 Code block segmentation and code block CRC attachment

The input bit sequence to the code block segmentation is denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where $B > 0$. If B is larger than the maximum code block size Z, segmentation of the input bit sequence is performed and an additional CRC sequence of $L = 24$ bits is attached to each code block. The maximum code block size is:

- $Z = 6144$.

If the number of filler bits F calculated below is not 0, filler bits are added to the beginning of the first block.

Note that if $B < 40$, filler bits are added to the beginning of the code block.

The filler bits shall be set to $<NULL>$ at the input to the encoder.

Total number of code blocks C is determined by:

if $B \le Z$

$L = 0$

Number of code blocks: $C = 1$

$B' = B$

else

$L = 24$

Number of code blocks: $C = \lceil B/(Z-L) \rceil$.

$B' = B + C \cdot L$

end if

The bits output from code block segmentation, for $C \neq 0$, are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number, and K_r is the number of bits for the code block number r.

Number of bits in each code block (applicable for $C \neq 0$ only):

First segmentation size: K_+ = minimum K in table 5.1.3-3 such that $C \cdot K \ge B'$

if $C = 1$

the number of code blocks with length K_+ is $C_+ = 1$, $K_- = 0$, $C_- = 0$

else if $C > 1$

Second segmentation size: K_- = maximum K in table 5.1.3-3 such that $K < K_+$

$\Delta_K = K_+ - K_-$

Number of segments of size K_-: $C_- = \left\lfloor \frac{C \cdot K_+ - B'}{\Delta_K} \right\rfloor$.

Number of segments of size K_+: $C_+ = C - C_-$.

end if

Number of filler bits: $F = C_+ \cdot K_+ + C_- \cdot K_- - B'$

for $k = 0$ to F-1 -- Insertion of filler bits

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$c_{0k} = < NULL >$

end for

$k = F$

$s = 0$

for $r = 0$ to C-1

if $r < C_-$

$K_r = K_-$

else

$K_r = K_+$

end if

while $k < K_r - L$

$c_{rk} = b_s$

$k = k + 1$

$s = s + 1$

end while

if $C > 1$

The sequence $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r - L - 1)}$ is used to calculate the CRC parity bits $p_{r0}, p_{r1}, p_{r2}, ..., p_{r(L-1)}$ according to section 5.1.1 with the generator polynomial $g_{CRC24B}(D)$. For CRC calculation it is assumed that filler bits, if present, have the value 0.

while $k < K_r$

$c_{rk} = p_{r(k+L-K_r)}$

$k = k + 1$

end while

end if

$k = 0$

end for

5.1.3 Channel coding

The bit sequence input for a given code block to channel coding is denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits to encode. After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, where D is the number of encoded bits per output stream and i indexes the encoder output stream. The relation between c_k and $d_k^{(i)}$ and between K and D is dependent on the channel coding scheme.

The following channel coding schemes can be applied to TrCHs:

- tail biting convolutional coding;
- turbo coding.

Usage of coding scheme and coding rate for the different types of TrCH is shown in table 5.1.3-1. Usage of coding scheme and coding rate for the different control information types is shown in table 5.1.3-2.

The values of D in connection with each coding scheme:

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- tail biting convolutional coding with rate 1/3: $D = K$;
- turbo coding with rate 1/3: $D = K + 4$.

The range for the output stream index i is 0, 1 and 2 for both coding schemes.

Table 5.1.3-1: Usage of channel coding scheme and coding rate for TrCHs.

TrCH	Coding scheme	Coding rate
UL-SCH	Turbo coding	1/3
DL-SCH		
PCH		
MCH		
SL-SCH		
SL-DCH		
BCH	Tail biting convolutional coding	1/3
SL-BCH		

Table 5.1.3-2: Usage of channel coding scheme and coding rate for control information.

Control Information	Coding scheme	Coding rate
DCI	Tail biting convolutional coding	1/3
CFI	Block code	1/16
HI	Repetition code	1/3
UCI	Block code	variable
	Tail biting convolutional coding	1/3
SCI	Tail biting convolutional coding	1/3

5.1.3.1 Tail biting convolutional coding

A tail biting convolutional code with constraint length 7 and coding rate 1/3 is defined.

The configuration of the convolutional encoder is presented in figure 5.1.3-1.

The initial value of the shift register of the encoder shall be set to the values corresponding to the last 6 information bits in the input stream so that the initial and final states of the shift register are the same. Therefore, denoting the shift register of the encoder by $s_0, s_1, s_2, ..., s_5$, then the initial value of the shift register shall be set to

$$s_i = c_{(K-1-i)}$$

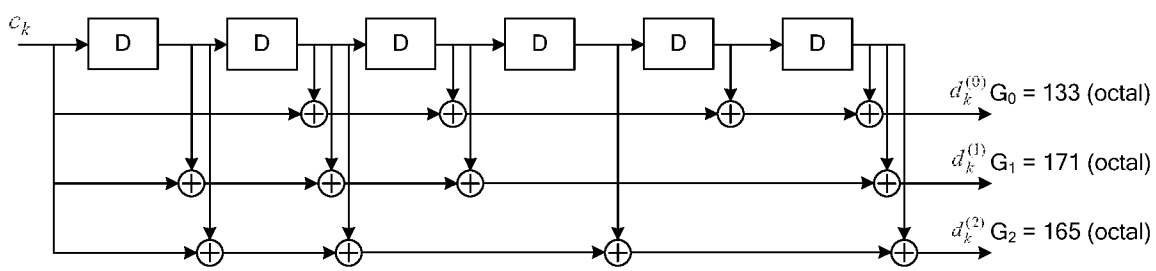


Figure 5.1.3-1: Rate 1/3 tail biting convolutional encoder.

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The encoder output streams $d_k^{(0)}$, $d_k^{(1)}$ and $d_k^{(2)}$ correspond to the first, second and third parity streams, respectively as shown in Figure 5.1.3-1.

5.1.3.2 Turbo coding

5.1.3.2.1 Turbo encoder

The scheme of turbo encoder is a Parallel Concatenated Convolutional Code (PCCC) with two 8-state constituent encoders and one turbo code internal interleaver. The coding rate of turbo encoder is 1/3. The structure of turbo encoder is illustrated in figure 5.1.3-2.

The transfer function of the 8-state constituent code for the PCCC is:

$$G(D) = \left[1, \frac{g_1(D)}{g_0(D)}\right],$$

where

$$g_0(D) = 1 + D^2 + D^3,$$

$$g_1(D) = 1 + D + D^3.$$

The initial value of the shift registers of the 8-state constituent encoders shall be all zeros when starting to encode the input bits.

The output from the turbo encoder is

$$d_k^{(0)} = x_k$$

$$d_k^{(1)} = z_k$$

$$d_k^{(2)} = z'_k$$

for $k = 0,1,2,\ldots, K-1$.

If the code block to be encoded is the 0-th code block and the number of filler bits is greater than zero, i.e., $F > 0$, then the encoder shall set $c_k = 0$, $k = 0,\ldots,(F\text{-}1)$ at its input and shall set $d_k^{(0)} = < NULL >$, $k = 0,\ldots,(F\text{-}1)$ and $d_k^{(1)} = < NULL >$, $k = 0,\ldots,(F\text{-}1)$ at its output.

The bits input to the turbo encoder are denoted by $c_0, c_1, c_2, c_3, \ldots, c_{K-1}$, and the bits output from the first and second 8-state constituent encoders are denoted by $z_0, z_1, z_2, z_3, \ldots, z_{K-1}$ and $z'_0, z'_1, z'_2, z'_3, \ldots, z'_{K-1}$, respectively. The bits output from the turbo code internal interleaver are denoted by $c'_0, c'_1, \ldots, c'_{K-1}$, and these bits are to be the input to the second 8-state constituent encoder.

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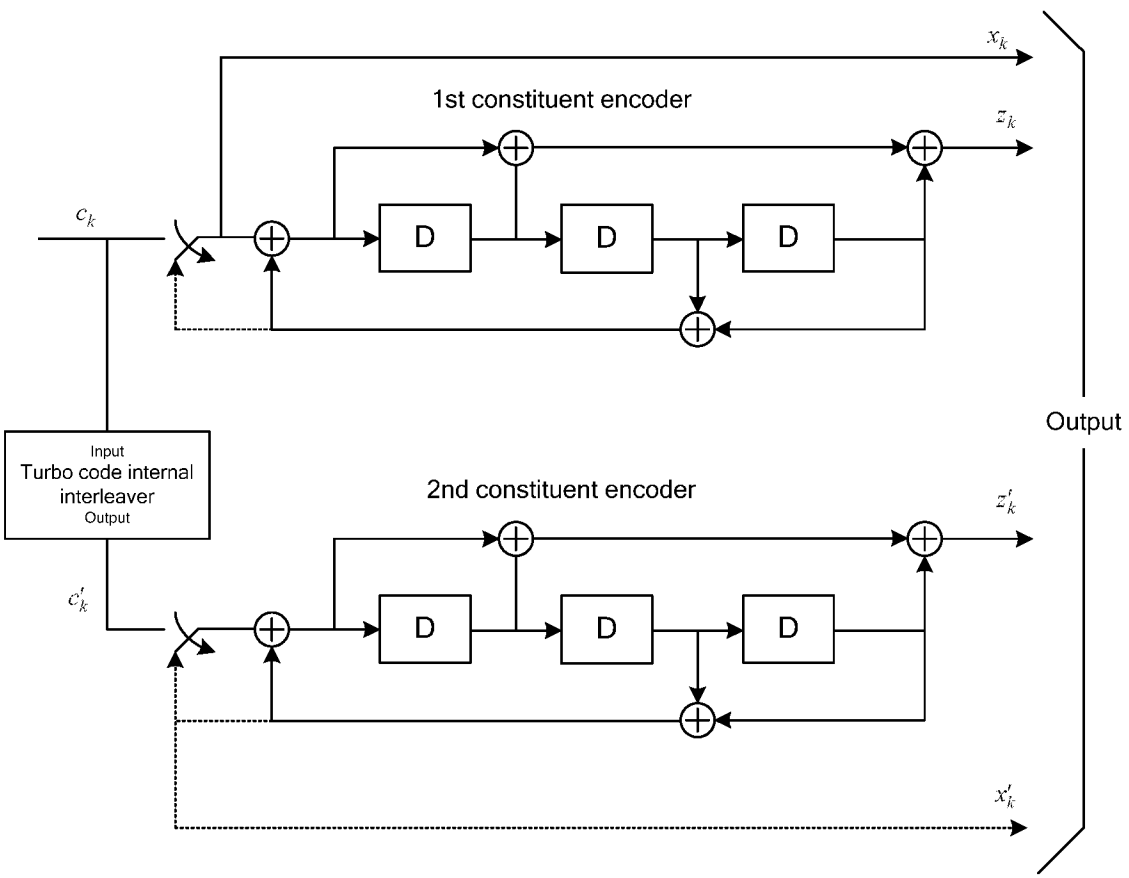


Figure 5.1.3-2: Structure of rate 1/3 turbo encoder (dotted lines apply for trellis termination only).

5.1.3.2.2 Trellis termination for turbo encoder

Trellis termination is performed by taking the tail bits from the shift register feedback after all information bits are encoded. Tail bits are padded after the encoding of information bits.

The first three tail bits shall be used to terminate the first constituent encoder (upper switch of figure 5.1.3-2 in lower position) while the second constituent encoder is disabled. The last three tail bits shall be used to terminate the second constituent encoder (lower switch of figure 5.1.3-2 in lower position) while the first constituent encoder is disabled.

The transmitted bits for trellis termination shall then be:

$$d_K^{(0)} = x_K,\ d_{K+1}^{(0)} = z_{K+1},\ d_{K+2}^{(0)} = x'_K,\ d_{K+3}^{(0)} = z'_{K+1}$$

$$d_K^{(1)} = z_K,\ d_{K+1}^{(1)} = x_{K+2},\ d_{K+2}^{(1)} = z'_K,\ d_{K+3}^{(1)} = x'_{K+2}$$

$$d_K^{(2)} = x_{K+1},\ d_{K+1}^{(2)} = z_{K+2},\ d_{K+2}^{(2)} = x'_{K+1},\ d_{K+3}^{(2)} = z'_{K+2}$$

5.1.3.2.3 Turbo code internal interleaver

The bits input to the turbo code internal interleaver are denoted by $c_0, c_1, ..., c_{K-1}$, where K is the number of input bits. The bits output from the turbo code internal interleaver are denoted by $c'_0, c'_1, ..., c'_{K-1}$.

The relationship between the input and output bits is as follows:

$c'_i = c_{\Pi(i)}$, i=0, 1,…, (K-1)

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where the relationship between the output index i and the input index $\Pi(i)$ satisfies the following quadratic form:

$$\Pi(i) = \left(f_1 \cdot i + f_2 \cdot i^2\right) \bmod K$$

The parameters f_1 and f_2 depend on the block size K and are summarized in Table 5.1.3-3.

Table 5.1.3-3: Turbo code internal interleaver parameters.

i	K	f_1	f_2	i	K	f_1	f_2	i	K	f_1	f_2	i	K	f_1	f_2
1	40	3	10	48	416	25	52	95	1120	67	140	142	3200	111	240
2	48	7	12	49	424	51	106	96	1152	35	72	143	3264	443	204
3	56	19	42	50	432	47	72	97	1184	19	74	144	3328	51	104
4	64	7	16	51	440	91	110	98	1216	39	76	145	3392	51	212
5	72	7	18	52	448	29	168	99	1248	19	78	146	3456	451	192
6	80	11	20	53	456	29	114	100	1280	199	240	147	3520	257	220
7	88	5	22	54	464	247	58	101	1312	21	82	148	3584	57	336
8	96	11	24	55	472	29	118	102	1344	211	252	149	3648	313	228
9	104	7	26	56	480	89	180	103	1376	21	86	150	3712	271	232
10	112	41	84	57	488	91	122	104	1408	43	88	151	3776	179	236
11	120	103	90	58	496	157	62	105	1440	149	60	152	3840	331	120
12	128	15	32	59	504	55	84	106	1472	45	92	153	3904	363	244
13	136	9	34	60	512	31	64	107	1504	49	846	154	3968	375	248
14	144	17	108	61	528	17	66	108	1536	71	48	155	4032	127	168
15	152	9	38	62	544	35	68	109	1568	13	28	156	4096	31	64
16	160	21	120	63	560	227	420	110	1600	17	80	157	4160	33	130
17	168	101	84	64	576	65	96	111	1632	25	102	158	4224	43	264
18	176	21	44	65	592	19	74	112	1664	183	104	159	4288	33	134
19	184	57	46	66	608	37	76	113	1696	55	954	160	4352	477	408
20	192	23	48	67	624	41	234	114	1728	127	96	161	4416	35	138
21	200	13	50	68	640	39	80	115	1760	27	110	162	4480	233	280
22	208	27	52	69	656	185	82	116	1792	29	112	163	4544	357	142
23	216	11	36	70	672	43	252	117	1824	29	114	164	4608	337	480
24	224	27	56	71	688	21	86	118	1856	57	116	165	4672	37	146
25	232	85	58	72	704	155	44	119	1888	45	354	166	4736	71	444
26	240	29	60	73	720	79	120	120	1920	31	120	167	4800	71	120
27	248	33	62	74	736	139	92	121	1952	59	610	168	4864	37	152
28	256	15	32	75	752	23	94	122	1984	185	124	169	4928	39	462
29	264	17	198	76	768	217	48	123	2016	113	420	170	4992	127	234
30	272	33	68	77	784	25	98	124	2048	31	64	171	5056	39	158
31	280	103	210	78	800	17	80	125	2112	17	66	172	5120	39	80
32	288	19	36	79	816	127	102	126	2176	171	136	173	5184	31	96
33	296	19	74	80	832	25	52	127	2240	209	420	174	5248	113	902
34	304	37	76	81	848	239	106	128	2304	253	216	175	5312	41	166
35	312	19	78	82	864	17	48	129	2368	367	444	176	5376	251	336
36	320	21	120	83	880	137	110	130	2432	265	456	177	5440	43	170
37	328	21	82	84	896	215	112	131	2496	181	468	178	5504	21	86
38	336	115	84	85	912	29	114	132	2560	39	80	179	5568	43	174
39	344	193	86	86	928	15	58	133	2624	27	164	180	5632	45	176
40	352	21	44	87	944	147	118	134	2688	127	504	181	5696	45	178
41	360	133	90	88	960	29	60	135	2752	143	172	182	5760	161	120
42	368	81	46	89	976	59	122	136	2816	43	88	183	5824	89	182
43	376	45	94	90	992	65	124	137	2880	29	300	184	5888	323	184
44	384	23	48	91	1008	55	84	138	2944	45	92	185	5952	47	186
45	392	243	98	92	1024	31	64	139	3008	157	188	186	6016	23	94
46	400	151	40	93	1056	17	66	140	3072	47	96	187	6080	47	190
47	408	155	102	94	1088	171	204	141	3136	13	28	188	6144	263	480

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5.1.4 Rate matching

5.1.4.1 Rate matching for turbo coded transport channels

The rate matching for turbo coded transport channels is defined per coded block and consists of interleaving the three information bit streams $d_k^{(0)}$, $d_k^{(1)}$ and $d_k^{(2)}$, followed by the collection of bits and the generation of a circular buffer as depicted in Figure 5.1.4-1. The output bits for each code block are transmitted as described in section 5.1.4.1.2.

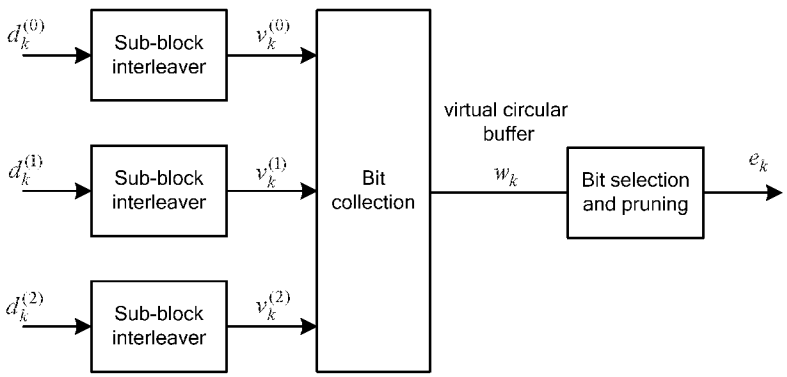


Figure 5.1.4-1. Rate matching for turbo coded transport channels.

The bit stream $d_k^{(0)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.1.1 with an output sequence defined as $v_0^{(0)}, v_1^{(0)}, v_2^{(0)}, ..., v_{K_\Pi-1}^{(0)}$ and where K_Π is defined in section 5.1.4.1.1.

The bit stream $d_k^{(1)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.1.1 with an output sequence defined as $v_0^{(1)}, v_1^{(1)}, v_2^{(1)}, ..., v_{K_\Pi-1}^{(1)}$.

The bit stream $d_k^{(2)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.1.1 with an output sequence defined as $v_0^{(2)}, v_1^{(2)}, v_2^{(2)}, ..., v_{K_\Pi-1}^{(2)}$.

The sequence of bits e_k for transmission is generated according to section 5.1.4.1.2.

5.1.4.1.1 Sub-block interleaver

The bits input to the block interleaver are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, ..., d_{D-1}^{(i)}$, where D is the number of bits. The output bit sequence from the block interleaver is derived as follows:

(1) Assign $C_{subblock}^{TC} = 32$ to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2,..., $C_{subblock}^{TC} - 1$ from left to right.

(2) Determine the number of rows of the matrix $R_{subblock}^{TC}$, by finding minimum integer $R_{subblock}^{TC}$ such that:

$$D \le \left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right)$$

The rows of rectangular matrix are numbered 0, 1, 2,..., $R_{subblock}^{TC} - 1$ from top to bottom.

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(3) If $\left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right) > D$, then $N_D = \left(R_{subblock}^{TC} \times C_{subblock}^{TC} - D\right)$ dummy bits are padded such that $y_k = <NULL>$ for $k = 0, 1, \ldots, N_D - 1$. Then, $y_{N_D+k} = d_k^{(i)}$, $k = 0, 1, \ldots, D-1$, and the bit sequence y_k is written into the $\left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right)$ matrix row by row starting with bit y_0 in column 0 of row 0:

$$\begin{bmatrix} y_0 & y_1 & y_2 & \cdots & y_{C_{subblock}^{TC}-1} \\ y_{C_{subblock}^{TC}} & y_{C_{subblock}^{TC}+1} & y_{C_{subblock}^{TC}+2} & \cdots & y_{2C_{subblock}^{TC}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} & y_{(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}+1} & y_{(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}+2} & \cdots & y_{(R_{subblock}^{TC}\times C_{subblock}^{TC}-1)} \end{bmatrix}$$

For $d_k^{(0)}$ and $d_k^{(1)}$:

(4) Perform the inter-column permutation for the matrix based on the pattern $\left\langle P(j)\right\rangle_{j\in\{0,1,\ldots,C_{subblock}^{TC}-1\}}$ that is shown in table 5.1.4-1, where P(j) is the original column position of the j-th permuted column. After permutation of the columns, the inter-column permuted $\left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right)$ matrix is equal to

$$\begin{bmatrix} y_{P(0)} & y_{P(1)} & y_{P(2)} & \cdots & y_{P(C_{subblock}^{TC}-1)} \\ y_{P(0)+C_{subblock}^{TC}} & y_{P(1)+C_{subblock}^{TC}} & y_{P(2)+C_{subblock}^{TC}} & \cdots & y_{P(C_{subblock}^{TC}-1)+C_{subblock}^{TC}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{P(0)+(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} & y_{P(1)+(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} & y_{P(2)+(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} & \cdots & y_{P(C_{subblock}^{TC}-1)+(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} \end{bmatrix}$$

(5) The output of the block interleaver is the bit sequence read out column by column from the inter-column permuted $\left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right)$ matrix. The bits after sub-block interleaving are denoted by $v_0^{(i)}, v_1^{(i)}, v_2^{(i)}, \ldots, v_{K_\Pi-1}^{(i)}$, where $v_0^{(i)}$ corresponds to $y_{P(0)}$, $v_1^{(i)}$ to $y_{P(0)+C_{subblock}^{TC}}$ ... and $K_\Pi = \left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right)$.

For $d_k^{(2)}$:

(4) The output of the sub-block interleaver is denoted by $v_0^{(2)}, v_1^{(2)}, v_2^{(2)}, \ldots, v_{K_\Pi-1}^{(2)}$, where $v_k^{(2)} = y_{\pi(k)}$ and where

$$\pi(k) = \left(P\left(\left\lfloor \frac{k}{R_{subblock}^{TC}} \right\rfloor\right) + C_{subblock}^{TC} \times \left(k \bmod R_{subblock}^{TC}\right) + 1\right) \bmod K_\Pi$$

The permutation function P is defined in Table 5.1.4-1.

Table 5.1.4-1 Inter-column permutation pattern for sub-block interleaver.

Number of columns $C_{subblock}^{TC}$	Inter-column permutation pattern $<P(0), P(1), \ldots, P(C_{subblock}^{TC}-1)>$
32	< 0, 16, 8, 24, 4, 20, 12, 28, 2, 18, 10, 26, 6, 22, 14, 30, 1, 17, 9, 25, 5, 21, 13, 29, 3, 19, 11, 27, 7, 23, 15, 31 >

5.1.4.1.2 Bit collection, selection and transmission

The circular buffer of length $K_w = 3K_\Pi$ for the r-th coded block is generated as follows:

$w_k = v_k^{(0)}$ for $k = 0, \ldots, K_\Pi - 1$

$w_{K_\Pi+2k} = v_k^{(1)}$ for $k = 0, \ldots, K_\Pi - 1$

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$$w_{K_\Pi+2k+1} = v_k^{(2)} \quad \text{for } k = 0, \ldots, K_\Pi - 1$$

Denote the soft buffer size for the transport block by N_{IR} bits and the soft buffer size for the r-th code block by N_{cb} bits. The size N_{cb} is obtained as follows, where C is the number of code blocks computed in section 5.1.2:

- $N_{cb} = \min\left(\left\lfloor \frac{N_{IR}}{C} \right\rfloor, K_w\right)$ for DL-SCH and PCH transport channels

- $N_{cb} = K_w$ for UL-SCH, MCH, SL-SCH and SL-DCH transport channels

For UE category 0, for DL-SCH associated with SI-RNTI and RA-RNTI and PCH transport channel, N_{cb} is always equal to K_w.

where N_{IR} is equal to:

$$N_{IR} = \left\lfloor \frac{N_{soft}}{K_C \cdot K_{MIMO} \cdot \min\left(M_{DL\_HARQ}, M_{limit}\right)} \right\rfloor$$

where:

If the UE signals *ue-CategoryDL-r12* indicating UE category 0, or if the UE signals *ue-CategoryDL-r12* indicating UE category 14 and is configured by higher layers with *altCQI-Table-r12* for the DL cell, N_{soft} is the total number of soft channel bits according to the UE category indicated by *ue-CategoryDL-r12*. Otherwise, if the UE signals *ue-Category-v11a0*, and is configured by higher layers with *altCQI-Table-r12* for the DL cell, N_{soft} is the total number of soft channel bits according to the UE category indicated by *ue-Category-v11a0*. Otherwise, if the UE signals *ue-Category-v1020*, and is configured with transmission mode 9 or transmission mode 10, or is configured with transmission mode 3 or transmission mode 4 and the higher layer parameter *maxLayersMIMO-r10* is configured to fourLayers, for the DL cell, N_{soft} is the total number of soft channel bits [4] according to the UE category indicated by *ue-Category-v1020* [6]. Otherwise, N_{soft} is the total number of soft channel bits [4] according to the UE category indicated by *ue-Category* (without suffix) [6].

If $N_{soft} = 35982720$ or 47431680,

$K_C = 5$,

elseif $N_{soft} = 7308288$ and the UE is configured by higher layers with *altCQI-Table-r12*,

if the UE is capable of supporting no more than a maximum of two spatial layers for the DL cell in the transmission mode configured for the UE, or if the configured maximum number of layers indicated by the *maxLayersMIMO-r10* field is no more than two,

$K_C = 3$

else

$K_C = 3/2$

end if.

elseif $N_{soft} = 3654144$ and the UE is capable of supporting no more than a maximum of two spatial layers for the DL cell, or if the configured maximum number of layers indicated by the *maxLayersMIMO-r10* field is no more than two,

$K_C = 2$

else

$K_C = 1$

End if.

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K_{MIMO} is equal to 2 if the UE is configured to receive PDSCH transmissions based on transmission modes 3, 4, 8, 9 or 10 as defined in section 7.1 of [3], and is equal to 1 otherwise.

M_{DL_HARQ} is the maximum number of DL HARQ processes as defined in section 7 of [3].

M_{limit} is a constant equal to 8.

Denoting by E the rate matching output sequence length for the r-th coded block, and rv_{idx} the redundancy version number for this transmission (rv_{idx} = 0, 1, 2 or 3), the rate matching output bit sequence is e_k, $k = 0,1,\ldots, E-1$.

Define by G the total number of bits available for the transmission of one transport block.

Set $G' = G/(N_L \cdot Q_m)$ where Q_m is equal to 2 for QPSK, 4 for 16QAM, 6 for 64QAM and 8 for 256QAM, and where

- For transmit diversity:
  - N_L is equal to 2,
- Otherwise:
  - N_L is equal to the number of layers a transport block is mapped onto

Set $\gamma = G' \bmod C$, where C is the number of code blocks computed in section 5.1.2.

if $r \le C - \gamma - 1$

set $E = N_L \cdot Q_m \cdot \lfloor G'/C \rfloor$

else

set $E = N_L \cdot Q_m \cdot \lceil G'/C \rceil$

end if

Set $k_0 = R^{TC}_{subblock} \cdot \left(2 \cdot \left\lceil \frac{N_{cb}}{8R^{TC}_{subblock}} \right\rceil \cdot rv_{idx} + 2 \right)$, where $R^{TC}_{subblock}$ is the number of rows defined in section 5.1.4.1.1.

Set $k = 0$ and $j = 0$

while { $k < E$ }

if $w_{(k_0+j) \bmod N_{cb}} \neq <NULL>$

$e_k = w_{(k_0+j) \bmod N_{cb}}$

$k = k + 1$

end if

$j = j + 1$

end while

5.1.4.2 Rate matching for convolutionally coded transport channels and control information

The rate matching for convolutionally coded transport channels and control information consists of interleaving the three bit streams, $d^{(0)}_k$, $d^{(1)}_k$ and $d^{(2)}_k$, followed by the collection of bits and the generation of a circular buffer as depicted in Figure 5.1.4-2. The output bits are transmitted as described in section 5.1.4.2.2.

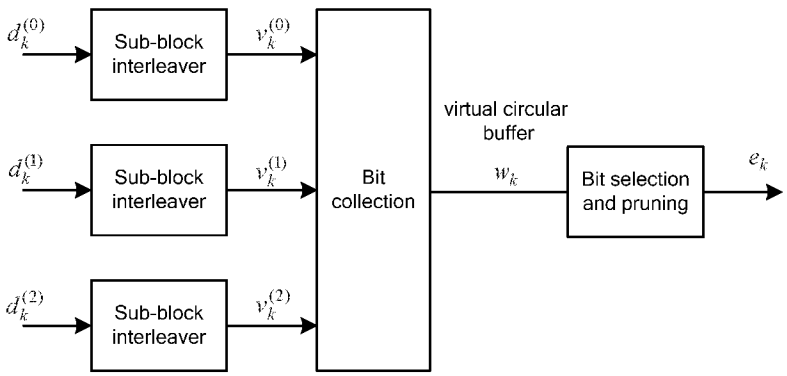


Figure 5.1.4-2. Rate matching for convolutionally coded transport channels and control information.

The bit stream $d_k^{(0)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.2.1 with an output sequence defined as $v_0^{(0)}, v_1^{(0)}, v_2^{(0)}, ..., v_{K_\Pi-1}^{(0)}$ and where K_Π is defined in section 5.1.4.2.1.

The bit stream $d_k^{(1)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.2.1 with an output sequence defined as $v_0^{(1)}, v_1^{(1)}, v_2^{(1)}, ..., v_{K_\Pi-1}^{(1)}$.

The bit stream $d_k^{(2)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.2.1 with an output sequence defined as $v_0^{(2)}, v_1^{(2)}, v_2^{(2)}, ..., v_{K_\Pi-1}^{(2)}$.

The sequence of bits e_k for transmission is generated according to section 5.1.4.2.2.

5.1.4.2.1 Sub-block interleaver

The bits input to the block interleaver are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, ..., d_{D-1}^{(i)}$, where D is the number of bits. The output bit sequence from the block interleaver is derived as follows:

(1) Assign $C_{subblock}^{CC} = 32$ to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2,…, $C_{subblock}^{CC} - 1$ from left to right.

(2) Determine the number of rows of the matrix $R_{subblock}^{CC}$, by finding minimum integer $R_{subblock}^{CC}$ such that:

$$D \le \left(R_{subblock}^{CC} \times C_{subblock}^{CC}\right)$$

The rows of rectangular matrix are numbered 0, 1, 2,…, $R_{subblock}^{CC} - 1$ from top to bottom.

(3) If $\left(R_{subblock}^{CC} \times C_{subblock}^{CC}\right) > D$, then $N_D = \left(R_{subblock}^{CC} \times C_{subblock}^{CC} - D\right)$ dummy bits are padded such that $y_k = <NULL>$ for $k = 0, 1, ..., N_D - 1$. Then, $y_{N_D+k} = d_k^{(i)}$, $k = 0, 1, ..., D-1$, and the bit sequence y_k is written into the $\left(R_{subblock}^{CC} \times C_{subblock}^{CC}\right)$ matrix row by row starting with bit y_0 in column 0 of row 0:

$$\begin{bmatrix} y_0 & y_1 & y_2 & \cdots & y_{C_{subblock}^{CC}-1} \\ y_{C_{subblock}^{CC}} & y_{C_{subblock}^{CC}+1} & y_{C_{subblock}^{CC}+2} & \cdots & y_{2C_{subblock}^{CC}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{(R_{subblock}^{CC}-1)\times C_{subblock}^{CC}} & y_{(R_{subblock}^{CC}-1)\times C_{subblock}^{CC}+1} & y_{(R_{subblock}^{CC}-1)\times C_{subblock}^{CC}+2} & \cdots & y_{(R_{subblock}^{CC}\times C_{subblock}^{CC}-1)} \end{bmatrix}$$

(4) Perform the inter-column permutation for the matrix based on the pattern $\left\langle P(j)\right\rangle_{j\in\left\{0,1,\ldots,C^{CC}_{subblock}-1\right\}}$ that is shown in table 5.1.4-2, where P(j) is the original column position of the j-th permuted column. After permutation of the columns, the inter-column permuted $\left(R^{CC}_{subblock}\times C^{CC}_{subblock}\right)$ matrix is equal to

$$\begin{bmatrix} y_{P(0)} & y_{P(1)} & y_{P(2)} & \cdots & y_{P(C^{CC}_{subblock}-1)} \\ y_{P(0)+C^{CC}_{subblock}} & y_{P(1)+C^{CC}_{subblock}} & y_{P(2)+C^{CC}_{subblock}} & \cdots & y_{P(C^{CC}_{subblock}-1)+C^{CC}_{subblock}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{P(0)+(R^{CC}_{subblock}-1)\times C^{CC}_{subblock}} & y_{P(1)+(R^{CC}_{subblock}-1)\times C^{CC}_{subblock}} & y_{P(2)+(R^{CC}_{subblock}-1)\times C^{CC}_{subblock}} & \cdots & y_{P(C^{CC}_{subblock}-1)+(R^{CC}_{subblock}-1)\times C^{CC}_{subblock}} \end{bmatrix}$$

(5) The output of the block interleaver is the bit sequence read out column by column from the inter-column permuted $\left(R^{CC}_{subblock}\times C^{CC}_{subblock}\right)$ matrix. The bits after sub-block interleaving are denoted by $v^{(i)}_0, v^{(i)}_1, v^{(i)}_2, \ldots, v^{(i)}_{K_\Pi-1}$, where $v^{(i)}_0$ corresponds to $y_{P(0)}$, $v^{(i)}_1$ to $y_{P(0)+C^{CC}_{subblock}}$ ... and $K_\Pi=\left(R^{CC}_{subblock}\times C^{CC}_{subblock}\right)$

Table 5.1.4-2 Inter-column permutation pattern for sub-block interleaver.

Number of columns $C^{CC}_{subblock}$	Inter-column permutation pattern $<P(0), P(1), \ldots, P(C^{CC}_{subblock}-1)>$
32	< 1, 17, 9, 25, 5, 21, 13, 29, 3, 19, 11, 27, 7, 23, 15, 31, 0, 16, 8, 24, 4, 20, 12, 28, 2, 18, 10, 26, 6, 22, 14, 30 >

This block interleaver is also used in interleaving PDCCH modulation symbols. In that case, the input bit sequence consists of PDCCH symbol quadruplets [2].

5.1.4.2.2 Bit collection, selection and transmission

The circular buffer of length $K_w=3K_\Pi$ is generated as follows:

$w_k=v^{(0)}_k$ for $k=0,\ldots,K_\Pi-1$

$w_{K_\Pi+k}=v^{(1)}_k$ for $k=0,\ldots,K_\Pi-1$

$w_{2K_\Pi+k}=v^{(2)}_k$ for $k=0,\ldots,K_\Pi-1$

Denoting by E the rate matching output sequence length, the rate matching output bit sequence is e_k, $k=0,1,\ldots,E-1$.

Set $k=0$ and $j=0$

while { $k<E$ }

if $w_{j \bmod K_w} \neq <NULL>$

$e_k=w_{j \bmod K_w}$

$k=k+1$

end if

$j=j+1$

end while

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5.1.5 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences e_{rk}, for $r = 0,..., C-1$ and $k = 0,..., E_r - 1$. The output bit sequence from the code block concatenation block is the sequence f_k for $k = 0,..., G-1$.

The code block concatenation consists of sequentially concatenating the rate matching outputs for the different code blocks. Therefore,

Set $k = 0$ and $r = 0$

while $r < C$

Set $j = 0$

while $j < E_r$

$f_k = e_{rj}$

$k = k + 1$

$j = j + 1$

end while

$r = r + 1$

end while

5.2 Uplink transport channels and control information

If the UE is configured with a Master Cell Group (MCG) and Secondary Cell Group (SCG) [6], the procedures described in this clause are applied to the MCG and SCG, respectively. When the procedures are applied to a SCG, the term primary cell refers to the primary SCell (PSCell) of the SCG.

If the UE is configured with a PUCCH SCell [6], the procedures described in this clause are applied to the group of DL cells associated with the primary cell and the group of DL cells associated with the PUCCH SCell, respectively. When the procedures are applied to the group of DL cells associated with the PUCCH SCell, the term primary cell refers to the PUCCH SCell.

If the UE is configured with a LAA SCell, the procedures described in this clause are applied assuming the LAA SCell is an FDD SCell.

5.2.1 Random access channel

The sequence index for the random access channel is received from higher layers and is processed according to [2].

5.2.2 Uplink shared channel

Figure 5.2.2-1 shows the processing structure for the UL-SCH transport channel on one UL cell. Data arrives to the coding unit in the form of a maximum of two transport blocks every transmission time interval (TTI) per UL cell. The following coding steps can be identified for each transport block of an UL cell:

- Add CRC to the transport block
- Code block segmentation and code block CRC attachment
- Channel coding of data and control information
- Rate matching

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- Code block concatenation
- Multiplexing of data and control information
- Channel interleaver

The coding steps for one UL-SCH transport block are shown in the figure below. The same general processing applies for each UL-SCH transport block on each UL cell with restrictions as specified in [3].

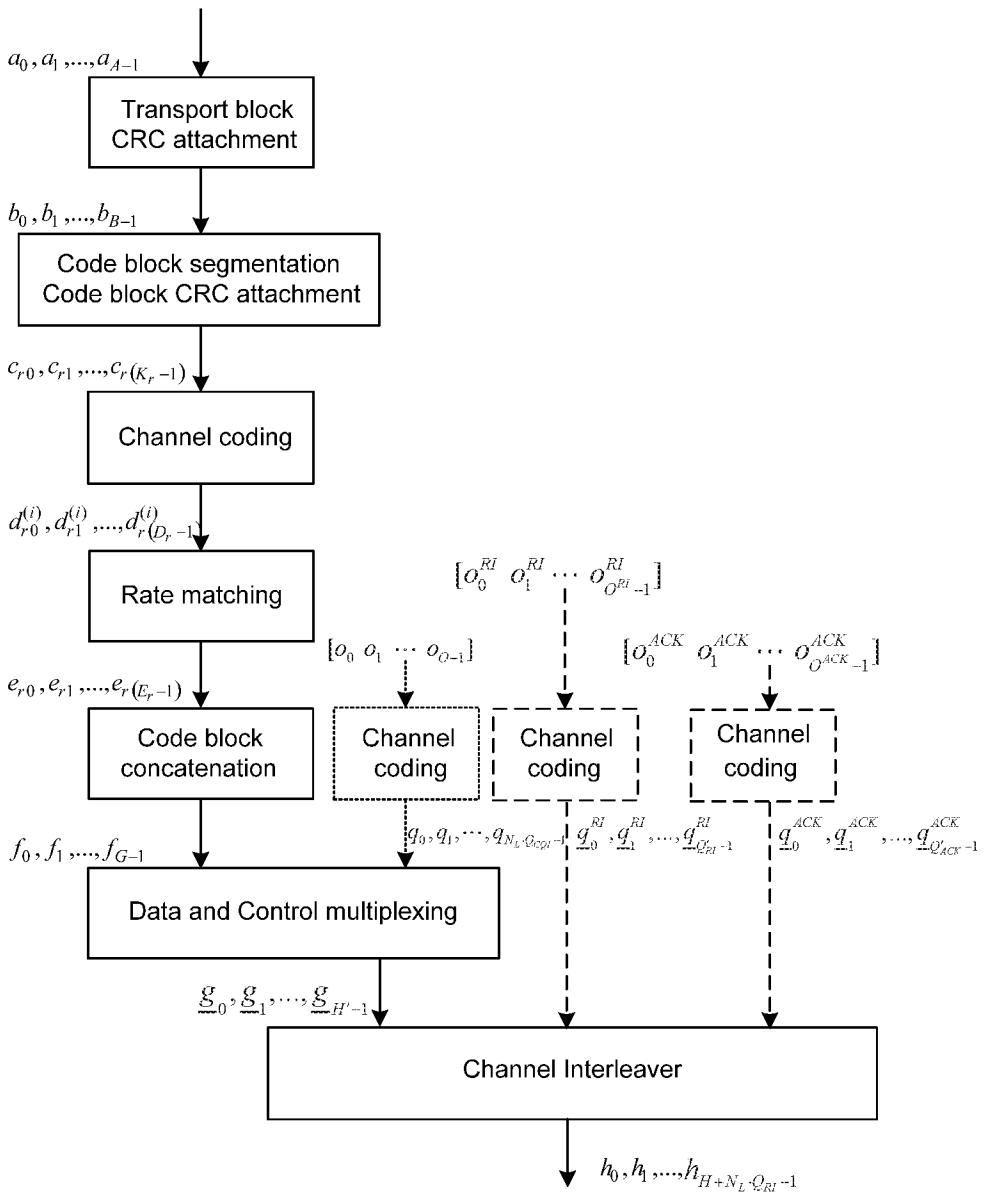


Figure 5.2.2-1: Transport block processing for UL-SCH.

5.2.2.1 Transport block CRC attachment

Error detection is provided on each UL-SCH transport block through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the size of the transport block and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in section 6.1.1 of [5].

The parity bits are computed and attached to the UL-SCH transport block according to section 5.1.1 setting L to 24 bits and using the generator polynomial $g_{CRC24A}(D)$.

5.2.2.2 Code block segmentation and code block CRC attachment

The bits input to the code block segmentation are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where B is the number of bits in the transport block (including CRC).

Code block segmentation and code block CRC attachment are performed according to section 5.1.2.

The bits after code block segmentation are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number and K_r is the number of bits for code block number r.

5.2.2.3 Channel coding of UL-SCH

Code blocks are delivered to the channel coding block. The bits in a code block are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number, and K_r is the number of bits in code block number r. The total number of code blocks is denoted by C and each code block is individually turbo encoded according to section 5.1.3.2.

After encoding the bits are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, ..., d_{r(D_r-1)}^{(i)}$, with $i = 0,1$, and 2 and where D_r is the number of bits on the i-th coded stream for code block number r, i.e. $D_r = K_r + 4$.

5.2.2.4 Rate matching

Turbo coded blocks are delivered to the rate matching block. They are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, ..., d_{r(D_r-1)}^{(i)}$, with $i = 0,1$, and 2, and where r is the code block number, i is the coded stream index, and D_r is the number of bits in each coded stream of code block number r. The total number of code blocks is denoted by C and each coded block is individually rate matched according to section 5.1.4.1.

After rate matching, the bits are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, ..., e_{r(E_r-1)}$, where r is the coded block number, and where E_r is the number of rate matched bits for code block number r.

5.2.2.5 Code block concatenation

The bits input to the code block concatenation block are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, ..., e_{r(E_r-1)}$ for $r = 0, ..., C-1$ and where E_r is the number of rate matched bits for the r-th code block.

Code block concatenation is performed according to section 5.1.5.

The bits after code block concatenation are denoted by $f_0, f_1, f_2, f_3, ..., f_{G-1}$, where G is the total number of coded bits for transmission of the given transport block over N_L transmission layers excluding the bits used for control transmission, when control information is multiplexed with the UL-SCH transmission.

5.2.2.6 Channel coding of control information

Control data arrives at the coding unit in the form of channel quality information (CQI and/or PMI), HARQ-ACK and rank indication, and CSI-RS resource indication (CRI). Different coding rates for the control information are achieved by allocating different number of coded symbols for its transmission. When control data are transmitted in the PUSCH, the channel coding for HARQ-ACK, rank indication, CRI and channel quality information $o_0, o_1, o_2, ..., o_{O-1}$ is done independently.

For the cases with TDD primary cell, the number of HARQ-ACK bits is determined as described in section 7.3 of [3].

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When the UE transmits HARQ-ACK bits, rank indicator bits or CRI bits, it shall determine the number of coded modulation symbols per layer Q' for HARQ-ACK, rank indicator or CRI bits as follows.

For the case when only one transport block is transmitted in the PUSCH conveying the HARQ-ACK bits, rank indicator bits or CRI bits:

$$Q' = \min\left(\left\lceil \frac{O \cdot M_{sc}^{PUSCH-initial} \cdot N_{symb}^{PUSCH-initial} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C-1} K_r} \right\rceil, 4 \cdot M_{sc}^{PUSCH}\right)$$

where

- O is the number of HARQ-ACK bits, rank indicator bits or CRI bits, and
- M_{sc}^{PUSCH} is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, expressed as a number of subcarriers in [2], and
- $N_{symb}^{PUSCH-initial}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the same transport block, respectively, given by $N_{symb}^{PUSCH-initial} = \left(2 \cdot \left(N_{symb}^{UL} - 1\right) - N_{SRS}\right)$, where
  - N_{SRS} is equal to 1
    - if UE configured with one UL cell is configured to send PUSCH and SRS in the same subframe for initial transmission, or
    - if UE transmits PUSCH and SRS in the same subframe in the same serving cell for initial transmission, or
    - if the PUSCH resource allocation for initial transmission even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or
    - if the subframe for initial transmission in the same serving cell is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or
    - if the subframe for initial transmission in the same serving cell is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs.
  - Otherwise N_{SRS} is equal to 0.
- $M_{sc}^{PUSCH-initial}$, C, and K_r are obtained from the initial PDCCH or EPDCCH for the same transport block. If there is no initial PDCCH or EPDCCH with DCI format 0 for the same transport block, $M_{sc}^{PUSCH-initial}$, C, and K_r shall be determined from:
  - the most recent semi-persistent scheduling assignment PDCCH or 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.

For the case when two transport blocks are transmitted in the PUSCH conveying the HARQ-ACK bits, rank indicator bits or CRI bits:

$$Q' = \max\left[\min\left(Q'_{temp}, 4 \cdot M_{sc}^{PUSCH}\right), Q'_{\min}\right] \text{ with}$$

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$$Q'_{temp}=\left\lceil \frac{O\cdot M_{sc}^{PUSCH-initial(1)}\cdot N_{symb}^{PUSCH-initial(1)}\cdot M_{sc}^{PUSCH-initial(2)}\cdot N_{symb}^{PUSCH-initial(2)}\cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C^{(1)}-1} K_r^{(1)}\cdot M_{sc}^{PUSCH-initial(2)}\cdot N_{symb}^{PUSCH-initial(2)}+\sum_{r=0}^{C^{(2)}-1} K_r^{(2)}\cdot M_{sc}^{PUSCH-initial(1)}\cdot N_{symb}^{PUSCH-initial(1)}} \right\rceil$$

where

- O is the number of HARQ-ACK bits, rank indicator bits or CRI bits, and
- $Q'_{\min}=O$ if $O\le 2$, $Q'_{\min}=\lceil 2O/Q'_m\rceil$ if $3\le O\le 11$ with $Q'_m=\min\left(Q_m^1,Q_m^2\right)$ where $Q_m^x, x=\{1,2\}$ is the modulation order of transport block "x", and $Q'_{\min}=\lceil 2O_1/Q'_m\rceil+\lceil 2O_2/Q'_m\rceil$ if $O>11$ with $O_1=\lceil O/2\rceil$ and $O_2=O-\lceil O/2\rceil$.
- $M_{\text{sc}}^{PUSCH\text{-}initial(x)}, x=\{1,2\}$ are the scheduled bandwidths for PUSCH transmission in the initial sub-frame for the first and second transport block, respectively, expressed as a number of subcarriers in [2], and
- $N_{\text{symb}}^{PUSCH\text{-}initial(x)}, x=\{1,2\}$ are the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the first and second transport block given by $N_{\text{symb}}^{PUSCH\text{-}initial(x)}=\left(2\cdot\left(N_{\text{symb}}^{\text{UL}}-1\right)-N_{\text{SRS}}^{(x)}\right), x=\{1,2\}$, where
  - $N_{SRS}^{(x)}, x=\{1,2\}$ is equal to 1
    - if UE configured with one UL cell is configured to send PUSCH and SRS in the same subframe for initial transmission, or
    - if UE transmits PUSCH and SRS in the same subframe in the same serving cell for initial transmission of transport block "x", or
    - if the PUSCH resource allocation for initial transmission of transport bock "x" even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2] , or
    - if the subframe for initial transmission of transport block "x" in the same serving cell is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or
    - if the subframe for initial transmission of transport block "x" in the same serving cell is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs.
  - Otherwise $N_{SRS}^{(x)}, x=\{1,2\}$ is equal to 0.
- $M_{sc}^{PUSCH-initial(x)}, x=\{1,2\}$, $C^{(x)}, x=\{1,2\}$, and $K_r^{(x)}, x=\{1,2\}$ are obtained from the initial PDCCH or EPDCCH for the corresponding transport block.

For HARQ-ACK, $Q_{ACK}=Q_m\cdot Q'$ and $\beta_{offset}^{PUSCH}=\beta_{offset}^{HARQ-ACK}$, where Q_m is the modulation order of a given transport block. For UEs configured with no more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH. For UEs configured with more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH and and the number of HARQ-ACK feedback bits.

For rank indication or CRI, $Q_{RI}=Q_m\cdot Q'$, $Q_{CRI}=Q_m\cdot Q'$ and $\beta_{offset}^{PUSCH}=\beta_{offset}^{RI}$, where Q_m is the modulation order of a given transport block, and β_{offset}^{RI} shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH, and on the uplink power control subframe set for the corresponding PUSCH when two uplink power control subframe sets are configured by higher layers for the cell.

For HARQ-ACK

Each positive acknowledgement (ACK) is encoded as a binary '1' and each negative acknowledgement (NACK) is encoded as a binary '0'

If HARQ-ACK feedback consists of 1-bit of information, i.e., $[o_0^{ACK}]$, it is first encoded according to Table 5.2.2.6-1.

If HARQ-ACK feedback consists of 2-bits of information, i.e., $[o_0^{ACK}\ o_1^{ACK}]$ with o_0^{ACK} corresponding to HARQ-ACK bit for codeword 0 and o_1^{ACK} corresponding to that for codeword 1, or if HARQ-ACK feedback consists of 2-bits of information as a result of the aggregation of HARQ-ACK bits corresponding to two DL cells with which the UE is configured by higher layers, or if HARQ-ACK feedback consists of 2-bits of information corresponding to two subframes for TDD, it is first encoded according to Table 5.2.2.6-2 where $o_2^{ACK} = (o_0^{ACK} + o_1^{ACK}) \bmod 2$.

Table 5.2.2.6-1: Encoding of 1-bit HARQ-ACK.

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK}$ y]
4	$[o_0^{ACK}$ y x x]
6	$[o_0^{ACK}$ y x x x x]

Table 5.2.2.6-2: Encoding of 2-bit HARQ-ACK.

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}]$
4	$[o_0^{ACK}\ o_1^{ACK}$ x x $o_2^{ACK}\ o_0^{ACK}$ x x $o_1^{ACK}\ o_2^{ACK}$ x x]
6	$[o_0^{ACK}\ o_1^{ACK}$ x x x x $o_2^{ACK}\ o_0^{ACK}$ x x x x $o_1^{ACK}\ o_2^{ACK}$ x x x x]

If HARQ-ACK feedback consists of $3 \le O^{ACK} \le 11$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, i.e., $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$, then a coded bit sequence $\tilde{q}_0^{ACK}\ \tilde{q}_1^{ACK},...,\tilde{q}_{31}^{ACK}$ is obtained by using the bit sequence $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$ as the input to the channel coding block described in section 5.2.2.6.4. In turn, the bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK},..., q_{Q_{ACK}-1}^{ACK}$ is obtained by the circular repetition of the bit sequence $\tilde{q}_0^{ACK}\ \tilde{q}_1^{ACK},...,\tilde{q}_{31}^{ACK}$ so that the total bit sequence length is equal to Q_{ACK}.

If HARQ-ACK feedback consists of $11 < O^{ACK} \le 22$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, i.e., $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$, then the coded bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK},..., q_{Q_{ACK}-1}^{ACK}$ is obtained by using the bit sequence $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$ as the input to the channel coding block described in section 5.2.2.6.5.

If HARQ-ACK feedback consists of $O^{ACK} > 22$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, the coded bit sequence is denoted by $q_0^{ACK}, q_1^{ACK}, q_2^{ACK},..., q_{Q_{ACK}-1}^{ACK}$. The CRC attachment, channel coding and rate matching of the HARQ-ACK bits are performed according to sections 5.1.1 setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

The "x" and "y" in Table 5.2.2.6-1 and 5.2.2.6-2 are placeholders for [2] to scramble the HARQ-ACK bits in a way that maximizes the Euclidean distance of the modulation symbols carrying HARQ-ACK information.

For FDD or TDD HARQ-ACK multiplexing or the aggregation of more than one DL cell including at least one cell using FDD and at least one cell using TDD when HARQ-ACK consists of one or two bits of information, the bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \ldots, q_{Q_{ACK}-1}^{ACK}$ is obtained by concatenation of multiple encoded HARQ-ACK blocks where Q_{ACK} is the total number of coded bits for all the encoded HARQ-ACK blocks. The last concatenation of the encoded HARQ-ACK block may be partial so that the total bit sequence length is equal to Q_{ACK}.

For UEs configured by higher layers with *codebooksizeDetermination-r13 = 0*, the bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined according to the Downlink Assignment Index (DAI) as in Table 5.3.3.1.1-2 and as defined in [3]. Otherwise, the bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined as below.

For FDD when HARQ ACK consists of 2 or more bits of information as a result of the aggregation of more than one DL cell, the bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for the multiple DL cells according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c < N_{cells}^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUSCH by higher layers $\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$j = j + 1$

end if

end if

$c = c + 1$

end while

For the aggregation of more than one DL cell including a primary cell using FDD and at least one secondary cell using TDD, the bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for one or multiple DL cells. Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number

of subframes for which the UE needs to feed back HARQ-ACK bits in UL subframe n for the c-th serving cell. For a cell using TDD, the subframes are determined by the DL-reference UL/DL configuration if the UE is configured with higher layer parameter *eimta-HARQ-ReferenceConfig*, and determined by the UL/DL configuration otherwise. For a cell using TDD, $B_c^{DL} = 1$ if subframe n-4 in the cell is a DL subframe or a special subframe with special subframe configurations 1/2/3/4/6/7/8/9 and normal downlink CP or a special subframe with special subframe configurations 1/2/3/5/6/7 and extended downlink CP, and $B_c^{DL} = 0$ otherwise. For a cell using FDD, $B_c^{DL} = 1$.

The bit sequence $\tilde{o}_0^{ACK}$ $\tilde{o}_1^{ACK}$,..., $\tilde{o}_{O^{ACK}-1}^{ACK}$ is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

if $B_c^{DL} = 1$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUSCH by higher layers $\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$j = j + 1$

end if

end if

end if

$c = c + 1$

end while

For the cases with TDD primary cell when HARQ-ACK is for the aggregation of one or more DL cells and the UE is configured with PUCCH format 3, PUCCH format 4 or PUCCH format 5 [3], the bit sequence $\tilde{o}_0^{ACK}$ $\tilde{o}_1^{ACK}$,..., $\tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for the one or more DL cells configured by higher layers and the multiple subframes as defined in [3].

Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits as defined in Section 7.3 of [3].

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The number of HARQ-ACK bits for the UE to convey if it is configured with PUCCH format 3, PUCCH format 4 or PUCCH format 5 is computed as follows:

Set $k = 0$ – counter of HARQ-ACK bits

Set c=0 – cell index: lower indices correspond to lower RRC indices of corresponding cell

while c < N_{cells}^{DL}

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$k = k + 1$

else

$k = k + 2$

end if

$l = l+1$

end while

$c = c + 1$

end while

When PUCCH format 3 is configured, if $k \leq 20$ when TDD is used in all the configured serving cell(s) of the UE, or if $k \leq 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell; or when PUCCH format 4 or PUCCH format 5 is configured and when the UE is not configured with spatial bundling on PUSCH by higher layers, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while c < N_{cells}^{DL}

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$[\tilde{o}_j^{ACK}, \tilde{o}_{j+1}^{ACK}] = [o_{c,2l}^{ACK}, o_{c,2l+1}^{ACK}]$ HARQ-ACK bits of this cell as defined in Section 7.3 of [3]

$j = j + 2$

end if

$l = l+1$

end while

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$c = c + 1$

end while

When PUCCH format 3 is configured, if $k > 20$ when TDD is used in all the configured serving cell(s) of the UE, or if $k > 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell, spatial bundling is applied to all subframes in all cells; or when PUCCH format 4 or PUCCH format 5 is configured and when the UE is configured with spatial bundling on PUSCH by higher layers, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while c < N_{cells}^{DL}

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell as defined in Section 7.3 of [3]

$j = j + 1$

end if

$l = l+1$

end while

$c = c + 1$

end while

For $O^{ACK} \le 11$ or $O^{ACK} > 22$, the bit sequence $o_0^{ACK}, o_1^{ACK}, ..., o_{O^{ACK}-1}^{ACK}$ is obtained by setting $o_i^{ACK} = \tilde{o}_i^{ACK}$.

For $11 < O^{ACK} \le 22$, the bit sequence $o_0^{ACK}, o_1^{ACK}, ..., o_{O^{ACK}-1}^{ACK}$ is obtained by setting $o_{i/2}^{ACK} = \tilde{o}_i^{ACK}$ if i is even and $o_{\lfloor O^{ACK}/2 \rfloor + (i-1)/2}^{ACK} = \tilde{o}_i^{ACK}$ if i is odd.

For the cases with TDD primary cell when HARQ-ACK is for the aggregation of two DL cells and the UE is configured with PUCCH format 1b with channel selection, the bit sequence $o_0^{ACK}, o_1^{ACK}, ..., o_{O^{ACK}-1}^{ACK}$ is obtained as described in section 7.3 of [3].

For TDD HARQ-ACK bundling, a bit sequence $\tilde{q}_0^{ACK}, \tilde{q}_1^{ACK}, \tilde{q}_2^{ACK}, ..., \tilde{q}_{Q_{ACK}-1}^{ACK}$ is obtained by concatenation of multiple encoded HARQ-ACK blocks where Q_{ACK} is the total number of coded bits for all the encoded HARQ-ACK blocks. The last concatenation of the encoded HARQ-ACK block may be partial so that the total bit sequence length is equal to Q_{ACK}. A scrambling sequence $\left[w_0^{ACK} w_1^{ACK} w_2^{ACK} w_3^{ACK}\right]$ is then selected from Table 5.2.2.6-A with index $i = (N_{bundled} - 1) \bmod 4$, where N_{bundled} is determined as described in section 7.3 of [3]. The bit sequence

$q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, ..., q_{Q_{ACK}-1}^{ACK}$ is then generated by setting $m = 1$ if HARQ-ACK consists of 1-bit and $m = 3$ if HARQ-ACK consists of 2-bits and then scrambling $\tilde{q}_0^{ACK}, \tilde{q}_1^{ACK}, \tilde{q}_2^{ACK}, ..., \tilde{q}_{Q_{ACK}-1}^{ACK}$ as follows

Set i, k to 0

while $i < Q_{ACK}$

if $\tilde{q}_i^{ACK} = y$ // place-holder repetition bit

$$q_i^{ACK} = \left(\tilde{q}_{i-1}^{ACK} + w_{\lfloor k/m \rfloor}^{ACK}\right) \bmod 2$$

$$k = (k+1) \bmod 4m$$

else

if $\tilde{q}_i^{ACK} = x$ // a place-holder bit

$$q_i^{ACK} = \tilde{q}_i^{ACK}$$

else // coded bit

$$q_i^{ACK} = \left(\tilde{q}_i^{ACK} + w_{\lfloor k/m \rfloor}^{ACK}\right) \bmod 2$$

$$k = (k+1) \bmod 4m$$

end if

$i = i + 1$

end while

Table 5.2.2.6-A: Scrambling sequence selection for TDD HARQ-ACK bundling.

i	$\left[w_0^{ACK} w_1^{ACK} w_2^{ACK} w_3^{ACK}\right]$
0	[1 1 1 1]
1	[1 0 1 0]
2	[1 1 0 0]
3	[1 0 0 1]

When HARQ-ACK information is to be multiplexed with UL-SCH at a given PUSCH, the HARQ-ACK information is multiplexed in all layers of all transport blocks of that PUSCH, For a given transport block, the vector sequence output of the channel coding for HARQ-ACK information is denoted by $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, ..., \underline{q}_{Q'_{ACK}-1}^{ACK}$, where $\underline{q}_i^{ACK}$, $i = 0, ..., Q'_{ACK} - 1$ are column vectors of length $(Q_m \cdot N_L)$ and where $Q'_{ACK} = Q_{ACK} / Q_m$ is obtained as follows:

Set i, k to 0

while $i < Q_{ACK}$

$\hat{\underline{q}}_k^{ACK} = [q_i^{ACK} \; ... \; q_{i+Q_m-1}^{ACK}]$ -- temporary row vector

$\underline{q}_k^{ACK} = [\overbrace{\hat{\underline{q}}_k^{ACK} \cdots \hat{\underline{q}}_k^{ACK}}^{N_L}]^T$ -- replicating the row vector $\hat{\underline{q}}_k^{ACK}$ N_L times and transposing into a column vector

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$i = i + Q_m$

$k = k + 1$

end while

where N_L is the number of layers onto which the UL-SCH transport block is mapped.

For rank indication (RI) (RI only, joint report of RI and i1, joint report of CRI and RI, joint report of CRI,RI and i1,joint report of CRI,RI, and PTI, and joint report of RI and PTI) or CRI

- The corresponding bit widths for CRI feedback for PDSCH transmissions are given by Tables 5.2.2.6.1-3A, 5.2.2.6.2-3A, 5.2.2.6.3-3A, 5.2.3.3.1-3D,
- The corresponding bit widths for RI feedback for PDSCH transmissions are given by Tables 5.2.2.6.1-2, 5.2.2.6.2-3, 5.2.2.6.2-3B, 5.2.2.6.3-3, 5.2.2.6.3-3B, 5.2.3.3.1-3, 5.2.3.3.1-3A, 5.2.3.3.1-3B, 5.2.3.3.1-3C, 5.2.3.3.1-3D, 5.2.3.3.2-4, and 5.2.3.3.2-4A, 5.2.3.3.2-4B, 5.2.3.3.2-4C, 5.2.3.3.2-4D which are determined assuming the maximum number of layers as follows:
  - If the *maxLayersMIMO-r10* is configured for the DL cell, the maximum number of layers is determined according to *maxLayersMIMO-r10* for the DL cell
  - Else,
    - If the UE is configured with transmission mode 9, and the *supportedMIMO-CapabilityDL-r10* field is included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the configured number of CSI-RS ports and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
    - If the UE is configured with transmission mode 9 and Class B CSI reporting with K>1 and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is included in the UE-EUTRA-Capability, the maximum number of layers is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination,.
    - If the UE is configured with transmission mode 9, and the *supportedMIMO-CapabilityDL-r10* field is not included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the configured number of CSI-RS ports and *ue-Category* (without suffix).
    - If the UE is configured with transmission mode 9 and Class B CSI reporting with K>1 and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is not included in the UE-EUTRA-Capability, the maximum number of layers is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources and ue-Category (without suffix).
    - If the UE is configured with transmission mode 10, and the *supportedMIMO-CapabilityDL-r10* field is included in the *UE-EUTRA-Capability*, the maximum number of layers for each CSI process is determined according to the minimum of the configured number of CSI-RS ports for that CSI process and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
    - If the UE is configured with transmission mode 10 and Class B CSI reporting with K>1 and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is included in the UE-EUTRA-Capability, the maximum number of layers for each CSI process is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources in that CSI process and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
    - If the UE is configured with transmission mode 10, and the *supportedMIMO-CapabilityDL-r10* field is not included in the *UE-EUTRA-Capability*, the maximum number of layers for each CSI process is determined according to the minimum of the configured number of CSI-RS ports for that CSI process and *ue-Category* (without suffix).

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- If the UE is configured with transmission mode 10 and Class B CSI reporting with K>1 and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is not included in the UE-EUTRA-Capability, the maximum number of layers for each CSI process is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources in that CSI process and ue-Category (without suffix).
- Otherwise the maximum number of layers is determined according to the minimum of the number of PBCH antenna ports and *ue-Category* (without suffix).

- If RI feedback consists of 1-bit of information, i.e., $[o_0^{RI}]$, it is first encoded according to Table 5.2.2.6-3. The $[o_0^{RI}]$ to RI mapping is given by Table 5.2.2.6-5.
- If RI feedback consists of 2-bits of information, i.e., $[o_0^{RI}\ o_1^{RI}]$ with o_0^{RI} corresponding to MSB of 2-bit input and o_1^{RI} corresponding to LSB, it is first encoded according to Table 5.2.2.6-4 where $o_2^{RI} = (o_0^{RI} + o_1^{RI}) \bmod 2$. The $[o_0^{RI}\ o_1^{RI}]$ to RI mapping is given by Table 5.2.2.6-6.

Table 5.2.2.6-3: Encoding of 1-bit RI.

Q_m	Encoded RI
2	$[o_0^{RI}$ y]
4	$[o_0^{RI}$ y x x]
6	$[o_0^{RI}$ y x x x x]

Table 5.2.2.6-4: Encoding of 2-bit RI.

Q_m	Encoded RI
2	$[o_0^{RI}\ o_1^{RI}\ o_2^{RI}\ o_0^{RI}\ o_1^{RI}\ o_2^{RI}]$
4	$[o_0^{RI}\ o_1^{RI}$ x x $o_2^{RI}\ o_0^{RI}$ x x $o_1^{RI}\ o_2^{RI}$ x x]
6	$[o_0^{RI}\ o_1^{RI}$ x x x x $o_2^{RI}\ o_0^{RI}$ x x x x $o_1^{RI}\ o_2^{RI}$ x x x x]

Table 5.2.2.6-5: o_0^{RI} to RI mapping.

O_0^{RI}	RI
0	1
1	2

Table 5.2.2.6-6: o_0^{RI}, o_1^{RI} to RI mapping.

O_0^{RI}, O_1^{RI}	RI
0, 0	1
0, 1	2
1, 0	3
1, 1	4

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Table 5.2.2.6-7: o_0^{RI}, o_1^{RI}, o_2^{RI} to RI mapping.

o_0^{RI}, o_1^{RI}, o_2^{RI}	RI
0, 0, 0	1
0, 0, 1	2
0, 1, 0	3
0, 1, 1	4
1, 0, 0	5
1, 0, 1	6
1, 1, 0	7
1, 1, 1	8

If RI feedback for a given DL cell consists of 3-bits of information, i.e., $[o_0^{RI}\ o_1^{RI}\ o_2^{RI}]$ with o_0^{RI} corresponding to MSB of 3-bit input and o_2^{RI} corresponding to LSB. The $[o_0^{RI}\ o_1^{RI}\ o_2^{RI}]$ to RI mapping is given by Table 5.2.2.6-7.

If RI feedback consists of $3 \le O^{RI} \le 11$ bits of information, i.e., $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$, then a coded bit sequence $[\tilde{q}_0^{RI}\ \tilde{q}_1^{RI},...,\tilde{q}_{31}^{RI}]$ is obtained by using the bit sequence $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$ as the input to the channel coding block described in section 5.2.2.6.4.

If RI feedback consists of $11 < O^{RI} \le 22$ bits of information as a result of the aggregation of RI bits corresponding to multiple DL cells or multiple CSI processes, i.e., $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$, then the coded bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI},..., q_{Q_{RI}-1}^{RI}$ is obtained by using the bit sequence $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$ as the input to the channel coding block described in section 5.2.2.6.5.

If RI feedback consists of $O^{RI} > 22$ bits of information as a result of the aggregation of RI bits corresponding to multiple DL cells or multiple CSI processes, i.e., $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$, then the coded bit sequence is denoted by $q_0^{RI}, q_1^{RI}, q_2^{RI},..., q_{Q_{RI}-1}^{RI}$. The CRC attachment, channel coding and rate matching of the HARQ-ACK bits are performed according to sections 5.1.1 setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

The "x" and "y" in Table 5.2.2.6-3 and 5.2.2.6-4 are placeholders for [2] to scramble the RI bits in a way that maximizes the Euclidean distance of the modulation symbols carrying rank information.

For the case where RI feedback for more than one DL cell is to be reported, the RI report for each DL cell is concatenated prior to coding in increasing order of cell index.

For the case where RI feedback for more than one CSI process is to be reported, the RI reports are concatenated prior to coding first in increasing order of CSI process index for each DL cell and then in increasing order of cell index.

For the case where RI feedback consists of one or two bits of information the bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI},..., q_{Q_{RI}-1}^{RI}$ is obtained by concatenation of multiple encoded RI blocks where Q_{RI} is the total number of coded bits for all the encoded RI blocks. The last concatenation of the encoded RI block may be partial so that the total bit sequence length is equal to Q_{RI}.

For the case where RI feedback consists of $3 \le O^{RI} \le 11$ bits of information, the bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI},..., q_{Q_{RI}-1}^{RI}$ is obtained by the circular repetition of the bit sequence $\tilde{q}_0^{RI}\ \tilde{q}_1^{RI},...,\tilde{q}_{31}^{RI}$ so that the total bit sequence length is equal to Q_{RI}.

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When rank information is to be multiplexed with UL-SCH at a given PUSCH, the rank information is multiplexed in all layers of all transport blocks of that PUSCH. For a given transport block, the vector sequence output of the channel coding for rank information is denoted by $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \ldots, \underline{q}_{Q'_{RI}-1}^{RI}$, where $\underline{q}_i^{RI}$, $i = 0, \ldots, Q'_{RI} - 1$ are column vectors of length $(Q_m \cdot N_L)$ and where $Q'_{RI} = Q_{RI} / Q_m$. The vector sequence is obtained as follows:

Set i, j, k to 0

while $i < Q_{RI}$

$\hat{\underline{q}}_k^{RI} = [q_i^{RI} \ldots q_{i+Q_m-1}^{RI}]$ -- temporary row vector

$\underline{q}_k^{RI} = [\overbrace{\hat{\underline{q}}_k^{RI} \cdots \hat{\underline{q}}_k^{RI}}^{N_L}]^T$ -- replicating the row vector $\hat{\underline{q}}_k^{RI}$ N_L times and transposing into a column vector

$i = i + Q_m$

$k = k + 1$

end while

where N_L is the number of layers onto which the UL-SCH transport block is mapped.

The same procedures for encoding of RI and RI multiplexing with UL-SCH at a given PUSCH are applied for CRI, using CRI instead of RI in the equations.

For channel quality control information (CQI and/or PMI denoted as CQI/PMI);

When the UE transmits channel quality control information bits, it shall determine the number of modulation coded symbols per layer Q' for channel quality information as

$$Q' = \min\left(\left\lceil \frac{(O+L) \cdot M_{sc}^{PUSCH-initial(x)} \cdot N_{symb}^{PUSCH-initial(x)} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C^{(x)}-1} K_r^{(x)}} \right\rceil, M_{sc}^{PUSCH} \cdot N_{symb}^{PUSCH} - \frac{Q_{RI}^{(x)}}{Q_m^{(x)}}\right)$$

where

- O is the number of CQI/PMI bits, and
- L is the number of CRC bits given by $L = \begin{cases} 0 & O \le 11 \\ 8 & \text{otherwise} \end{cases}$, and
- $Q_{CQI} = Q_m^{(x)} \cdot Q'$ and $\beta_{offset}^{PUSCH} = \beta_{offset}^{CQI}$, where β_{offset}^{CQI} shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH, and on the uplink power control subframe set for the corresponding PUSCH when two uplink power control subframe sets are configured by higher layers for the cell.
- If RI or CRI is not transmitted then $Q_{RI}^{(x)} = 0$.

The variable "x" in $K_r^{(x)}$ represents the transport block index corresponding to the highest I_{MCS} value indicated by the initial UL grant. In case the two transport blocks have the same I_{MCS} value in the corresponding initial UL grant, "x = 1", which corresponds to the first transport block. $M_{sc}^{PUSCH-initial(x)}$, $C^{(x)}$, and $K_r^{(x)}$ are obtained from the initial PDCCH or EPDCCH for the same transport block. If there is no initial PDCCH or EPDCCH with DCI format 0 for the same transport block, $M_{sc}^{PUSCH-initial(x)}$, $C^{(x)}$, and $K_r^{(x)}$ shall be determined from:

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- the most recent semi-persistent scheduling assignment PDCCH or 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.

$N_{symb}^{PUSCH-initial(x)}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the same transport block.

For UL-SCH data information $G = N_L^{(x)} \cdot \left(N_{\text{symb}}^{\text{PUSCH}} \cdot M_{\text{sc}}^{\text{PUSCH}} \cdot Q_m^{(x)} - Q_{CQI} - Q_{RI}^{(x)}\right)$, where

- $N_L^{(x)}$ is the number of layers the corresponding UL-SCH transport block is mapped onto, and
- $M_{\text{sc}}^{\text{PUSCH}}$ is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, and
- $N_{\text{symb}}^{\text{PUSCH}}$ is the number of SC-FDMA symbols in the current PUSCH transmission sub-frame given by $N_{\text{symb}}^{\text{PUSCH}} = \left(2 \cdot \left(N_{\text{symb}}^{\text{UL}} - 1\right) - N_{SRS}\right)$, where
  - N_{SRS} is equal to 1
    - if UE configured with one UL cell is configured to send PUSCH and SRS in the same subframe for initial transmission, or
    - if UE transmits PUSCH and SRS in the same subframe for the current subframe in the same serving cell, or
    - if the PUSCH resource allocation for the current subframe even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or
    - if the current subframe in the same serving cell is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or
    - if the current subframe in the same serving cell is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs.
  - Otherwise N_{SRS} is equal to 0.

In case of CQI/PMI report for more than one DL cell, $o_0, o_1, o_2, ..., o_{O-1}$ is the result of concatenating the CQI/PMI report for each DL cell in increasing order of cell index. For the case where CQI/PMI feedback for more than one CSI process is to be reported, $o_0, o_1, o_2, ..., o_{O-1}$ is the result of concatenating the CQI/PMI reports in increasing order of CSI process index for each DL cell and then in increasing order of cell index.

- If the payload size is less than or equal to 11 bits, the channel coding of the channel quality information is performed according to section 5.2.2.6.4 with input sequence $o_0, o_1, o_2, ..., o_{O-1}$.
- For payload sizes greater than 11 bits, the CRC attachment, channel coding and rate matching of the channel quality information is performed according to sections 5.1.1, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $o_0, o_1, o_2, ..., o_{O-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

The output sequence for the channel coding of channel quality information is denoted by $q_0, q_1, q_2, q_3, ..., q_{N_L \cdot Q_{CQI}-1}$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto.

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5.2.2.6.1 Channel quality information formats for wideband CQI reports

If the parameter *CQI-ReportModeAperiodic* is configured to the value of *rm10-v13xy* by higher layers [6], Table 5.2.3.3.1-1 shows the fields and the corresponding bit widths for the channel quality information feedback, Table 5.2.3.3.1-3 shows the fields and the corresponding bit widths for the rank indication feedback.

If the parameter *CQI-ReportModeAperiodic* is configured to the value of *rm11-v13xx* by higher layers [6], Table 5.2.3.3.1-2, Table 5.2.3.3.1-2A, Table 5.2.3.3.1-2B, Table 5.2.3.3.1-2C and Table 5.2.3.3.1-2D show the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback, Table 5.2.3.3.1-3 shows the fields and the corresponding bit widths for the rank indication feedback, and Table 5.2.3.3.1-3A and Table 5.2.3.3.1-3B show the fields and the corresponding bit widths for the joint transmission of rank indication and i1.

If the parameter *CQI-ReportModeAperiodic* is configured to the value of *rm12* by higher layers [6], the fields and the corresponding bit widths for channel quality information and rank indication feedback are described as below.

Table 5.2.2.6.1-1, Table 5.2.2.6.1-1A and Table 5.2.2.6.1-1B show the fields and the corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with transmission mode 4, transmission mode 6, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config* =2. The number of CSI-RS resources K is defined in [3] and *PMI-Config* is configured by higher layers [6].

Table 5.2.2.6.1-1C and Table 5.2.2.6.1-1D show the fields and the corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting.

Table 5.2.2.6.2-1E shows the fields and corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =1.

For Table 5.2.2.6.1-1, Table 5.2.2.6.1-1A, Table 5.2.2.6.1-1B, Table 5.2.2.6.1-1C, Table 5.2.2.6.1-D and Table 5.2.2.6.1-1E, N is defined in section 7.2 of [3]. For Table 5.2.2.6.1-1C and Table 5.2.2.6.1-D, the codebook configuration (N_1, N_2, O_1, O_2) is defined in [3], and *Codebook-Subset-SelectionConfig* is configured by higher layers [6]. The parameters (S_1, S_2) in rank 3 and 4 are defined as $(S_1, S_2) = (1, 1)$ for *Codebook-Subset-SelectionConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=2, $(S_1, S_2) = \left(O_1, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=3, $(S_1, S_2) = \left(O_1, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=4. The parameters (S_1, S_2) in rank 5 to 8 are defined as $(S_1, S_2) = (1, 1)$ for *Codebook-Subset-SelectionConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=2/3/4.

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Table 5.2.2.6.1-1: Fields for channel quality information feedback for wideband CQI reports (transmission mode 4, transmission mode 6, transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with 2/4 antenna ports with K>1, and K=1 with *PMI-Config*=2, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*).

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	0	4
Precoding matrix indicator	$2N$	N	$4N$	$4N$

Table 5.2.2.6.1-1A: Fields for channel quality information feedback for wideband CQI reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with 8 antenna ports with K>1, and K=1 with *PMI-Config*=2).

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	4	4
Wideband first PMI i1	4	4	2	2
Subband second PMI i2	$4N$	$4N$	$4N$	$3N$
Field	Bit width			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	4	4	4	4
Wideband first PMI i1	2	2	2	0
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.1-1B: Fields for channel quality information feedback for wideband CQI reports with 4 antenna ports (transmission mode 8, transmission mode 9 and transmission mode 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with 4 antenna ports with K>1, and K=1 with *PMI-Config*=2, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	4	4
Wideband first PMI i1	4	4	0	0
Subband second PMI i2	$4N$	$4N$	$4N$	$4N$

Table 5.2.2.6.1-1C: Fields for channel quality information feedback for wideband CQI reports (transmission mode 9/10 configured with PMI/RI reporting for Class A CSI reporting with codebook configuration (N_1, N_2, O_1, O_2) and *Codebook-Subset-SelectionConfig*=1)

Field	Bit width			
	Rank = 1	Rank = 2	Rank =3	Rank =4

Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	4	4
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1) \rceil$	$\lceil \log_2(N_1O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$
Subband second PMI i2	$2N$	$2N$	N	N
Field	**Bit width**			
	Rank = 5	**Rank = 6**	**Rank =7**	**Rank =8**
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	4	4	4	4
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.1-1D: Fields for channel quality information feedback for wideband CQI reports (transmission mode 9/10 configured with Class A CSI reporting with codebook configuration (N_1,N_2,O_1,O_2) and *Codebook-Subset-SelectionConfig*=2/3/4)

Field	**Bit width**			
	Rank = 1	**Rank = 2**	**Rank = 3**	**Rank = 4**
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	4	4
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/2) \rceil$	$\lceil \log_2(N_1O_1/2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/2) \rceil$	$\lceil \log_2(N_2O_2/2) \rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$
Subband second PMI i2	$4N$	$4N$	$4N$	$3N$
Field	**Bit width**			
	Rank = 5	**Rank = 6**	**Rank = 7**	**Rank= 8**

Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	4	4	4	4
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.1-1E: Fields for channel quality information feedback for wideband CQI reports (transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with 2/4/8 antenna ports with K=1 with *PMI-Config* =1)

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank =2	Rank =3	Rank =4
Wideband CQI codeword 0	4	4	4	4	4	4
Wideband CQI codeword 1	0	4	0	4	4	4
Precoding matrix indicator	$2N$	N	$3N$	$3N$	$2N$	N
Field	**Bit width**					
	8 antenna ports					
	Rank = 1	Rank = 2	Rank = 3	Rank =4	Rank =5~8	
Wideband CQI codeword 0	4	4	4	4	4	
Wideband CQI codeword 1	0	4	0	4	4	
Precoding matrix indicator	$4N$	$4N$	$4N$	$3N$	0	

Table 5.2.2.6.1-2 shows the fields and the corresponding bit width for the rank indication feedback for wideband CQI reports for PDSCH transmissions associated with transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting, and transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting.

Table 5.2.2.6.1-2A shows the fields and the corresponding bit width for the joint CRI and RI feedback for wideband CQI reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1.

Table 5.2.2.6.1-2: Fields for rank indication feedback for wideband CQI reports (transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting, and transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting).

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

Table 5.2.2.6.1-2A: Fields for CRI feedback for wideband CQI reports (transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1).

Field	Bit width		
	Max 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	2	3

The channel quality bits in Table 5.2.2.6.1-1, Table 5.2.2.6.1-1A, Table 5.2.2.6.1-1B, Table 5.2.2.6.1-1C, Table 5.2.2.6.1-1D and Table 5.2.2.6.1-1E form the bit sequence $o_0, o_1, o_2, ..., o_{O-1}$ with o_0 corresponding to the first bit of the first field in the table, o_1 corresponding to the second bit of the first field in the table, and o_{O-1} corresponding to the last bit in the last field in the table. The field of PMI shall be in the increasing order of the subband index [3]. The first bit of each field corresponds to MSB and the last bit LSB. The RI bits sequence in Table 5.2.2.6.1-2 and Table 5.2.2.6.1-2A are encoded according to section 5.2.2.6.

5.2.2.6.2 Channel quality information formats for higher layer configured subband CQI reports

Table 5.2.2.6.2-1 shows the fields and the corresponding bit width for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port. N in Table 5.2.2.6.2-1 is defined in section 7.2 of [3].

Table 5.2.2.6.2-1A shows the fields and the corresponding bit width for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports.

Table 5.2.2.6.2-1: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port)

Field	Bit width
Wide-band CQI codeword	4
Subband differential CQI	$2N$

Table 5.2.2.6.2-1A Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports)

Field	Bit width	
	Rank = 1	Rank > 1
Wide-band CQI codeword 0	4	4
Subband differential CQI codeword 0	$2N$	$2N$
Wide-band CQI codeword 1	0	4
Subband differential CQI codeword 1	0	$2N$

Table 5.2.2.6.2-2, Table 5.2.2.6.2-2A and Table 5.2.2.6.2-2B show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 4, transmission mode 5, transmission mode 6, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI

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reporting with 2/4/8 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config* =2. The number of CSI-RS resources K is defined in [3] and *PMI-Config* is configured by higher layers [6].

Table 5.2.2.6.2-2B-1 and Table 5.2.2.6.2-2B-2 show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting.

Table5.2.2.6.2-2B-3 shows the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =1.

For Table 5.2.2.6.2-2, Table 5.2.2.6.2-2A, Table 5.2.2.6.2-2B, Table 5.2.2.6.2-2B-1, Table 5.2.2.6.2-2B-2 and Table 5.2.2.6.2-2B-3, N is defined in section 7.2 of [3]. For Table 5.2.2.6.2-2B-1 and Table 5.2.2.6.2-2B-2, the codebook configuration (N_1, N_2, O_1, O_2) is defined in [3], and *Codebook-Subset-SelectionConfig* is configured by higher layers [6]. The parameters (S_1, S_2) in rank 3 and 4 are defined as $(S_1, S_2) = (1, 1)$ for *Codebook-Subset-SelectionConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=2, $(S_1, S_2) = \left(O_1, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=3, $(S_1, S_2) = \left(O_1, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=4. The parameters (S_1, S_2) in rank 5 to 8 are defined as $(S_1, S_2) = (1, 1)$ for *Codebook-Subset-SelectionConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=2/3/4.

Table 5.2.2.6.2-2: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 4, transmission mode 5, transmission mode 6, transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config*=2, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wide-band CQI codeword 1	0	4	0	4
Subband differential CQI codeword 1	0	$2N$	0	$2N$
Precoding matrix indicator	2	1	4	4

Table 5.2.2.6.2-2A: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 8 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config*=2).

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4

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Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	2	2
Wideband second PMI i2	4	4	4	3
Field	**Bitwidth**			
	Rank = 5	**Rank = 6**	**Rank = 7**	**Rank = 8**
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1	2	2	2	0
Wideband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2B: Fields for channel quality information feedback for higher layer configured subband CQI reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 4 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config*=2, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	**Bitwidth**			
	Rank = 1	**Rank = 2**	**Rank = 3**	**Rank = 4**
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	0	0
Wideband second PMI i2	4	4	4	4

Table 5.2.2.6.2-2B-1: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured with Class A CSI reporting with codebook configuration (N_1, N_2, O_1, O_2) and *Codebook-Subset-SelectionConfig*=1)

Field	**Bit width**			
	Rank = 1	**Rank = 2**	**Rank =3**	**Rank =4**

Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1) \rceil$	$\lceil \log_2(N_1O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	2	2	1	1
Field	**Bit width**			
	Rank = 5	**Rank = 6**	**Rank =7**	**Rank =8**
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2B-2: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured with Class A CSI reporting with codebook configuration (N_1,N_2,O_1,O_2) and *Codebook-Subset-SelectionConfig*=2/3/4)

Field	**Bit width**			
	Rank = 1	**Rank = 2**	**Rank =3**	**Rank =4**

Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1) \rceil$	$\lceil \log_2(N_1O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$
Wideband second PMI i2	2	2	4	3
Field	**Bit width**			
	Rank = 5	**Rank = 6**	**Rank =7**	**Rank =8**
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2B-3: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured with Class B CSI reporting with 2/4/8 antenna ports with K=1 and *PMI-Config*=1)

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank =2	Rank =3	Rank =4
Wideband CQI codeword 0	4	4	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	0	$2N$	$2N$	$2N$
Precoding matrix indicator	2	1	3	3	2	1
Field	**Bit width**					
	8 antenna ports					
	Rank = 1	**Rank = 2**	**Rank = 3**	**Rank =4**	**Rank =5 to Rank = 8**	
Wideband CQI codeword 0	4	4	4	4	4	
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	
Wideband CQI codeword 1	0	4	4	4	4	
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$	$2N$	
Precoding matrix indicator	4	4	4	3	0	

Table 5.2.2.6.2-2C, Table 5.2.2.6.2-2D and Table 5.2.2.6.2-2E show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 4, transmission mode 6, transmission mode 8 configured with subband PMI/RI reporting, transmission mode 9 configured with subband PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with subband PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with subband PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K>1 and K=1 with *PMI-Config* =2. The number of CSI-RS resources K is defined in [3] and *PMI-Config* is configured by higher layers [6].

Table 5.2.2.6.2-2E-1 and Table 5.2.2.6.2-2E-2 show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured with subband PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting.

Table5.2.2.6.2-2E-3 shows the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured with subband PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =1.

For Table 5.2.2.6.2-2C, Table 5.2.2.6.2-2D, Table 5.2.2.6.2-2E, Table 5.2.2.6.2-2E-1, Table 5.2.2.6.2-2E-2 and Table 5.2.2.6.2-2E-3, N is defined in section 7.2 of [3]. For 5.2.2.6.2-2E-1 and Table 5.2.2.6.2-2E-2, the codebook configuration $\left(N_1, N_2, O_1, O_2\right)$ is defined in [3], and *Codebook-Subset-SelectionConfig* is configured by higher layers [6]. The parameters $\left(S_1, S_2\right)$ in rank 3 and 4 are defined as $\left(S_1, S_2\right) = \left(1, 1\right)$ for *Codebook-Subset-SelectionConfig*=1, $\left(S_1, S_2\right) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=2, $\left(S_1, S_2\right) = \left(O_1, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=3, $\left(S_1, S_2\right) = \left(O_1, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=4. The parameters $\left(S_1, S_2\right)$ in rank 5 to 8 are defined as $\left(S_1, S_2\right) = \left(1, 1\right)$ for *Codebook-Subset-SelectionConfig*=1, $\left(S_1, S_2\right) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=2/3/4.

Table 5.2.2.6.2-2C: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports (transmission mode 4 and transmission mode 6 configured with subband PMI reporting, transmission mode 8 configured with subband PMI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 and transmission 10 configured with subband PMI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with subband PMI/RI reporting with 2/4 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config*=2, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*).

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI codeword 0	4	4	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	$2N$
Wide-band CQI codeword 1	0	4	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	0	$2N$	$2N$	$2N$
Subband precoding matrix indicator	$2N$	N	$4N$	$4N$	$4N$	$4N$

Table 5.2.2.6.2-2D: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports with 8 antenna ports (transmission mode 9 configured with subband PMI reporting, transmission mode 10 configured with subband PMI reporting, and transmission mode 9/10 configured with subband PMI/RI reporting for Class B CSI reporting with K>1, and K=1 with *PMI-Config*=2)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	2	2
Subband second PMI i2	$4N$	$4N$	$4N$	$3N$
Field	Bitwidth			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1	2	2	2	0
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2E: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with subband PMI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9/10 configured with subband PMI/RI reporting with 2/4 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config*=2, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4

Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	0	0
Subband second PMI i2	$4N$	$4N$	$4N$	$4N$

Table 5.2.2.6.2-2E-1: Fields for channel quality information feedback for higher layer configured subband CQI reports and subband PMI reports (transmission mode 9/10 configured with Class A CSI reporting with codebook configuration (N_1,N_2,O_1,O_2) and *Codebook-Subset-SelectionConfig*=1)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1) \rceil$	$\lceil \log_2(N_1O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$
Subband second PMI i2	$2N$	$2N$	N	N
Field	**Bitwidth**			
	Rank = 5	**Rank = 6**	**Rank = 7**	**Rank = 8**
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2E-2: Fields for channel quality information feedback for higher layer configured subband CQI reports and subband PMI reports (transmission mode 9/10 configured with Class A CSI reporting with codebook configuration (N_1,N_2,O_1,O_2) and *Codebook-Subset-SelectionConfig*=2/3/4)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4

Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/2) \rceil$	$\lceil \log_2(N_1O_1/2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/2) \rceil$	$\lceil \log_2(N_2O_2/2) \rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$
Subband second PMI i2	$4N$	$4N$	$4N$	$3N$
Field	**Bitwidth**			
	Rank = 5	**Rank = 6**	**Rank = 7**	**Rank = 8**
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2E-3: Fields for channel quality information feedback for higher layer configured subband CQI reports and subband PMI reports (transmission mode 9/10 configured with Class B CSI reporting with 2/4/8 antenna ports with K=1 and *PMI-Config*=1)

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank =2	Rank =3	Rank =4
Wideband CQI codeword 0	4	4	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$	$2N$	$2N$
Precoding matrix indicator	$2N$	N	$3N$	$3N$	$2N$	N
Field	**Bit width**					
	8 antenna ports					
	Rank = 1	**Rank = 2**	**Rank = 3**	**Rank =4**	**Rank = 5 to Rank = 8**	
Wideband CQI codeword 0	4	4	4	4	4	
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	
Wideband CQI codeword 1	0	4	4	4	4	
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$	$2N$	
Precoding matrix indicator	$4N$	$4N$	$4N$	$3N$	0	

Table 5.2.2.6.2-3 shows the fields and the corresponding bit width for the rank indication feedback for higher layer configured subband CQI reports for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K=1 with 2/4/8 antenna ports.

Table 5.2.2.6.2-3A shows the fields and the corresponding bit width for the CSI-RS resource indication feedback for higher layer configured subband CQI reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1.

Table 5.2.2.6.2-3B shows the fields and the corresponding bit width for the joint CRI and RI feedback for higher layer configured subband CQI reports for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K>1, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1 and 2/4/8 antenna ports.

Table 5.2.2.6.2-3: Fields for rank indication feedback for higher layer configured subband CQI reports (transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K=1 with 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

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Table 5.2.2.6.2-3A: Fields for CRI feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K>1).

Field	Bit width		
	K = 2	K = 3 and K = 4	K = 5 to K = 8
CRI	1	2	3

Table 5.2.2.6.2-3B: Fields for joint CRI and RI feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K>1, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1 and 2/4/8 antenna ports).

Field	Bit width		
	Max 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	2	3

The channel quality bits in Table 5.2.2.6.2-1, Table 5.2.2.6.2-2, Table 5.2.2.6.2-2A, Table 5.2.2.6.2-2B, Table 5.2.2.6.2-2C, Table 5.2.2.6.2-2D, Table 5.2.2.6.2-2E, Table 5.2.2.6.2-2B-1, Table 5.2.2.6.2-2B-2, Table 5.2.2.6.2-2B-3, Table 5.2.2.6.2-2E-1, Table 5.2.2.6.2-2E-2 and Table 5.2.2.6.2-2E-3 form the bit sequence $o_0, o_1, o_2, ..., o_{O-1}$ with o_0 corresponding to the first bit of the first field in each of the tables, o_1 corresponding to the second bit of the first field in each of the tables, and o_{O-1} corresponding to the last bit in the last field in each of the tables. The field of the PMI and subband differential CQI shall be in the increasing order of the subband index [3]. The first bit of each field corresponds to MSB and the last bit LSB. The RI bits sequence in Table 5.2.2.6.2-3, 5.2.2.6.2-3B and the CRI sequence in Table 5.2.2.6.2-3A are encoded according to section 5.2.2.6.

5.2.2.6.3 Channel quality information formats for UE selected subband CQI reports

Table 5.2.2.6.3-1 shows the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port. L in Table 5.2.2.6.3-1 is defined in section 7.2 of [3].

Table 5.2.2.6.3-1A shows the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports.

Table 5.2.2.6.3-1: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port)

Field	Bit width
Wide-band CQI codeword	4
Subband differential CQI	2
Position of the M selected subbands	L

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Table 5.2.2.6.3-1A Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports)

Field	Bit width	
	Rank = 1	Rank >1
Wide-band CQI codeword 0	4	4
Subband differential CQI codeword 0	2	2
Wide-band CQI codeword 1	0	4
Subband differential CQI codeword 1	0	2
Position of the M selected subbands	L	L

Table 5.2.2.6.3-2, Table 5.2.2.6.3-2A and Table 5.2.2.6.3-2B show the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 4, transmission mode 6, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna port, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K>1 and K=1 with *PMI-Config* =2, where the number of CSI-RS resources K is defined in [3] and *PMI-Config* is configured by higher layers [6].

Table 5.2.2.6.3-2C and Table 5.2.2.6.3-2D show the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting.

Table 5.2.2.6.3-2E shows the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =1.

For Table 5.2.2.6.3-2, Table 5.2.2.6.3-2A, Table 5.2.2.6.3-2B, Table 5.2.2.6.3-2C, Table 5.2.2.6.3-2D and Table 5.2.2.6.3-2E, L is defined in section 7.2 of [3]. For Table 5.2.2.6.3-2C and Table 5.2.2.6.3-2D, the codebook configuration $\left(N_1, N_2, O_1, O_2\right)$ is defined in [3], and *Codebook-Subset-SelectionConfig* is configured by higher layers [6]. The parameters $\left(S_1, S_2\right)$ in rank 3 and 4 are defined as $\left(S_1, S_2\right)=\left(1, 1\right)$ for *Codebook-Subset-SelectionConfig*=1, $\left(S_1, S_2\right)=\left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=2, $\left(S_1, S_2\right)=\left(O_1, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=3, $\left(S_1, S_2\right)=\left(O_1, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=4. The parameters $\left(S_1, S_2\right)$ in rank 5 to 8 are defined as $\left(S_1, S_2\right)=\left(1, 1\right)$ for *Codebook-Subset-SelectionConfig*=1, $\left(S_1, S_2\right)=\left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=2/3/4.

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Table 5.2.2.6.3-2: Fields for channel quality information feedback for UE selected subband CQI reports
(transmission mode 4, transmission mode 6, transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config=2*, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	0	4	0	4
Subband differential CQI codeword 1	0	2	0	2
Position of the M selected subbands	L	L	L	L
Precoding matrix indicator	4	2	8	8

Table 5.2.2.6.3-2A: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 8 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config*=2).

Field	Bit width							
	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI codeword 0	4	4	4	4	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2	2	2	2	2
Wide-band CQI codeword 1	0	4	4	4	4	4	4	4
Subband differential CQI codeword 1	0	2	2	2	2	2	2	2
Position of the M selected subbands	L	L	L	L	L	L	L	L
Wideband first PMI i1	4	4	2	2	2	2	2	0
Wideband second PMI i2	4	4	4	3	0	0	0	0
Subband second PMI i2	4	4	4	3	0	0	0	0

Table 5.2.2.6.3-2B: Fields for channel quality information feedback for UE selected subband CQI reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 4 antenna ports for Class B CSI reporting with K>1, and K=1 with *PMI-Config*=2, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	2	2	2
Position of the M selected subbands	L	L	L	L
Wideband first PMI i1	4	4	0	0
Wideband second PMI i2	4	4	4	4
Subband second PMI i2	4	4	4	4

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Table 5.2.2.6.3-2C: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9/10 configured with PMI/RI reporting for Class A CSI reporting with codebook configuration (N_1, N_2, O_1, O_2) and *Codebook-Subset-SelectionConfig*=1)

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	2	2	2
Position of the M selected subbands	L	L	L	L
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1) \rceil$	$\lceil \log_2(N_1O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	2	2	1	1
Subband second PMI i2	2	2	1	1
Field	**Bit width**			
	Rank = 5	**Rank = 6**	**Rank = 7**	**Rank = 8**
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	2	2	2	2
Position of the M selected subbands	L	L	L	L
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	0	0	0	0
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.3-2D: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9/10 configured with PMI/RI reporting for Class A CSI reporting with codebook configuration (N_1, N_2, O_1, O_2) and *Codebook-Subset-SelectionConfig*=2/3/4)

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4

Field	Bit width			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	2	2	2
Position of the M selected subbands	L	L	L	L
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/2) \rceil$	$\lceil \log_2(N_1O_1/2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/2) \rceil$	$\lceil \log_2(N_2O_2/2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	4	4	4	3
Subband second PMI i2	4	4	4	3

Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	2	2	2	2
Position of the M selected subbands	L	L	L	L
Wideband first PMI i1,1	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$
Wideband second PMI i2	0	0	0	0
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.3-2E: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config*=1)

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank =2	Rank =3	Rank =4
Wideband CQI codeword 0	4	4	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2	2	2
Wideband CQI codeword 1	0	4	0	4	4	4
Subband differential CQI codeword 1	0	2	2	2	2	2
Position of the M selected subbands	L	L	L	L	L	L
Wideband Precoding matrix indicator	2	1	3	3	2	1
Subband Precoding matrix indicator	2	1	3	3	2	1

Field	Bit width				
	8 antenna ports				
	Rank = 1	Rank = 2	Rank = 3	Rank =4	Rank =5~8
Wideband CQI codeword 0	4	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2	2
Wideband CQI codeword 1	0	4	4	4	4
Subband differential CQI codeword 1	0	2	2	2	2
Position of the M selected subbands	L	L	L	L	L
Wideband Precoding matrix indicator	4	4	4	3	0
Subband Precoding matrix indicator	4	4	4	3	0

Table 5.2.2.6.3-3 shows the fields and the corresponding bit widths for the rank indication feedback for UE selected subband CQI reports for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna

ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K=1 with with 2/4/8 antenna ports.

Table 5.2.2.6.3-3A shows the fields and the corresponding bit widths for the CSI-RS resource indication feedback for UE selected subband CQI reports for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K>1.

Table 5.2.2.6.3-3B shows the fields and the corresponding bit widths for the joint CRI and RI feedback for UE selected subband CQI report for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K>1, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1 and 2/4/8 antenna ports.

Table 5.2.2.6.3-3: Fields for rank indication feedback for UE selected subband CQI reports (transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K=1 with with 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

Table 5.2.2.6.3-3A: Fields for CSI-RS resource indication feedback for UE selected subband CQI reports (transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K>1).

Field	Bit width		
	K = 2	K = 3 and K= 4	K = 5 to K = 8
CRI	1	2	3

Table 5.2.2.6.3-3B: Fields for joint CRI and RI feedback for UE selected subband CQI report (transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K>1, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1 and 2/4/8 antenna ports).

Field	Bit width		
	Max 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	2	3

The channel quality bits in Table 5.2.2.6.3-1, Table 5.2.2.6.3-2, Table 5.2.2.6.3-2A, Table 5.2.2.6.3-2B, Table 5.2.2.6.3-2C, Table 5.2.2.6.3-2D, and Table 5.2.2.6.3-2E form the bit sequence $o_0, o_1, o_2, \ldots, o_{O-1}$ with o_0 corresponding to the first bit of the first field in each of the tables, o_1 corresponding to the second bit of the first field in each of the tables, and o_{O-1} corresponding to the last bit in the last field in each of the tables. The field of PMI shall start with the wideband PMI followed by the PMI for the M selected subbands. The first bit of each field corresponds to MSB and the last bit LSB. The RI bits sequence in Table 5.2.2.6.3-3, Table 5.2.2.6.3-3B, and the CRI sequence in Table 5.2.2.6.3-3A are encoded according to section 5.2.2.6.

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5.2.2.6.4 Channel coding for CQI/PMI information in PUSCH

The channel quality bits input to the channel coding block are denoted by $o_0, o_1, o_2, o_3, ..., o_{O-1}$ where O is the number of bits. The number of channel quality bits depends on the transmission format. When PUCCH-based reporting format is used, the number of CQI/PMI bits is defined in section 5.2.3.3.1 for wideband reports and in section 5.2.3.3.2 for UE selected subbands reports. When PUSCH-based reporting format is used, the number of CQI/PMI bits is defined in section 5.2.2.6.1 for wideband reports, in section 5.2.2.6.2 for higher layer configured subbands reports and in section 5.2.2.6.3 for UE selected subbands reports.

The channel quality information is first coded using a (32, O) block code. The code words of the (32, O) block code are a linear combination of the 11 basis sequences denoted $M_{i,n}$ and defined in Table 5.2.2.6.4-1.

Table 5.2.2.6.4-1: Basis sequences for (32, O) code.

i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$	$M_{i,5}$	$M_{i,6}$	$M_{i,7}$	$M_{i,8}$	$M_{i,9}$	$M_{i,10}$
0	1	1	0	0	0	0	0	0	0	0	1
1	1	1	1	0	0	0	0	0	0	1	1
2	1	0	0	1	0	0	1	0	1	1	1
3	1	0	1	1	0	0	0	0	1	0	1
4	1	1	1	1	0	0	0	1	0	0	1
5	1	1	0	0	1	0	1	1	1	0	1
6	1	0	1	0	1	0	1	0	1	1	1
7	1	0	0	1	1	0	0	1	1	0	1
8	1	1	0	1	1	0	0	1	0	1	1
9	1	0	1	1	1	0	1	0	0	1	1
10	1	0	1	0	0	1	1	1	0	1	1
11	1	1	1	0	0	1	1	0	1	0	1
12	1	0	0	1	0	1	0	1	1	1	1
13	1	1	0	1	0	1	0	1	0	1	1
14	1	0	0	0	1	1	0	1	0	0	1
15	1	1	0	0	1	1	1	1	0	1	1
16	1	1	1	0	1	1	1	0	0	1	0
17	1	0	0	1	1	1	0	0	1	0	0
18	1	1	0	1	1	1	1	1	0	0	0
19	1	0	0	0	0	1	1	0	0	0	0
20	1	0	1	0	0	0	1	0	0	0	1
21	1	1	0	1	0	0	0	0	0	1	1
22	1	0	0	0	1	0	0	1	1	0	1
23	1	1	1	0	1	0	0	0	1	1	1
24	1	1	1	1	1	0	1	1	1	1	0
25	1	1	0	0	0	1	1	1	0	0	1
26	1	0	1	1	0	1	0	0	1	1	0
27	1	1	1	1	0	1	0	1	1	1	0
28	1	0	1	0	1	1	1	0	1	0	0
29	1	0	1	1	1	1	1	1	1	0	0
30	1	1	1	1	1	1	1	1	1	1	1
31	1	0	0	0	0	0	0	0	0	0	0

The encoded CQI/PMI block is denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where $B = 32$ and

$$b_i = \sum_{n=0}^{O-1} (o_n \cdot M_{i,n}) \bmod 2 \text{ where } i = 0, 1, 2, \ldots, B\text{-}1.$$

The output bit sequence $q_0, q_1, q_2, q_3, ..., q_{N_L \cdot Q_{CQI}-1}$ is obtained by circular repetition of the encoded CQI/PMI block as follows

$q_i = b_{(i \bmod B)}$ where $i = 0, 1, 2, \ldots, N_L Q_{CQI}\text{-}1$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto .

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5.2.2.6.5 Channel coding for more than 11 bits of HARQ-ACK information

The HARQ-ACK bits input to the channel coding block are denoted by $o_0^{ACK}, o_1^{ACK}, ..., o_{O^{ACK}-1}^{ACK}$ where $11 < O^{ACK} \leq 22$ is the number of bits.

The sequences of bits $o_0^{ACK}, o_1^{ACK}, o_2^{ACK}, ..., o_{\lceil O^{ACK}/2 \rceil - 1}^{ACK}$ and $o_{\lceil O^{ACK}/2 \rceil}^{ACK}, o_{\lceil O^{ACK}/2 \rceil + 1}^{ACK}, o_{\lceil O^{ACK}/2 \rceil + 2}^{ACK}, ..., o_{O^{ACK}-1}^{ACK}$ are encoded as follows

$$\tilde{q}_i = \sum_{n=0}^{\lceil O^{ACK}/2 \rceil - 1} \left(o_n^{ACK} \cdot M_{i,n} \right) \bmod 2$$

and

$$\tilde{\tilde{q}}_i = \sum_{n=0}^{O^{ACK} - \lceil O^{ACK}/2 \rceil - 1} \left(o_{\lceil O^{ACK}/2 \rceil + n}^{ACK} \cdot M_{i,n} \right) \bmod 2$$

where $i = 0, 1, 2, \ldots, 31$ and the basis sequences $M_{i,n}$ are defined in Table 5.2.2.6.4-1.

The output bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, ..., q_{Q_{ACK}-1}^{ACK}$ is obtained by the concatenation and circular repetition of the bit sequences $\tilde{q}_0, \tilde{q}_1, \tilde{q}_2, ..., \tilde{q}_{31}$ and $\tilde{\tilde{q}}_0, \tilde{\tilde{q}}_1, \tilde{\tilde{q}}_2, ..., \tilde{\tilde{q}}_{31}$ as follows:

Set $i = 0$

while $i < \lceil Q/2 \rceil \cdot Q_m$

$q_i^{ACK} = \tilde{q}_{i \bmod 32}$

$i = i + 1$

end while

Set $i = 0$

while $i < (Q - \lceil Q/2 \rceil) \cdot Q_m$

$q_{\lceil Q'/2 \rceil Q_m + i}^{ACK} = \tilde{\tilde{q}}_{i \bmod 32}$

$i = i + 1$

end while

5.2.2.7 Data and control multiplexing

The control and data multiplexing is performed such that HARQ-ACK information is present on both slots and is mapped to resources around the demodulation reference signals. In addition, the multiplexing ensures that control and data information are mapped to different modulation symbols.

The inputs to the data and control multiplexing are the coded bits of the control information denoted by $q_0, q_1, q_2, q_3, ..., q_{N_L \cdot Q_{CQI}-1}$ and the coded bits of the UL-SCH denoted by $f_0, f_1, f_2, f_3, ..., f_{G-1}$. The output of the data and control multiplexing operation is denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, \underline{g}_3, ..., \underline{g}_{H'-1}$, where $H = (G + N_L \cdot Q_{CQI})$ and $H' = H/(N_L \cdot Q_m)$, and where $\underline{g}_i$, $i = 0, ..., H'-1$ are column vectors of length $(Q_m \cdot N_L)$. H is the total number of coded bits allocated for UL-SCH data and CQI/PMI information across the N_L transmission layers of the transport block.

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In case where more than one UL-SCH transport block are transmitted in a subframe of an UL cell, the CQI/PMI information is multiplexed with data only on the UL-SCH transport block with highest I_{MCS} value on the initial grant. In case the two transport blocks have the same I_{MCS} value in the corresponding initial UL grant, the CQI/PMI information is multiplexed with data only on the first transport block. For that UL-SCH transport block or in the case of single transport block transmission, and assuming that N_L is the number of layers onto which the UL-SCH transport block is mapped, the control information and the data shall be multiplexed as follows:

Set i, j, k to 0

while $j < N_L \cdot Q_{CQI}$ -- first place the control information

$\underline{g}_k = [q_j \ldots q_{j+N_L \cdot Q_m - 1}]^T$

$j = j + N_L \cdot Q_m$

$k = k + 1$

end while

while $i < G$ -- then place the data

$\underline{g}_k = [f_i \ldots f_{i+Q_m \cdot N_L - 1}]^T$

$i = i + Q_m \cdot N_L$

$k = k + 1$

end while

5.2.2.8 Channel interleaver

The channel interleaver described in this section in conjunction with the resource element mapping for PUSCH in [2] implements a time-first mapping of modulation symbols onto the transmit waveform while ensuring that the HARQ-ACK and RI information are present on both slots in the subframe. HARQ-ACK information is mapped to resources around the uplink demodulation reference signals while RI information is mapped to resources around those used by HARQ-ACK.

The input to the channel interleaver are denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, \ldots, \underline{g}_{H'-1}$, $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, \ldots, \underline{q}_{Q'_{RI}-1}^{RI}$ and $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, \ldots, \underline{q}_{Q'_{ACK}-1}^{ACK}$. In case where more than one UL-SCH transport block are transmitted in a subframe of an UL cell, the HARQ-ACK and RI information are multiplexed with data on both UL-SCH transport blocks.

The number of modulation symbols per layer in the subframe is given by $H'_{total} = H' + Q'_{RI}$. The output bit sequence from the channel interleaver is derived as follows:

(1) Assign $C_{mux} = N_{\text{symb}}^{\text{PUSCH}}$ to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2,…, $C_{mux} - 1$ from left to right. $N_{\text{symb}}^{\text{PUSCH}}$ is determined according to section 5.2.2.6.

(2) The number of rows of the matrix is $R_{mux} = (H'_{total} \cdot Q_m \cdot N_L)/C_{mux}$ and we define $R'_{mux} = R_{mux}/(Q_m \cdot N_L)$.

The rows of the rectangular matrix are numbered 0, 1, 2,…, $R_{mux} - 1$ from top to bottom.

(3) If rank information is transmitted in this subframe, the vector sequence $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, \ldots, \underline{q}_{Q'_{RI}-1}^{RI}$ is written onto the columns indicated by Table 5.2.2.8-1, and by sets of $(Q_m \cdot N_L)$ rows starting from the last row and moving upwards according to the following pseudo-code.

Set i, j to 0.

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Set r to $R'_{mux}-1$

while $i < Q'_{RI}$

$c_{RI} = \text{Column Set}(j)$

$\underline{y}_{r\times C_{mux}+c_{RI}} = \underline{q}_i^{RI}$

$i = i+1$

$r = R'_{mux}-1-\lfloor i/4 \rfloor$

$j = (j+3) \bmod 4$

end while

Where ColumnSet is given in Table 5.2.2.8-1 and indexed left to right from 0 to 3.

(4) Write the input vector sequence, for $k = 0, 1, \ldots, H'-1$, into the $(R_{mux} \times C_{mux})$ matrix by sets of $(Q_m \cdot N_L)$ rows starting with the vector $\underline{y}_0$ in column 0 and rows 0 to $(Q_m \cdot N_L - 1)$ and skipping the matrix entries that are already occupied:

$$\begin{bmatrix} \underline{y}_0 & \underline{y}_1 & \underline{y}_2 & \cdots & \underline{y}_{C_{mux}-1} \\ \underline{y}_{C_{mux}} & \underline{y}_{C_{mux}+1} & \underline{y}_{C_{mux}+2} & \cdots & \underline{y}_{2C_{mux}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \underline{y}_{(R'_{mux}-1)\times C_{mux}} & \underline{y}_{(R'_{mux}-1)\times C_{mux}+1} & \underline{y}_{(R'_{mux}-1)\times C_{mux}+2} & \cdots & \underline{y}_{(R'_{mux}\times C_{mux}-1)} \end{bmatrix}$$

The pseudocode is as follows:

Set i, k to 0.

while k < H',

if $\underline{y}_i$ is not assigned to RI symbols

$\underline{y}_i = \underline{g}_k$

k = k + 1

end if

i = i+1

end while

(5) If HARQ-ACK information is transmitted in this subframe, the vector sequence $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, \ldots, \underline{q}_{Q'_{ACK}-1}^{ACK}$ is written onto the columns indicated by Table 5.2.2.8-2, and by sets of $(Q_m \cdot N_L)$ rows starting from the last row and moving upwards according to the following pseudo-code. Note that this operation overwrites some of the channel interleaver entries obtained in step (4).

Set i, j to 0.

Set r to $R'_{mux}-1$

while $i < Q'_{ACK}$

$c_{ACK} = \text{ColumnSet}(j)$

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$\underline{y}_{r \times C_{mux}+c_{ACK}} = \underline{q}_i^{ACK}$

$i = i+1$

$r = R'_{mux} - 1 - \lfloor i/4 \rfloor$

$j = (j+3) \bmod 4$

end while

Where ColumnSet is given in Table 5.2.2.8-2 and indexed left to right from 0 to 3.

(6) The output of the block interleaver is the bit sequence read out column by column from the $(R_{mux} \times C_{mux})$ matrix. The bits after channel interleaving are denoted by $h_0, h_1, h_2, ..., h_{H+N_L \cdot Q_{RI}-1}$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto.

Table 5.2.2.8-1: Column set for insertion of rank information.

CP configuration	Column Set
Normal	{1, 4, 7, 10}
Extended	{0, 3, 5, 8}

Table 5.2.2.8-2: Column set for insertion of HARQ-ACK information.

CP configuration	Column Set
Normal	{2, 3, 8, 9}
Extended	{1, 2, 6, 7}

The same channel interleaver procedures for RI are applied for CRI, using CRI instead of RI in the equations.

5.2.3 Uplink control information on PUCCH

Data arrives to the coding unit in the form of indicators for measurement indication, scheduling request and HARQ acknowledgement.

Three forms of channel coding are used as shown in Figure 5.2.3-1,

- one for HARQ-ACK and for combination of HARQ-ACK and periodic CSI transmitted on PUCCH format 3, including the cases with scheduling request,
- another for the channel quality information CQI/PMI transmitted on PUCCH format 2,
- and another for combination of CQI/PMI and HARQ-ACK transmitted on PUCCH format 2/2a/2b.

A fourth form of channel coding is used as shown in Figure 5.2.3-2, for HARQ-ACK and for combination of HARQ-ACK and periodic CSI transmitted on PUCCH format 4 or PUCCH format 5 including the cases with scheduling request, or for periodic CSI transmitted on PUCCH format 4 or PUCCH format 5 including the cases with scheduling request.

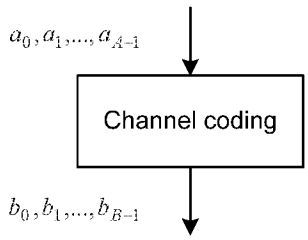


Figure 5.2.3-1: Processing for UCI.

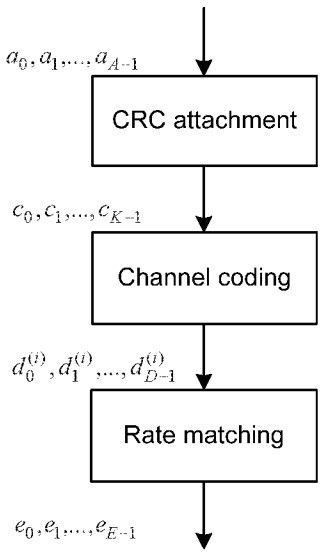


Figure 5.2.3-2: Processing for UCI.

5.2.3.1 Channel coding for UCI HARQ-ACK

The HARQ-ACK bits are received from higher layers for each subframe of each cell. Each positive acknowledgement (ACK) is encoded as a binary '1' and each negative acknowledgement (NACK) is encoded as a binary '0'. For UEs configured with no more than five DL cells, or for UEs configured by higher layers with *codebooksizeDetermination-r13 = 1*, and for the case where PUCCH format 3, PUCCH format 4 or PUCCH format 5 [2] is configured by higher layers and is used for transmission of the HARQ-ACK feedback information, the HARQ-ACK feedback consists of the concatenation of HARQ-ACK bits for each of the serving cells. For UEs configured by higher layers with *codebooksizeDetermination-r13 = 0*, the HARQ-ACK feedback consists of the HARQ-ACK bits for the serving cells depending on the Downlink Assignment Index (DAI) as in Table 5.3.3.1.1-2 and as defined in [3]. For cells configured with transmission modes 1, 2, 5, 6 or 7 [3], i.e., single codeword transmission modes, 1 bit of HARQ-ACK information, a_k, is used for that cell. For cells configured with other transmission modes, 2 bits of HARQ-ACK information are used for those cells, i.e., a_k, a_{k+1} with a_k corresponding to HARQ-ACK bit for codeword 0 and a_{k+1} corresponding to that for codeword 1.

Define O^{ACK} as the number of HARQ-ACK feedback bits and $N_{A/N}^{\text{PUCCH format 3}}$ as the number of HARQ-ACK feedback bits including the possible concurrent transmission of scheduling request and/or periodic CSI when PUCCH format 3 is used for transmission of HARQ-ACK feedback (section 10.1 in [3]), and $N_{A/N}^{\text{PUCCH format 4}}$ as the number of HARQ-ACK feedback bits including the possible concurrent transmission of scheduling request and/or periodic CSI when PUCCH format 4 is used for transmission of HARQ-ACK feedback (section 10.1 in [3]), and $N_{A/N}^{\text{PUCCH format 5}}$ as the number of HARQ-ACK feedback bits including the possible concurrent transmission of scheduling request and/or periodic CSI when PUCCH format 5 is used for transmission of HARQ-ACK feedback (section 10.1 in [3]).

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For UEs configured by higher layers with *codebooksizeDetermination-r13* = *0*, the bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined according to the Downlink Assignment Index (DAI) as in Table 5.3.3.1.1-2 and as defined in [3]. Otherwise, the bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined as below.

For FDD, the sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for different cells according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c < N_{cells}^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUCCH by higher layers $\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$j = j + 1$

end if

end if

$c = c + 1$

end while

For the aggregation of more than one DL cell including a primary cell using FDD and at least one secondary cell using TDD, the sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for different cells. Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits in UL subframe n for the c-th serving cell. For a cell using TDD, the subframes are determined by the DL-reference UL/DL configuration if the UE is configured with higher layer parameter *eimta-HARQ-ReferenceConfig*, and determined by the UL/DL configuration otherwise. For a cell using TDD, $B_c^{DL} = 1$ if subframe n-4 in the cell is a DL subframe or a special subframe with special subframe configurations 1/2/3/4/6/7/8/9 and normal downlink CP or a special subframe with special subframe configurations 1/2/3/5/6/7 and extended downlink CP, and $B_c^{DL} = 0$ otherwise. For a cell using FDD, $B_c^{DL} = 1$.

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The sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

if $B_c^{DL} = 1$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUCCH by higher layers $\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$j = j + 1$

end if

end if

end if

$c = c + 1$

end while

For the cases with TDD primary cell, the sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is obtained from the HARQ-ACK bits for different cells and different subframes.

Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits in cell c as defined in Section 7.3 of [3].

The number of HARQ-ACK bits k and the number of HARQ-ACK bits after spatial bundling k_b are computed as follows:

Set $k = 0$ – counter of HARQ-ACK bits

Set $k_b = 0$ – counter of HARQ-ACK bits after spatial bundling

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

while c < N_{cells}^{DL}

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set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$k = k + 1$

$k_b = k_b + 1$

else

$k = k + 2$

$k_b = k_b + 1$

end if

$l = l+1$

end while

$c = c + 1$

end while

In case the transmission of HARQ-ACK feedback using PUCCH format 3, PUCCH format 4 or PUCCH format 5 coincides with a sub-frame configured to the UE by higher layers for transmission of scheduling request, the number of scheduling request bit O^{SR} is 1; otherwise O^{SR}=0.

In case the transmission of HARQ-ACK feedback using PUCCH format 3, PUCCH format 4 or PUCCH format 5 coincides with a sub-frame configured to the UE by higher layers for transmission of periodic CSI, O^{CSI} is the number of periodic CSI bit(s) for the CSI report as defined in section 7.2.2 [3]; otherwise O^{CSI}=0.

For PUCCH format 3, the number of HARQ-ACK feedback bits O^{ACK} is computed as follows:
Set $k_{\max} = 20$ when TDD is used in all the configured serving cell(s) of the UE and $k_{\max} = 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell.

If $k \le k_{\max}$ and $O^{\text{CSI}} = 0$, or if $k + O^{\text{CSI}} + O^{SR} \le 22$ and $O^{\text{CSI}} > 0$, or if $k_b + O^{\text{CSI}} + O^{SR} > 22$ and $k \le k_{\max}$, then

- $O^{ACK} = k$

else,

- $O^{ACK} = k_b$.

For PUCCH format 4 or PUCCH format 5, $O^{ACK} = k$ if the UE is not configured with spatial bundling on PUCCH by higher layers; otherwise $O^{ACK} = k_b$.

If $O^{ACK} = k$, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set $c = 0$ -- cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ -- HARQ-ACK bit index

while c < N_{cells}^{DL}

set $l = 0$;

while $l < B_c^{DL}$

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if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$[\tilde{o}_j^{ACK}, \tilde{o}_{j+1}^{ACK}] = [o_{c,2l}^{ACK}, o_{c,2l+1}^{ACK}]$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 2$

end if

$l = l+1$

end while

$c = c + 1$

end while

If $O^{ACK} = k_b$, spatial bundling is applied to all subframes in all cells and the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while c < N_{cells}^{DL}

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell as defined in Section 7.3 of [3]

$j = j + 1$

end if

$l = l+1$

end while

$c = c + 1$

end while

In case the transmission of HARQ-ACK feedback using PUCCH format 3, PUCCH format 4 or PUCCH format 5 [2] coincides with a sub-frame configured to the UE by higher layers for transmission of scheduling request, the scheduling request bit (1 = positive SR; 0 = negative SR) is appended at the end of the sequence of concatenated HARQ-ACK bits.

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In case the transmission of HARQ-ACK feedback using PUCCH format 3, PUCCH format 4 or PUCCH format 5 [2] coincides with a sub-frame configured to the UE by higher layers for transmission of periodic CSI, and periodic CSI is not dropped as defined in section 7.3.2 and section 10.1.1 of [3], the periodic CSI bits for the CSI report as defined in section 7.2.2 [3] are appended at the end of the sequence of concatenated HARQ-ACK bits and scheduling request bit (if any), where in case of CSI report for more than one DL cell, the CSI report for each DL cell is appended in increasing order of cell index. As with the transmission of the scheduling request, the procedure above is used with $N_{A/N}^{\text{PUCCH format 3}}$, $N_{A/N}^{\text{PUCCH format 4}}$ or $N_{A/N}^{\text{PUCCH format 5}}$ including the number of periodic CSI bits and scheduling request bit (if any).

For $N_{A/N}^{\text{PUCCH format 3}} \le 11$, the bit sequence $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 3}}-1}$ is obtained by setting $a_i = \tilde{o}_i^{ACK}$.

For $11 < N_{A/N}^{\text{PUCCH format 3}} \le 22$, the bit sequence $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 3}}-1}$ is obtained by setting $a_{i/2} = \tilde{o}_i^{ACK}$ if i is even and $a_{\left\lceil N_{A/N}^{PUCCH format 3}/2 \right\rceil + (i-1)/2} = \tilde{o}_i^{ACK}$ if i is odd.

For $N_{A/N}^{\text{PUCCH format 3}} \le 11$, the sequence of bits $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 3}}-1}$ is encoded as follows

$$\tilde{b}_i = \sum_{n=0}^{N_{A/N}^{\text{PUCCH format 3}}-1} (a_n \cdot M_{i,n}) \bmod 2$$

where $i = 0, 1, 2, \ldots, 31$ and the basis sequences $M_{i,n}$ are defined in Table 5.2.2.6.4-1.

The output bit sequence $b_0, b_1, b_2, \ldots, b_{B-1}$ is obtained by circular repetition of the sequence $\tilde{b}_0, \tilde{b}_1, \tilde{b}_2, \ldots, \tilde{b}_{31}$

$$b_i = \tilde{b}_{(i \bmod 32)}$$

where $i = 0, 1, 2, \ldots, B$-1 and where $B = 4 \cdot N_{\text{sc}}^{\text{RB}}$.

For $11 < N_{A/N}^{\text{PUCCH format 3}} \le 22$, the sequences of bits $a_0, a_1, a_2, \ldots, a_{\left\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \right\rceil - 1}$ and $a_{\left\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \right\rceil}, a_{\left\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \right\rceil + 1}, a_{\left\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \right\rceil + 2}, \ldots, a_{N_{A/N}^{\text{PUCCH format 3}}-1}$ are encoded as follows

$$\tilde{b}_i = \sum_{n=0}^{\left\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \right\rceil - 1} (a_n \cdot M_{i,n}) \bmod 2$$

and

$$\tilde{\tilde{b}}_i = \sum_{n=0}^{N_{A/N}^{\text{PUCCH format 3}} - \left\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \right\rceil - 1} \left(a_{\left\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \right\rceil + n} \cdot M_{i,n} \right) \bmod 2$$

where $i = 0, 1, 2, \ldots, 23$ and the basis sequences $M_{i,n}$ are defined in Table 5.2.2.6.4-1.

The output bit sequence $b_0, b_1, b_2, \ldots, b_{B-1}$ where $B = 4 \cdot N_{\text{sc}}^{\text{RB}}$ is obtained by the alternate concatenation of the bit sequences $\tilde{b}_0, \tilde{b}_1, \tilde{b}_2, \ldots, \tilde{b}_{23}$ and $\tilde{\tilde{b}}_0, \tilde{\tilde{b}}_1, \tilde{\tilde{b}}_2, \ldots, \tilde{\tilde{b}}_{23}$ as follows

Set $i, j = 0$

while $i < 4 \cdot N_{\text{sc}}^{\text{RB}}$

$$b_i = \tilde{b}_j, \; b_{i+1} = \tilde{b}_{j+1}$$

$b_{i+2} = \tilde{\tilde{b}}_j$, $b_{i+3} = \tilde{\tilde{b}}_{j+1}$

$i = i + 4$

$j = j + 2$

end while

For $N_{A/N}^{\text{PUCCH format 4}} > 22$, the bit sequence $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 4}}-1}$ is obtained by setting $a_i = \tilde{o}_i^{ACK}$, and the output bit sequence after the rate matching is denoted by $e_0, e_1, e_2, \ldots, e_{E-1}$, where $E = Q_m \cdot M_{RB}^{PUCCH4} \cdot N_{symb}^{PUSCH} \cdot N_{sc}^{RB}$, Q_m is the modulation order of the PUCCH format 4, N_{symb}^{PUSCH} is determined according to section 5.2.4.1, and M_{RB}^{PUCCH4} represents the bandwidth of the PUCCH format 4 in terms of resource blocks [2]. The CRC attachment, channel coding and rate matching are performed according to sections 5.1.1 by setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 4}}-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

For $N_{A/N}^{\text{PUCCH format 5}} > 22$, the bit sequence $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 5}}-1}$ is obtained by setting $a_i = \tilde{o}_i^{ACK}$, and the output bit sequence after the rate matching is denoted by $e_0, e_1, e_2, \ldots, e_{E-1}$, where $E = Q_m \cdot N_{symb}^{PUSCH} \cdot N_{sc}^{RB} / 2$, Q_m is the modulation order of the PUCCH format 5 and N_{symb}^{PUSCH} is determined according to section 5.2.4.1. The CRC attachment, channel coding and rate matching are performed according to sections 5.1.1 by setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 5}}-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

When PUCCH format 3, PUCCH format 4 or PUCCH format 5 is not used for transmission of HARQ-ACK feedback, the HARQ-ACK bits are processed for transmission according to section 10.1 in [3].

5.2.3.2 Channel coding for UCI scheduling request

The scheduling request indication is received from higher layers and is processed according to [2].

5.2.3.3 Channel coding for UCI channel quality information

The channel quality and possible concurrent scheduling request bits input to the channel coding block are denoted by $a_0, a_1, a_2, a_3, \ldots, a_{A-1}$ where A is the number of bits. The number of channel quality bits depends on the transmission format as indicated in section 5.2.3.3.1 for wideband reports and in section 5.2.3.3.2 for UE-selected subbands reports.

For PUCCH format 2, the channel quality information is coded using a $(20, A)$ code. The code words of the $(20, A)$ code are a linear combination of the 13 basis sequences denoted $M_{i,n}$ and defined in Table 5.2.3.3-1.

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Table 5.2.3.3-1: Basis sequences for (20, *A*) code.

i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$	$M_{i,5}$	$M_{i,6}$	$M_{i,7}$	$M_{i,8}$	$M_{i,9}$	$M_{i,10}$	$M_{i,11}$	$M_{i,12}$
0	1	1	0	0	0	0	0	0	0	0	1	1	0
1	1	1	1	0	0	0	0	0	0	1	1	1	0
2	1	0	0	1	0	0	1	0	1	1	1	1	1
3	1	0	1	1	0	0	0	0	1	0	1	1	1
4	1	1	1	1	0	0	0	1	0	0	1	1	1
5	1	1	0	0	1	0	1	1	1	0	1	1	1
6	1	0	1	0	1	0	1	0	1	1	1	1	1
7	1	0	0	1	1	0	0	1	1	0	1	1	1
8	1	1	0	1	1	0	0	1	0	1	1	1	1
9	1	0	1	1	1	0	1	0	0	1	1	1	1
10	1	0	1	0	0	1	1	1	0	1	1	1	1
11	1	1	1	0	0	1	1	0	1	0	1	1	1
12	1	0	0	1	0	1	0	1	1	1	1	1	1
13	1	1	0	1	0	1	0	1	0	1	1	1	1
14	1	0	0	0	1	1	0	1	0	0	1	0	1
15	1	1	0	0	1	1	1	1	0	1	1	0	1
16	1	1	1	0	1	1	1	0	0	1	0	1	1
17	1	0	0	1	1	1	0	0	1	0	0	1	1
18	1	1	0	1	1	1	1	1	0	0	0	0	0
19	1	0	0	0	0	1	1	0	0	0	0	0	0

After encoding the bits are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where $B = 20$ and with

$$b_i = \sum_{n=0}^{A-1} \left(a_n \cdot M_{i,n}\right) \bmod 2 \text{ where } i = 0, 1, 2, \ldots, B\text{-}1.$$

For PUCCH format 4, the output bit sequence after the rate matching is denoted by $e_0, e_1, e_2, ..., e_{E-1}$, where $E = Q_m \cdot M_{RB}^{PUCCH\,4} \cdot N_{symb}^{PUSCH} \cdot N_{sc}^{RB}$, Q_m is the modulation order of the PUCCH format 4, N_{symb}^{PUSCH} is determined according to section 5.2.4.1, and $M_{RB}^{PUCCH\,4}$ represents the bandwidth of the PUCCH format 4 in terms of resource blocks [2]. The CRC attachment, channel coding and rate matching are performed according to sections 5.1.1 by setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $a_0, a_1, a_2, ..., a_{A-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

For PUCCH format 5, the output bit sequence after the rate matching is denoted by $e_0, e_1, e_2, ..., e_{E-1}$, where $E = Q_m \cdot N_{symb}^{PUSCH} \cdot N_{sc}^{RB} / 2$, Q_m is the modulation order of the PUCCH format 5 and N_{symb}^{PUSCH} is determined according to section 5.2.4.1. The CRC attachment, channel coding and rate matching are performed according to sections 5.1.1 by setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $a_0, a_1, a_2, ..., a_{A-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

5.2.3.3.1 Channel quality information formats for wideband reports

Table 5.2.3.3.1-1 shows the fields and the corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with a transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 9/10 configured without PMI with Class B CSI reporting.

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Table 5.2.3.3.1-1A shows the fields and the corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports.

Table 5.2.3.3.1-1: UCI fields for channel quality information feedback for wideband CQI reports (transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 9/10 configured without PMI with Class B CSI reporting).

Field	Bit width
Wide-band CQI	4

Table 5.2.3.3.1-1A: UCI fields for channel quality information feedback for wideband CQI reports (transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports)

Field	Bit width	
	Rank = 1	Rank > 1
Wide-band CQI	4	4
Spatial differential CQI	0	3

Table 5.2.3.3.1-2 shows the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 4, transmission mode 5, transmission mode 6, and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.1-2: UCI fields for channel quality information feedback for wideband CQI reports (transmission mode 4, transmission mode 5, transmission mode 6, and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
Precoding matrix indicator	2	1	4	4

Table 5.2.3.3.1-2A and Table 5.2.3.3.1-2B show the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 10 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =2, K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*. The number of CSI-RS resources K is defined in [3] and *PMI-Config* is configured by higher layers [6].

Table 5.2.3.3.1-2A-1and Table 5.2.3.3.1-2A-2 show the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9 /10 configured with PMI/RI reporting with Class A CSI reporting.

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Table 5.2.3.3.1-2A: UCI fields for transmission of wideband CQI and precoding information (i2) (transmission mode 9 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 10 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config*=2, K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width							
	2 antenna ports		4 antenna ports		8 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank > 1	Rank = 1	Rank = 2,3	Rank = 4	Rank > 4
Wide-band CQI	4	4	4	4	4	4	4	4
Spatial differential CQI	0	3	0	3	0	3	3	3
Wide-band PMI (2 or 4 antenna ports) or i2 (8 antenna ports)	2	1	4	4	4	4	3	0

Table 5.2.3.3.1-2A-1: UCI fields for transmission of wideband CQI and precoding information (i2) (transmission mode 9/10 configured PMI/RI with Class A CSI reporting and with codebook configuration (N_1, N_2, O_1, O_2), and *Codebook-Subset-SelectionConfig*=1)

Field	Bit width							
	8/12/16 antenna ports							
	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI	4	4	4	4	4	4	4	4
Spatial differential CQI	0	3	3	3	3	3	3	3
Wide-band i2	2	2	1	1	0	0	0	0

Table 5.2.3.3.1-2A-2: UCI fields for transmission of wideband CQI and precoding information (i2) (transmission mode 9/10 configured PMI/RI with Class A CSI reporting and with codebook configuration (N_1, N_2, O_1, O_2), and *Codebook-Subset-SelectionConfig*=2/3/4)

Field	Bit width							
	8/12/16 antenna ports							
	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI	4	4	4	4	4	4	4	4
Spatial differential CQI	0	3	3	3	3	3	3	3
Wide-band i2	4	4	4	3	0	0	0	0

Table 5.2.3.3.1-2B: UCI fields for transmission of wideband CQI and precoding information (i1, i2) for transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config*=2, K>1

Field	Bit width							
	8 antenna ports							
	Rank = 1	Rank = 2	Rank = 3	Rank =4	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI	4	4	4	4	4	4	4	4
Spatial differential CQI	0	3	3	3	3	3	3	3
i1	3	3	1	1	2	2	2	0
Wide-band i2	1	1	3	3	0	0	0	0

Table 5.2.3.3.1-2C and Table 5.2.3.3.1-2D show the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions for 4 antenna ports associated with transmission modes 8, 9 and 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with 4 antenna ports with K=1 and *PMI-Config* =2, K>1, and *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

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Table 5.2.3.3.1-2E shows the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =1.

Table 5.2.3.3.1-2C: UCI fields for transmission of wideband CQI and precoding information (i2) with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with 4 antenna ports for Class B CSI reporting with K=1 with *PMI-Config*=2, K>1, and *alternativeCodeBookEnabledFor4TX-r12=TRUE*))

Field	Bit width			
	4 antenna ports			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	3	3
Wideband i2	4	4	4	4

Table 5.2.3.3.1-2D: UCI fields for transmission of wideband CQI and precoding information (i1, i2) with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with 4 antenna ports for Class B CSI reporting with K=1 and *PMI-Config*=2, K>1, and *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	4 antenna ports			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	3	3
i1	2	2	0	0
Wideband i2	2	2	4	4

Table 5.2.3.3.1-2E: UCI fields for transmission of wideband CQI and precoding information (transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config*=1)

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI	4	4	4	4	4	4
Spatial differential CQI	0	3	0	3	3	3
Wide-band PMI	2	1	3	3	2	1
Field	Bit width					
	8 antenna ports					
	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Rank = 5 to Rank = 8	
Wide-band CQI	4	4	4	4	4	
Spatial differential CQI	0	3	3	3	3	
Wide-band PMI	4	4	4	3	0	

Table 5.2.3.3.1-3 shows the fields and the corresponding bit widths for the rank indication feedback for wideband reports for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting , transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports.

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Table 5.2.3.3.1-3: UCI fields for rank indication feedback for wideband reports (transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

Table 5.2.3.3.1-3A shows the fields and the corresponding bit widths for the joint transmission of rank indication and i1 for wideband reports for PDSCH transmissions associated with transmission mode 9 and transmission mode 10, and transmission mode 9/10 configured with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config=2*, and K>1, except with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*.

Table 5.2.3.3.1-3A: UCI fields for joint report of RI and i1 (transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12 =TRUE* and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*, and transmission mode 9/10 configured with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config=2*, and K>1, except with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*)

Field	Bit width					
	2 antenna ports	4 antenna ports		8 antenna ports		
		Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	4	5	5
i1	-	-	-			

Table 5.2.3.3.1-3B shows the fields and the corresponding bit widths for the joint transmission of rank indication and i1 for wideband reports for PDSCH transmissions associated with transmission modes 8, 9 and 10 configured with PMI/RI reporting with 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12 =TRUE*, and transmission mode 9/10 configured with 4 antenna ports for Class B CSI reporting with K=1 and *PMI-Config=2*, and K>1, with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*..

Table 5.2.3.3.1-3B: UCI fields for joint report of RI and i1 with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with 4 antenna ports for Class B CSI reporting with K=1 and *PMI-Config=2*, and K>1, with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*)

Field	Bit width	
	4 antenna ports	
	Max 2 layers	Max 4 layers
Rank indication and i1	4	5

Table 5.2.3.3.1-3C shows the fields and the corresponding bit widths for the joint report of CRI and rank indication feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K>1.

Table 5.2.3.3.1-3C: UCI fields for joint report of CRI and rank indication feedback for wideband reports (transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K>1).

Field	Bit width		
	Max 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	2	3

Table 5.2.3.3.1-3D shows the fields and the corresponding bit widths for the joint report of CRI , rank indication and i1 feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 4/8 ports, Class B CSI reporting with K>1, with alternativeCodeBookEnabledFor4TX-r12=TRUE.

Table 5.2.3.3.1-3D: UCI fields for joint report of CRI, rank indication and i1 feedback for wideband reports (transmission mode 9/10 configured with PMI/RI reporting with 4/8 ports, Class B CSI reporting with K>1, *with alternativeCodeBookEnabledFor4TX-r12=TRUE*).

Field	Bit width				
	Maximum of number of antenna port of the configured CSI-RS resources is 4		Maximum of number of antenna port of the configured CSI-RS resources is 8		
	Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication i1	4	5	4	5	5

Table 5.2.3.3.1-4 show the fields and the corresponding bit widths for the precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting. The parameters (S_1, S_2) in rank 3 and 4 are defined as $(S_1, S_2) = (1, 1)$ for *Codebook-Subset-SelectionConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=2, $(S_1, S_2) = \left(O_1, \frac{O_2}{2}\right)$ for *Codebook-Subset-SelectionConfig*=3, $(S_1, S_2) = \left(O_1, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=4. The parameters (S_1, S_2) in rank 5 to 8 are defined as $(S_1, S_2) = (1, 1)$ for *Codebook-Subset-SelectionConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *Codebook-Subset-SelectionConfig*=2/3/4.

Table 5.2.3.3.1-4: UCI fields for channel quality information feedback for precoding information (i1) (transmission mode 9/10 configured with Class A CSI reporting with codebook configuration (N_1, N_2, O_1, O_2))

Field	Bit width			
	Rank = 1	Rank = 2	Rank =3	Rank =4

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Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Field	**Bit width**			
	Rank = 5	**Rank = 6**	**Rank =7**	**Rank =8**
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$

The channel quality bits in Table 5.2.3.3.1-1 through Table 5.2.3.3.1-4 form the bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ with a_0 corresponding to the first bit of the first field in each of the tables, a_1 corresponding to the second bit of the first field in each of the tables, and a_{A-1} corresponding to the last bit in the last field in each of the tables. The first bit of each field corresponds to MSB and the last bit LSB. The RI feedback for one bit is mapped according to Table 5.2.2.6-5 with o_0^{RI} replaced by a_0. The RI feedback for two bits is mapped according to Table 5.2.2.6-6 with o_0^{RI}, o_1^{RI} replaced by a_0, a_1. The RI feedback for three bits is mapped according to Table 5.2.2.6-7 with o_0^{RI}, o_1^{RI}, o_2^{RI} replaced by a_0, a_1, a_2. The mapping for the jointly coded RI and i1 is provided in Table 7.2.2-1E of [3].

When multiplexed with UL-SCH, the channel coding and multiplexing for the transmission configurations in Table 5.2.3.3.1-3, Table 5.2.3.3.1-3A, Table 5.2.3.3.1-3B, Table 5.2.3.3.1-3C and Table 5.2.3.3.1-3D is performed assuming RI transmission in section 5.2.2.6. All other transmission configurations in this section are coded and multiplexed assuming CQI/PMI transmission in section 5.2.2.6.

5.2.3.3.2 Channel quality information formats for UE-selected sub-band reports

Table 5.2.3.3.2-1 shows the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port.

Table 5.2.3.3.2-1A shows the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports.

Table 5.2.3.3.2-1: UCI fields for channel quality information feedback for UE-selected sub-band CQI reports (transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 9/10 configured without PMI/RI with Class B CSI reporting)

Field	Bit width
Sub-band CQI	4
Sub-band label	1 or 2

Table 5.2.3.3.2-1A: UCI fields for channel quality information feedback for UE-selected subband CQI reports (transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports)

Field	Bit width	
	Rank = 1	Rank > 1
Wide-band CQI	4	4
Spatial differential CQI	0	3
Sub-band label	1 or 2	1 or 2

Table 5.2.3.3.2-2 shows the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 4, transmission mode 5, transmission mode 6, and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.2-2: UCI fields for channel quality information feedback for UE-selected sub-band reports (transmission mode 4, transmission mode 5, transmission mode 6 and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Sub-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
Sub-band label	1 or 2	1 or 2	1 or 2	1 or 2

Table 5.2.3.3.2-2A and Table 5.2.3.3.2-2B show the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config=2*,K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*. The number of CSI-RS resources K is defined in [3] and *PMI-Config* is configured by higher layers [6].

Table 5.2.3.3.2-2A-1 shows UCI fields for channel quality information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config=1*, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports.

Table 5.2.3.3.2-2C shows the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission modes 8, 9 and 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12 =TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 4 antenna ports for Class B CSI reporting with K=1 with *PMI-Config* =2, and with *alternativeCodeBookEnabledFor4TX-r12=TRUE*..

Table 5.2.3.3.2-2A: UCI fields for channel quality information feedback for UE-selected sub-band reports (transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with 2/4 antenna ports for Class B CSI reporting with K=1 and *PMI-Config=2*, K>1 except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI	0	0	0	0
Sub-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
Wide-band i2	0	0	0	0
Sub-band i2	0	0	0	0
Sub-band label	1 or 2	1 or 2	1 or 2	1 or 2

Table 5.2.3.3.2-2A-1: UCI fields for channel quality information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config=1, transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with 2/4/8 antenna ports*)

Field	Bit width	
	2/4/8 antenna ports	
	Rank = 1	Rank > 1
Wide-band CQI	0	0
Sub-band CQI	4	4
Spatial differential CQI	0	3
Wide-band i2	0	0
Sub-band i2	0	0
Sub-band label	1 or 2	1 or 2

Table 5.2.3.3.2-2B: UCI fields for channel quality feedback for UE-selected sub-band reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with 8 antenna ports for Class B CSI reporting with K=1 with *PMI-Config*=2, and K>1)

Field	Bit width									
	8 antenna ports									
	Rank = 1		Rank = 2, 3		Rank = 4		Rank = 5, 6, 7		Rank = 8	
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	4	0	4	0	4	0	4	0	4	0
Sub-band CQI	0	4	0	4	0	4	0	4	0	4
Spatial differential CQI	0	0	3	3	3	3	3	3	3	3
Wide-band i2	4	0	4	0	3	0	0	0	0	0
Sub-band i2	0	4	0	2	0	2	0	0	0	0
Sub-band label	0	1 or 2	0	1 or 2	0	1 or 2	0	1 or 2	0	1 or 2

Table 5.2.3.3.2-2C: UCI fields for channel quality feedback for UE-selected sub-band reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with 4 antenna ports for Class B CSI reporting with K=1 and *PMI-Config*=2, and K>1, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width					
	4 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	Rank=4
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=1	PTI=1
Wide-band CQI	4	0	4	0	0	0
Sub-band CQI	0	4	0	4	4	4
Spatial differential CQI	0	0	3	3	3	3
Wide-band i2	4	0	4	0	0	0
Sub-band i2	0	4	0	2	2	2
Sub-band label	0	1 or 2	0	1 or 2	1 or 2	1 or 2

Table 5.2.3.3.2-3 shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 4, transmission mode 5, transmission mode 6 and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.2-3: UCI fields for channel quality information feedback for UE-selected sub-band CQI reports (transmission mode 4, transmission mode 5, transmission mode 6 and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
Precoding matrix indicator	2	1	4	4

Table 5.2.3.3.2-3A and Table 5.2.3.3.2-3B show the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =2, and K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*

Table 5.2.3.3.2-3A-1 shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =1.

Table 5.2.3.3.2-3C shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 4 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =2, K>1 with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

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Table 5.2.3.3.2-3A: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4 antenna ports for Class B CSI reporting with K=1 and *PMI-Config*=2, K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
i1	0	0	0	0
Wide-band i2	2	1	4	4

Table 5.2.3.3.2-3A-1: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config*=1)

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank =2	Rank =3	Rank =4
Wideband CQI	4	4	4	4	4	4
Spatial differential CQI	0	3	0	3	3	3
i1	0	0	0	0	0	0
Wide-band i2	2	1	3	3	2	1

Field	Bit width				
	8 antenna ports				
	Rank = 1	Rank = 2	Rank = 3	Rank =4	Rank =5~8
Wideband CQI	4	4	4	4	4
Spatial differential CQI	0	3	3	3	3
i1	0	0	0	0	0
Wide-band i2	4	4	4	3	0

Table 5.2.3.3.2-3B: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports and transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config*=2, K>1)

Field	Bit width					
	8 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	0	4	0	4	0	4
Spatial differential CQI	0	0	0	3	0	3
i1	4	0	4	0	2	0
Wide-band i2	0	4	0	4	0	4

Field	Bit width					
	8 antenna ports					
	Rank = 4		Rank = 5, 6, 7		Rank = 8	
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	0	4	0	4	0	4
Spatial differential CQI	0	3	0	3	0	3
i1	2	0	2	0	0	0
Wide-band i2	0	3	0	0	0	0

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Table 5.2.3.3.2-3B-1 shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting for Class A CSI reporting with *Codebook-Subset-SelectionConfig*=1.

Table 5.2.3.3.2-3B-2 shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting for Class A CSI reporting with *Codebook-Subset-SelectionConfig*=2/3/4.

Table 5.2.3.3.2-3B-1: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with Class A CSI reporting with codebook configuration (N_1, N_2, O_1, O_2), and *Codebook-Subset-SelectionConfig*=1)

Field	Bit width					
	8/12/16 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	0	4	0	4	0	4
Spatial differential CQI	0	0	0	3	0	3
Wideband first PMI i1,1	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3}\right\rfloor$	0
Wideband first PMI i1,2	$\left\lceil \log_2\left(\frac{N_2 O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2 O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2 O_2}{S_2}\right)\right\rceil$	0
Wide-band i2	0	2	0	2	0	1

Field	Bit width			
	8/12/16 antenna ports			
	Rank = 4		Rank = 5 to Rank = 8	
	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	0	4	0	4
Spatial differential CQI	0	3	0	3
Wideband first PMI i1,1	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3}\right\rfloor$	0	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right)\right\rceil$	0
Wideband first PMI i1,2	$\left\lceil \log_2\left(\frac{N_2 O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2 O_2}{S_2}\right)\right\rceil$	0
Wide-band i2	0	1	0	0

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Table 5.2.3.3.2-3B-2: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with Class A CSI reporting with codebook configuration (N_1, N_2, O_1, O_2), and *Codebook-Subset-SelectionConfig*=2/3/4)

Field	Bit width 8/12/16 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	0	4	0	4	0	4
Spatial differential CQI	0	0	0	3	0	3
Wideband first PMI i1,1	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3}\right\rfloor$	0
Wideband first PMI i1,2	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0
Wide-band i2	0	4	0	4	0	4
Field	**Bit width 8/12/16 antenna ports**			
	Rank = 4		**Rank = 5 to Rank = 8**	
	PTI=0	**PTI=1**	**PTI=0**	**PTI=1**
Wide-band CQI	0	4	0	4
Spatial differential CQI	0	3	0	3
Wideband first PMI i1,1	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3}\right\rfloor$	0	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil$	0
Wideband first PMI i1,2	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0
Wide-band i2	0	3	0	0

Table 5.2.3.3.2-3C: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with Class B CSI reporting with K=1 and *PMI-Config*=2, and K>1, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width 4 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	Rank=4
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=1	PTI=1
Wide-band CQI	0	4	0	4	4	4
Spatial differential CQI	0	0	0	3	3	3
i1	4	0	4	0	0	0
Wide-band i2	0	4	0	4	4	4

Table 5.2.3.3.2-4 shows the fields and the corresponding bit width for the rank indication feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports with Class B CSI reporting with K=1 and *PMI-*

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Config=1, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K=1 and *PMI-Config*=1 for 2/4/8 antenna ports.

Table 5.2.3.3.2-4: UCI fields for rank indication feedback for UE-selected sub-band reports (transmission mode 3, transmission mode 4, and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports with Class B CSI reporting with K=1 and *PMI-Config*=1, and transmission mode 9/10 configured without PMI reporting for Class B CSI reporting with K=1 and *PMI-Config*=1 for 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8 antenna ports		
		Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

Table 5.2.3.3.2-4A shows the fields and the corresponding bit width for the rank indication and precoder type indication (PTI) feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports for Class B CSI reporting with K=1 and *PMI-Config* =2, K>1 except with *alternativeCodeBookEnabledFor4TX-r12=TRUE, and* transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting.

Table 5.2.3.3.2-4B shows the fields and the corresponding bit width for the rank indication and precoder type indication (PTI) feedback with 4 antenna ports for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 8, transmission mode 9 and transmission mode 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12 =TRUE*, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K=1 and *PMI-Config*=2, K>1, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.2-4A: UCI fields for joint report of RI and PTI (transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports with Class B CSI reporting with K=1 and *PMI-Config*=2, K>1 except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports for Class A CSI reporting)

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3
Precoder type indication	-	-	-	1	1	1

Table 5.2.3.3.2-4B: UCI fields for joint report of RI and PTI with 4 antenna ports (transmission mode 8, transmission mode 9 and transmission mode 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K=1 and *PMI-Config*=2, K>1, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width	
	4 antenna ports	
	Max 2 layers	Max 4 layers
Rank indication	1	2
Precoder type indication	1	1

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Table 5.2.3.3.2-4C shows the fields and the corresponding bit widths for the joint report of CRI and rank indication feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1,and transmission mode 9/10 configured without PMI reporting with 2/4 antenna ports for Class B CSI reporting with K>1.

Table 5.2.3.3.2-4D shows the fields and the corresponding bit widths for the joint report of CRI , rank indication and PTI feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting for Class B CSI reporting with K>1.

Table 5.2.3.3.2-4C: UCI fields for joint report of CRI and rank indication feedback for wideband reports (transmission mode 9/10 configured with PMI/RI reporting with 2/4 antenna ports for Class B CSI reporting with K>1, and transmission mode 9/10 configured without PMI reporting with 2/4 antenna ports for Class B CSI reporting with K>1).

Field	Bit width	
	Max 2 layers	Max 4 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	2

Table 5.2.3.3.2-4D: UCI fields for joint report of CRI, RI and PTI (transmission mode 9/10 configured with PMI/RI reporting with 4/8 antenna ports with Class B CSI reporting with K>1, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width				
	Maximum of number of antenna port of the configured CSI-RS resources is 4		Maximum of number of antenna port of the configured CSI-RS resources is 8		
	Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	2	1	2	3
Precoder type indication	1	1	1	1	1

The channel quality bits in Table 5.2.3.3.2-1 through Table 5.2.3.3.2-4D form the bit sequence $a_0, a_1, a_2, a_3, \ldots, a_{A-1}$ with a_0 corresponding to the first bit of the first field in each of the tables, a_1 corresponding to the second bit of the first field in each of the tables, and a_{A-1} corresponding to the last bit in the last field in each of the tables. The first bit of each field corresponds to MSB and the last bit LSB. The RI feedback for one bit is mapped according to Table 5.2.2.6-5 with o_0^{RI} replaced by a_0 . The RI feedback for two bits is mapped according to Table 5.2.2.6-6 with o_0^{RI} , o_1^{RI} replaced by a_0, a_1 . The RI feedback for three bits is mapped according to Table 5.2.2.6-7 with o_0^{RI} , o_1^{RI} , o_2^{RI} replaced by a_0, a_1, a_2 .

When multiplexed with UL-SCH, the channel coding and multiplexing for the transmission configurations in Table 5.2.3.3.2-4, Table 5.2.3.3.2-4A, Table 5.2.3.3.2-4B, Table 5.2.3.3.2-4C and Table 5.2.3.3.2-4D is performed assuming RI transmission in section 5.2.2.6. All other transmission configurations in this section are coded and multiplexed assuming CQI/PMI transmission in section 5.2.2.6.

5.2.3.4 Channel coding for UCI channel quality information and HARQ-ACK

This section defines the channel coding scheme for the simultaneous transmission of channel quality information and HARQ-ACK information in a subframe.

When normal CP is used for uplink transmission, the channel quality information is coded according to section 5.2.3.3 with input bit sequence $a'_0, a'_1, a'_2, a'_3, \ldots, a'_{A'-1}$ and output bit sequence $b'_0, b'_1, b'_2, b'_3, \ldots, b'_{B'-1}$, where $B' = 20$. The

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HARQ-ACK bits are denoted by a_0'' in case one HARQ-ACK bit or a_0'', a_1'' in case two HARQ-ACK bits are reported per subframe. Each positive acknowledgement (ACK) is encoded as a binary '1' and each negative acknowledgement (NACK) is encoded as a binary '0'.

The output of this channel coding block for normal CP is denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where

$$b_i = b_i', i = 0, ..., B' - 1$$

In case one HARQ-ACK bit is reported per subframe:

$$b_{B'} = a_0'' \text{ and } B = (B' + 1)$$

In case two HARQ-ACK bits are reported per subframe:

$$b_{B'} = a_0'', b_{B'+1} = a_1'' \text{ and } B = (B' + 2)$$

When extended CP is used for uplink transmission, the channel quality information and the HARQ-ACK bits are jointly coded. The HARQ-ACK bits are denoted by a_0'' in case one HARQ-ACK bit or $[a_0'', a_1'']$ in case two HARQ-ACK bits are reported per subframe.

The channel quality information denoted by $a_0', a_1', a_2', a_3', ..., a_{A'-1}'$ is multiplexed with the HARQ-ACK bits to yield the sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ as follows

$$a_i = a_i', i = 0, ..., A' - 1$$

and

$a_{A'} = a_0''$ and $A = (A' + 1)$ in case one HARQ-ACK bit is reported per subframe, or

$a_{A'} = a_0''$, $a_{(A'+1)} = a_1''$ and $A = (A' + 2)$ in case two HARQ-ACK bits are reported per subframe.

The sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ is encoded according to section 5.2.3.3 to yield the output bit sequence $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where $B = 20$.

5.2.4 Uplink control information on PUSCH without UL-SCH data

When control data are sent via PUSCH without UL-SCH data, the following coding steps can be identified:

- Channel coding of control information
- Control information mapping
- Channel interleaver

5.2.4.1 Channel coding of control information

Control data arrives at the coding unit in the form of channel quality information (CQI and/or PMI), HARQ-ACK and rank indication. Different coding rates for the control information are achieved by allocating different number of coded symbols for its transmission. When the UE transmits HARQ-ACK bits or rank indicator bits, it shall determine the number of coded symbols Q' for HARQ-ACK or rank indicator as

$$Q' = \min\left(\left\lceil \frac{O \cdot M_{sc}^{PUSCH} \cdot N_{symb}^{PUSCH} \cdot \beta_{offset}^{PUSCH}}{O_{CQI-MIN}} \right\rceil, 4 \cdot M_{sc}^{PUSCH}\right)$$

where O is the number of HARQ-ACK bits as defined in section 5.2.2.6, or rank indicator bits, $O_{CQI-MIN}$ is the number of CQI bits including CRC bits assuming rank equals to 1 for all serving cells for which an aperiodic CSI report

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is triggered [3], M_{sc}^{PUSCH} is the scheduled bandwidth for PUSCH transmission in the current subframe expressed as a number of subcarriers in [2], and N_{symb}^{PUSCH} is the number of SC-FDMA symbols in the current PUSCH transmission sub-frame given by $N_{symb}^{PUSCH} = \left(2 \cdot \left(N_{symb}^{UL} - 1\right) - N_{SRS}\right)$, where N_{SRS} is equal to 1 if UE is configured to send PUSCH and SRS in the same subframe for the current subframe, or if the PUSCH resource allocation for the current subframe even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or if the current subframe is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or if the current subframe is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs. Otherwise N_{SRS} is equal to 0.

For HARQ-ACK information $Q_{ACK} = Q_m \cdot Q'$ and [$\beta_{offset}^{PUSCH} = \beta_{offset}^{HARQ-ACK} / \beta_{offset}^{CQI}$]. For UEs configured with no more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3]. For UEs configured with more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of HARQ-ACK feedback bits.

For rank indication or CRI, $Q_{RI} = Q_m \cdot Q'$, $Q_{CRI} = Q_m \cdot Q'$ and [$\beta_{offset}^{PUSCH} = \beta_{offset}^{RI} / \beta_{offset}^{CQI}$], where β_{offset}^{RI} shall be determined according to [3].

For CQI and/or PMI information $Q_{CQI} = N_{symb}^{PUSCH} \cdot M_{sc}^{PUSCH} \cdot Q_m - Q_{RI}$.

The channel coding and rate matching of the control data is performed according to section 5.2.2.6. The coded output sequence for channel quality information is denoted by $q_0, q_1, q_2, q_3, \ldots, q_{Q_{CQI}-1}$, the coded vector sequence output for HARQ-ACK is denoted by $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, \ldots, \underline{q}_{Q'_{ACK}-1}^{ACK}$ and the coded vector sequence output for rank indication or CRI, is denoted by $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, \ldots, \underline{q}_{Q'_{RI}-1}^{RI}$.

5.2.4.2 Control information mapping

The input are the coded bits of the channel quality information denoted by $q_0, q_1, q_2, q_3, \ldots, q_{Q_{CQI}-1}$. The output is denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, \underline{g}_3, \ldots, \underline{g}_{H'-1}$, where $H = Q_{CQI}$ and $H' = H / Q_m$, and where $\underline{g}_i$, $i = 0, \ldots, H'-1$ are column vectors of length Q_m. H is the total number of coded bits allocated for CQI/PMI information.

The control information shall be mapped as follows:

Set j, k to 0

while $j < Q_{CQI}$

$\underline{g}_k = [q_j \ldots q_{j+Q_m-1}]^T$

$j = j + Q_m$

$k = k + 1$

end while

5.2.4.3 Channel interleaver

The vector sequences $\underline{g}_0, \underline{g}_1, \underline{g}_2, \ldots, \underline{g}_{H'-1}$, $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, \ldots, \underline{q}_{Q'_{RI}-1}^{RI}$ and $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, \ldots, \underline{q}_{Q'_{ACK}-1}^{ACK}$ are channel interleaved according section 5.2.2.8. The bits after channel interleaving are denoted by $h_0, h_1, h_2, \ldots, h_{H+Q_{RI}-1}$.

5.3 Downlink transport channels and control information

If the UE is configured with a Master Cell Group (MCG) and Secondary Cell Group (SCG) [6], the procedures described in this clause are applied to the MCG and SCG, respectively. When the procedures are applied to a SCG, the term primary cell refers to the primary SCell (PSCell) of the SCG.

If the UE is configured with a PUCCH SCell [6], the procedures described in this clause are applied to the group of DL cells associated with the primary cell and the group of DL cells associated with the PUCCH SCell, respectively. When the procedures are applied to the group of DL cells associated with the PUCCH SCell, the term primary cell refers to the PUCCH SCell.

5.3.1 Broadcast channel

Figure 5.3.1-1 shows the processing structure for the BCH transport channel. Data arrives to the coding unit in the form of a maximum of one transport block every transmission time interval (TTI) of 40ms. The following coding steps can be identified:

- Add CRC to the transport block
- Channel coding
- Rate matching

The coding steps for BCH transport channel are shown in the figure below.

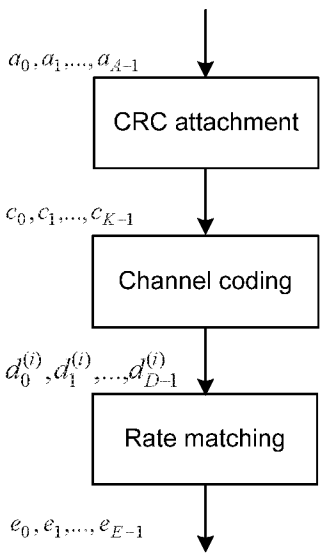


Figure 5.3.1-1: Transport channel processing for BCH.

5.3.1.1 Transport block CRC attachment

Error detection is provided on BCH transport blocks through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the size of the transport block and set to 24 bits and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in section 6.1.1 of [5].

The parity bits are computed and attached to the BCH transport block according to section 5.1.1 setting L to 16 bits. After the attachment, the CRC bits are scrambled according to the eNodeB transmit antenna configuration with the sequence $x_{ant,0}, x_{ant,1}, ..., x_{ant,15}$ as indicated in Table 5.3.1.1-1 to form the sequence of bits $c_0, c_1, c_2, c_3, ..., c_{K-1}$ where

$c_k = a_k$ for $k = 0, 1, 2, \ldots, A\text{-}1$

$c_k = \left(p_{k-A} + x_{ant,k-A}\right) \bmod 2$ for $k = A, A+1, A+2, \ldots, A+15$.

Table 5.3.1.1-1: CRC mask for PBCH.

Number of transmit antenna ports at eNodeB	PBCH CRC mask $< x_{ant,0}, x_{ant,1}, \ldots, x_{ant,15} >$
1	<0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0>
2	<1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1>
4	<0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1>

5.3.1.2 Channel coding

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3, \ldots, c_{K-1}$, where K is the number of bits, and they are tail biting convolutionally encoded according to section 5.1.3.1.

After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, \ldots, d_{D-1}^{(i)}$, with $i = 0,1$, and 2, and where D is the number of bits on the i-th coded stream, i.e., $D = K$.

5.3.1.3 Rate matching

A tail biting convolutionally coded block is delivered to the rate matching block. This block of coded bits is denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, \ldots, d_{D-1}^{(i)}$, with $i = 0,1$, and 2, and where i is the coded stream index and D is the number of bits in each coded stream. This coded block is rate matched according to section 5.1.4.2.

After rate matching, the bits are denoted by $e_0, e_1, e_2, e_3, \ldots, e_{E-1}$, where E is the number of rate matched bits as defined in section 6.6.1 of [2].

5.3.2 Downlink shared channel, Paging channel and Multicast channel

Figure 5.3.2-1 shows the processing structure for each transport block for the DL-SCH, PCH and MCH transport channels. Data arrives to the coding unit in the form of a maximum of two transport blocks every transmission time interval (TTI) per DL cell. The following coding steps can be identified for each transport block of a DL cell:

- Add CRC to the transport block
- Code block segmentation and code block CRC attachment
- Channel coding
- Rate matching
- Code block concatenation

The coding steps for PCH and MCH transport channels, and for one transport block of DL-SCH are shown in the figure below. The same processing applies for each transport block on each DL cell.

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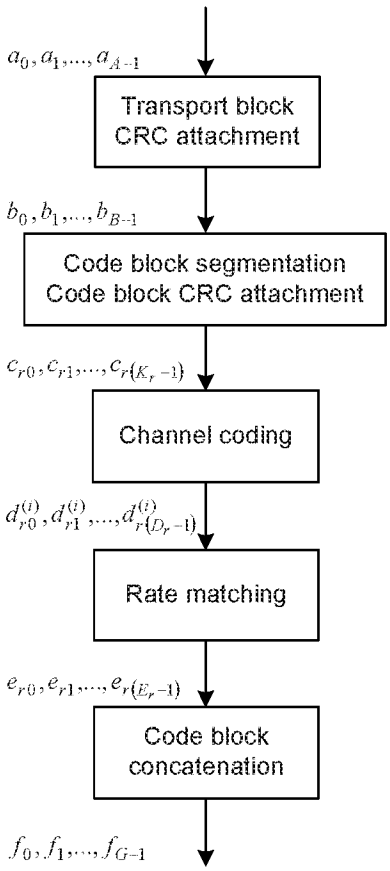


Figure 5.3.2-1: Transport block processing for DL-SCH, PCH and MCH.

5.3.2.1 Transport block CRC attachment

Error detection is provided on transport blocks through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the size of the transport block and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in section 6.1.1 of [5].

The parity bits are computed and attached to the transport block according to section 5.1.1 setting L to 24 bits and using the generator polynomial $g_{CRC24A}(D)$.

5.3.2.2 Code block segmentation and code block CRC attachment

The bits input to the code block segmentation are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where B is the number of bits in the transport block (including CRC).

Code block segmentation and code block CRC attachment are performed according to section 5.1.2.

The bits after code block segmentation are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number and K_r is the number of bits for code block number r.

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5.3.2.3 Channel coding

Code blocks are delivered to the channel coding block. They are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number, and K_r is the number of bits in code block number r. The total number of code blocks is denoted by C and each code block is individually turbo encoded according to section 5.1.3.2.

After encoding the bits are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, ..., d_{r(D_r-1)}^{(i)}$, with $i = 0,1$, and 2 , and where D_r is the number of bits on the i-th coded stream for code block number r, i.e. $D_r = K_r + 4$.

5.3.2.4 Rate matching

Turbo coded blocks are delivered to the rate matching block. They are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, ..., d_{r(D_r-1)}^{(i)}$, with $i = 0,1$, and 2 , and where r is the code block number, i is the coded stream index, and D_r is the number of bits in each coded stream of code block number r. The total number of code blocks is denoted by C and each coded block is individually rate matched according to section 5.1.4.1.

After rate matching, the bits are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, ..., e_{r(E_r-1)}$, where r is the coded block number, and where E_r is the number of rate matched bits for code block number r.

5.3.2.5 Code block concatenation

The bits input to the code block concatenation block are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, ..., e_{r(E_r-1)}$ for $r = 0, ..., C-1$ and where E_r is the number of rate matched bits for the r-th code block.

Code block concatenation is performed according to section 5.1.5.

The bits after code block concatenation are denoted by $f_0, f_1, f_2, f_3, ..., f_{G-1}$, where G is the total number of coded bits for transmission. This sequence of coded bits corresponding to one transport block after code block concatenation is referred to as one codeword in section 6.3.1 of [2]. In case of multiple transport blocks per TTI, the transport block to codeword mapping is specified according to section 5.3.3.1.5, 5.3.3.1.5A or 5.3.3.1.5B, depending on the DCI Format.

5.3.3 Downlink control information

A DCI transports downlink, uplink or sidelink scheduling information, requests for aperiodic CQI reports, LAA common information, notifications of MCCH change [6] or uplink power control commands for one cell and one RNTI. The RNTI is implicitly encoded in the CRC.

Figure 5.3.3-1 shows the processing structure for one DCI. The following coding steps can be identified:

- Information element multiplexing
- CRC attachment
- Channel coding
- Rate matching

The coding steps for DCI are shown in the figure below.

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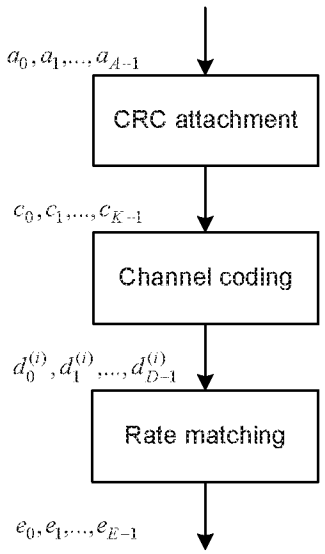


Figure 5.3.3-1: Processing for one DCI.

5.3.3.1 DCI formats

The fields defined in the DCI formats below are mapped to the information bits a_0 to a_{A-1} as follows.

Each field is mapped in the order in which it appears in the description, including the zero-padding bit(s), if any, with the first field mapped to the lowest order information bit a_0 and each successive field mapped to higher order information bits. The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to a_0.

5.3.3.1.1 Format 0

DCI format 0 is used for the scheduling of PUSCH in one UL cell.

The following information is transmitted by means of the DCI format 0:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].
- Flag for format0/format1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A
- Frequency hopping flag – 1 bit as defined in section 8.4 of [3]. This field is used as the MSB of the corresponding resource allocation field for resource allocation type 1.
- Resource block assignment and hopping resource allocation – $\left\lceil \log_2(N_{RB}^{UL}(N_{RB}^{UL}+1)/2) \right\rceil$ bits
  - For PUSCH hopping (resource allocation type 0 only):
    - N_{UL_hop} MSB bits are used to obtain the value of $\tilde{n}_{PRB}(i)$ as indicated in section 8.4 of [3]
    - $\left(\left\lceil \log_2(N_{RB}^{UL}(N_{RB}^{UL}+1)/2) \right\rceil - N_{UL\_hop} \right)$ bits provide the resource allocation of the first slot in the UL subframe
  - For non-hopping PUSCH with resource allocation type 0:
    - $\left(\left\lceil \log_2(N_{RB}^{UL}(N_{RB}^{UL}+1)/2) \right\rceil \right)$ bits provide the resource allocation in the UL subframe as defined in section 8.1.1 of [3]
  - For non-hopping PUSCH with resource allocation type 1:

- The concatenation of the frequency hopping flag field and the resource block assignment and hopping resource allocation field provides the resource allocation field in the UL subframe as defined in section 8.1.2 of [3]

- Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3]

- New data indicator – 1 bit

- TPC command for scheduled PUSCH – 2 bits as defined in section 5.1.1.1 of [3]

- Cyclic shift for DM RS and OCC index – 3 bits as defined in section 5.5.2.1.1 of [2]

- UL index – 2 bits as defined in sections 5.1.1.1, 7.2.1, 8 and 8.4 of [3] (this field is present only for TDD operation with uplink-downlink configuration 0)

- Downlink Assignment Index (DAI) – 2 bits as defined in section 7.3 of [3] (this field is present only for cases with TDD primary cell and either TDD operation with uplink-downlink configurations 1-6 or FDD operation)

- CSI request – 1, 2 or 3 bits as defined in section 7.2.1 of [3]. The 2-bit field applies to UEs configured with no more than five DL cells and to

  - UEs that are configured with more than one DL cell and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];

  - UEs that are configured by higher layers with more than one CSI process and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];

  - UEs that are configured with two CSI measurement sets by higher layers with the parameter *csi-MeasSubframeSet*, and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];

  the 3-bit field applies to UEs that are configured with more than five DL cells and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];

  otherwise the 1-bit field applies

- SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PUSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in section 8.2 of [3]

- Resource allocation type – 1 bit. This field is only present if $N_{\mathrm{RB}}^{\mathrm{UL}} \leq N_{\mathrm{RB}}^{\mathrm{DL}}$. The interpretation of this field is provided in section 8.1 of [3]

If the number of information bits in format 0 mapped onto a given search space is less than the payload size of format 1A for scheduling the same serving cell and mapped onto the same search space (including any padding bits appended to format 1A), zeros shall be appended to format 0 until the payload size equals that of format 1A.

5.3.3.1.2 Format 1

DCI format 1 is used for the scheduling of one PDSCH codeword in one cell.

The following information is transmitted by means of the DCI format 1:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]:

    - $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

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- For resource allocation type 1 as defined in section 7.1.6.2 of [3]:

  - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

  - 1 bit indicates a shift of the resource allocation span

  - $\left(\left\lceil N_{RB}^{DL} / P \right\rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

  where the value of P depends on the number of DL resource blocks as indicated in section 7.1.6.1 of [3]

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- HARQ process number – 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- New data indicator – 1 bit

- Redundancy version – 2 bits

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If the UE is not configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI and the number of information bits in format 1 is equal to that for format 0/1A, one bit of value zero shall be appended to format 1.

If the UE is configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI and the number of information bits in format 1 is equal to that for format 0/1A for scheduling the same serving cell and mapped onto the UE specific search space given by the C-RNTI as defined in [3], one bit of value zero shall be appended to format 1.

If the number of information bits in format 1 carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one or more zero bit(s) shall be appended to format 1 until the payload size of format 1 does not belong to one of the sizes in Table 5.3.3.1.2-1 and is not equal to that of format 0/1A mapped onto the same search space.

Table 5.3.3.1.2-1: Ambiguous Sizes of Information Bits.

{12, 14, 16 ,20, 24, 26, 32, 40, 44, 56}

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Table 5.3.3.1.2-2: Number of bits for Downlink Assignment Index.

Number of bits	
4	For UEs configured by higher layers with *codebooksizeDetermination-r13 = 0*, the 4-bit DAI further consists of a 2-bit counter DAI and a 2-bit total DAI. - Counter DAI – 2 bits as defined in section 7.3 of [3] - Total DAI – 2 bits as defined in section 7.3 of [3]
2	For UEs configured with no more than five DL cells, or for UEs configured by higher layers with *codebooksizeDetermination-r13 = 1*, this field is present for FDD or TDD operation, for cases with TDD primary cell. If the UL/DL configuration of all TDD serving cells is same and the UE is not configured to decode PDCCH with CRC scrambled by *eimta-RNTI*, then this field only applies to serving cell with UL/DL configuration 1-6 If at least two TDD serving cells have different UL/DL configurations or the UE is configured to decode PDCCH with CRC scrambled by *eimta-RNTI*, then this field applies to a serving cell with DL-reference UL/DL configuration 1-6 as defined in section 10.2 of [3]
0	For UEs configured with no more than five DL cells, or for UEs configured by higher layers with *codebooksizeDetermination-r13 = 1*, this field is not present for FDD or TDD operation, for cases with FDD primary cell.

5.3.3.1.3 Format 1A

DCI format 1A is used for the compact scheduling of one PDSCH codeword in one cell and random access procedure initiated by a PDCCH order. The DCI corresponding to a PDCCH order can be carried by PDCCH or EPDCCH.

The following information is transmitted by means of the DCI format 1A:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].

- Flag for format0/format1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A

Format 1A is used for random access procedure initiated by a PDCCH order only if format 1A CRC is scrambled with C-RNTI and all the remaining fields are set as follows:

- Localized/Distributed VRB assignment flag – 1 bit is set to '0'

- Resource block assignment – $\left\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \right\rceil$ bits, where all bits shall be set to 1

- Preamble Index – 6 bits

- PRACH Mask Index – 4 bits, [5]

- All the remaining bits in format 1A for compact scheduling assignment of one PDSCH codeword are set to zero

Otherwise,

- Localized/Distributed VRB assignment flag – 1 bit as defined in 7.1.6.3 of [3]

- Resource block assignment – $\left\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \right\rceil$ bits as defined in section 7.1.6.3 of [3]:

  - For localized VRB:

    $\left\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \right\rceil$ bits provide the resource allocation

  - For distributed VRB:

- If $N_{RB}^{DL} < 50$ or if the format 1A CRC is scrambled by RA-RNTI, P-RNTI, SI-RNTI, SC-RNTI or G-RNTI:

  - $\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \rceil$ bits provide the resource allocation

  - Else

    - 1 bit, the MSB indicates the gap value, where value 0 indicates $N_{gap} = N_{gap,1}$ and value 1 indicates $N_{gap} = N_{gap,2}$

    - $(\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \rceil - 1)$ bits provide the resource allocation,

  where N_{gap} is defined in [2].

- Modulation and coding scheme – 5bits as defined in section 7.1.7 of [3]

- HARQ process number – 3 bits (for cases with FDD primary cell) , 4 bits (for cases with TDD primary cell)

- New data indicator – 1 bit

  - If the format 1A CRC is scrambled by RA-RNTI, P-RNTI, SI-RNTI, SC-RNTI or G-RNTI:

    - If $N_{RB}^{DL} \geq 50$ and Localized/Distributed VRB assignment flag is set to 1

      - the new data indicator bit indicates the gap value, where value 0 indicates $N_{gap} = N_{gap,1}$ and value 1 indicates $N_{gap} = N_{gap,2}$.

    - Else the new data indicator bit is reserved.

  - Else

    - The new data indicator bit as defined in [5]

- Redundancy version – 2 bits

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

  - If the format 1A CRC is scrambled by RA-RNTI, P-RNTI, or SI-RNTI:

    - The most significant bit of the TPC command is reserved.

    - The least significant bit of the TPC command indicates column N_{PRB}^{1A} of the TBS table defined of [3].

    - If least significant bit is 0 then $N_{PRB}^{1A} = 2$ else $N_{PRB}^{1A} = 3$.

  - Else

    - The two bits including the most significant bit indicates the TPC command

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PDSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in section 8.2 of [3]

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

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If the UE is not configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI, and the number of information bits in format 1A is less than that of format 0, zeros shall be appended to format 1A until the payload size equals that of format 0.

If the UE is configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI and the number of information bits in format 1A mapped onto a given search space is less than that of format 0 for scheduling the same serving cell and mapped onto the same search space, zeros shall be appended to format 1A until the payload size equals that of format 0, except when format 1A assigns downlink resource on a secondary cell without an uplink configuration associated with the secondary cell.

If the number of information bits in format 1A carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 1A.

When the format 1A CRC is scrambled with a RA-RNTI, P-RNTI, SI-RNTI, SC-RNTI or G-RNTI then the following fields among the fields above are reserved:

- HARQ process number
- Downlink Assignment Index (used for cases with TDD primary cell and either FDD operation or TDD operation, and is not present for cases with FDD primary cell and either FDD operation or TDD operation)

5.3.3.1.3A Format 1B

DCI format 1B is used for the compact scheduling of one PDSCH codeword in one cell with precoding information.

The following information is transmitted by means of the DCI format 1B:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Localized/Distributed VRB assignment flag – 1 bit as defined in section 7.1.6.3 of [3]
- Resource block assignment – $\left\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \right\rceil$ bits as defined in section 7.1.6.3 of [3]
  - For localized VRB:

    $\left\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \right\rceil$ bits provide the resource allocation
  - For distributed VRB:
    - For $N_{RB}^{DL} < 50$
      - $\left\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \right\rceil$ bits provide the resource allocation
    - For $N_{RB}^{DL} \geq 50$
      - 1 bit, the MSB indicates the gap value, where value 0 indicates $N_{gap} = N_{gap,1}$ and value 1 indicates $N_{gap} = N_{gap,2}$
      - $\left(\left\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \right\rceil - 1\right)$ bits provide the resource allocation
- Modulation and coding scheme – 5bits as defined in section 7.1.7 of [3]
- HARQ process number – 3 bits (for cases with FDD primary cell) , 4 bits (for cases with TDD primary cell)
- New data indicator – 1 bit
- Redundancy version – 2 bits
- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]
- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

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- TPMI information for precoding – number of bits as specified in Table 5.3.3.1.3A-1

  TPMI information indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2] corresponding to the single-layer transmission.

- PMI confirmation for precoding – 1 bit as specified in Table 5.3.3.1.3A-2

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If PMI confirmation indicates that the eNodeB has applied precoding according to PMI(s) reported by the UE, the precoding for the corresponding RB(s) in subframe n is according to the latest PMI(s) in an aperiodic CSI reported on or before subframe n-4.

Table 5.3.3.1.3A-1: Number of bits for TPMI information.

Number of antenna ports at eNodeB	Number of bits
2	2
4	4

Table 5.3.3.1.3A-2: Content of PMI confirmation.

Bit field mapped to index	Message
0	Precoding according to the indicated TPMI in the TPMI information field
1	Precoding using the precoder(s) according to PMI(s) indicated in the latest aperiodic CSI report. For aperiodic CSI mode 2-2: - Precoding of scheduled resource blocks belonging to the reported preferred M subband(s), use precoder(s) according to the preferred M subband PMI(s) indicated in the latest aperiodic CSI report; - Precoding of scheduled resource blocks not belonging to the reported preferred M subband(s), precoding using a precoder according to the wideband PMI indicated in the latest aperiodic CSI report.

If the number of information bits in format 1B is equal to that for format 0/1A for scheduling the same serving cell and mapped onto the UE specific search space given by the C-RNTI as defined in [3], one bit of value zero shall be appended to format 1B.

If the number of information bits in format 1B carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one or more zero bit(s) shall be appended to format 1B until the payload size of format 1B does not belong to one of the sizes in Table 5.3.3.1.2-1 and is not equal to that of format 0/1A mapped onto the same search space.

5.3.3.1.4 Format 1C

DCI format 1C is used for very compact scheduling of one PDSCH codeword, notifying MCCH change [6], notifying SC-MCCH change [6] , reconfiguring TDD, and LAA common information.

The following information is transmitted by means of the DCI format 1C:

If the format 1C is used for very compact scheduling of one PDSCH codeword

- 1 bit indicates the gap value, where value 0 indicates $N_{\text{gap}} = N_{\text{gap},1}$ and value 1 indicates $N_{\text{gap}} = N_{\text{gap},2}$

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- For $N_{RB}^{DL} < 50$, there is no bit for gap indication
- Resource block assignment – $\left\lceil \log_2\left(\left\lfloor N_{VRB,gap1}^{DL} / N_{RB}^{step} \right\rfloor \cdot \left(\left\lfloor N_{VRB,gap1}^{DL} / N_{RB}^{step} \right\rfloor + 1\right)/2\right)\right\rceil$ bits as defined in 7.1.6.3 of [3] where $N_{VRB,gap1}^{DL}$ is defined in [2] and N_{RB}^{step} is defined in [3]
- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

Else if the format 1C is used for notifying MCCH change

- Information for MCCH change notification – 8 bits as defined in section 5.8.1.3 of [6]
- Reserved information bits are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

Else if the format 1C is used for notifying SC-MCCH change

- Information for SC-MCCH change notification – 8 bits as defined in section 5.8a.1.3 of [6]
- Reserved information bits are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

Else if the format 1C is used for reconfiguring TDD

- UL/DL configuration indication:

  UL/DL configuration number 1, UL/DL configuration number 2,…, UL/DL configuration number I

  Where each UL/DL configuration is 3 bits, $I = \left\lfloor \frac{L_{\text{format 1c}}}{3} \right\rfloor$, $L_{\text{format 1c}}$ is equal to the payload size of format 1C used for very compact scheduling of one PDSCH codeword. The parameter *eimta-UL-DL-ConfigIndex* provided by higher layers determines the index to the UL/DL configuration indication for a serving cell.
- Zeros are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

Else

- Subframe configuration for LAA – 4 bits as defined in section x.y.z of [3]
- Reserved information bits are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

5.3.3.1.4A Format 1D

DCI format 1D is used for the compact scheduling of one PDSCH codeword in one cell with precoding and power offset information.

The following information is transmitted by means of the DCI format 1D:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Localized/Distributed VRB assignment flag – 1 bit as defined in section 7.1.6.3 of [3]
- Resource block assignment – $\left\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \right\rceil$ bits as defined in section 7.1.6.3 of [3]:
  - For localized VRB:

    $\left\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \right\rceil$ bits provide the resource allocation
  - For distributed VRB:
    - For $N_{RB}^{DL} < 50$

- $\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \rceil$ bits provide the resource allocation

- For $N_{RB}^{DL} \geq 50$

  - 1 bit, the MSB indicates the gap value, where value 0 indicates $N_{gap} = N_{gap,1}$ and value 1 indicates $N_{gap} = N_{gap,2}$

  - $(\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \rceil - 1)$ bits provide the resource allocation

- Modulation and coding scheme – 5bits as defined in section 7.1.7 of [3]

- HARQ process number – 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- New data indicator – 1 bit

- Redundancy version – 2 bits

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- TPMI information for precoding – number of bits as specified in Table 5.3.3.1.4A-1

  TPMI information indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2] corresponding to the single-layer transmission.

- Downlink power offset – 1 bit as defined in section 7.1.5 of [3]

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

Table 5.3.3.1.4A-1: Number of bits for TPMI information.

Number of antenna ports at eNodeB	Number of bits
2	2
4	4

If the number of information bits in format 1D is equal to that for format 0/1A for scheduling the same serving cell and mapped onto the UE specific search space given by the C-RNTI as defined in [3], one bit of value zero shall be appended to format 1D.

If the number of information bits in format 1D carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one or more zero bit(s) shall be appended to format 1D until the payload size of format 1D does not belong to one of the sizes in Table 5.3.3.1.2-1 and is not equal to that of format 0/1A mapped onto the same search space.

5.3.3.1.5 Format 2

The following information is transmitted by means of the DCI format 2:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

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- For resource allocation type 0 defined in section 7.1.6.1 of [3]:

  - $\lceil N_{RB}^{DL} / P \rceil$ bits provide the resource allocation

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]:

  - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

  - 1 bit indicates a shift of the resource allocation span

  - $\left(\lceil N_{RB}^{DL} / P \rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section 7.1.6.1 of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Transport block to codeword swap flag – 1 bit

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- Precoding information – number of bits as specified in Table 5.3.3.1.5-3

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-1.

In case one of the transport blocks is disabled as specified in section 7.1.7.2 of [3], the transport block to codeword swap flag is reserved and the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2.

Table 5.3.3.1.5-1: Transport block to codeword mapping (two transport blocks enabled).

transport block to codeword swap flag value	codeword 0 (enabled)	codeword 1 (enabled)
0	transport block 1	transport block 2
1	transport block 2	transport block 1

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Table 5.3.3.1.5-2: Transport block to codeword mapping (one transport block enabled).

transport block 1	transport block 2	codeword 0 (enabled)	codeword 1 (disabled)
enabled	disabled	transport block 1	-
disabled	enabled	transport block 2	-

The interpretation of the precoding information field depends on the number of enabled codewords according to Table 5.3.3.1.5-4 and Table 5.3.3.1.5-5. Note that TPMI indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2]. For a single enabled codeword, indices 18 to 34 inclusive in Table 5.3.3.1.5-5 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers with closed-loop spatial multiplexing.

If the number of information bits in format 2 carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2.

Some entries in Table 5.3.3.1.5-4 and Table 5.3.3.1.5-5 are used for indicating that the eNodeB has applied precoding according to PMI(s) reported by the UE. In these cases the precoding for the corresponding RB(s) in subframe n is according to the latest PMI(s) in an aperiodic CSI reported on or before subframe n-4. For aperiodic CSI mode 2-2: Precoding of scheduled resource blocks belonging to the reported preferred M subband(s) use precoder(s) according to the preferred M subband PMI indicated by the latest aperiodic CSI report; Precoding of scheduled resource blocks not belonging to the reported preferred M subband(s) use a precoder according to the wideband PMI indicated by the latest aperiodic CSI report.

Table 5.3.3.1.5-3: Number of bits for precoding information.

Number of antenna ports at eNodeB	Number of bits for precoding information
2	3
4	6

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Table 5.3.3.1.5-4: Content of precoding information field for 2 antenna ports.

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	**Message**	**Bit field mapped to index**	**Message**
0	2 layers: Transmit diversity	0	2 layers: Precoding corresponding to precoder matrix $\frac{1}{2}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$
1	1 layer: Precoding corresponding to precoding vector $\begin{bmatrix}1 & 1\end{bmatrix}^T/\sqrt{2}$	1	2 layers: Precoding corresponding to precoder matrix $\frac{1}{2}\begin{bmatrix}1 & 1\\ j & -j\end{bmatrix}$
2	1 layer: Precoding corresponding to precoder vector $\begin{bmatrix}1 & -1\end{bmatrix}^T/\sqrt{2}$	2	2 layers: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s)
3	1 layer: Precoding corresponding to precoder vector $\begin{bmatrix}1 & j\end{bmatrix}^T/\sqrt{2}$	3	reserved
4	1 layer: Precoding corresponding to precoder vector $\begin{bmatrix}1 & -j\end{bmatrix}^T/\sqrt{2}$	4	reserved
5	1 layer: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s), if RI=2 was reported, using 1st column multiplied by $\sqrt{2}$ of all precoders implied by the reported PMI(s)	5	reserved
6	1 layer: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s), if RI=2 was reported, using 2nd column multiplied by $\sqrt{2}$ of all precoders implied by the reported PMI(s)	6	reserved
7	reserved	7	reserved

Table 5.3.3.1.5-5: Content of precoding information field for 4 antenna ports.

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	4 layers: Transmit diversity	0	2 layers: TPMI=0
1	1 layer: TPMI=0	1	2 layers: TPMI=1
2	1 layer: TPMI=1	⋮	⋮
⋮	⋮	15	2 layers: TPMI=15
16	1 layer: TPMI=15	16	2 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)
17	1 layer: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)	17	3 layers: TPMI=0
18	2 layers: TPMI=0	18	3 layers: TPMI=1
19	2 layers: TPMI=1	⋮	⋮
⋮	⋮	32	3 layers: TPMI=15
33	2 layers: TPMI=15	33	3 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)
34	2 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)	34	4 layers: TPMI=0
35 – 63	reserved	35	4 layers: TPMI=1
		⋮	⋮
		49	4 layers: TPMI=15
		50	4 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)
		51 – 63	Reserved

5.3.3.1.5A Format 2A

The following information is transmitted by means of the DCI format 2A:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]

    - $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

  - For resource allocation type 1 as defined in section 7.1.6.2 of [3]

    - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

    - 1 bit indicates a shift of the resource allocation span

    - $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

  where the value of P depends on the number of DL resource blocks as indicated in section 7.1.6.1 of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Transport block to codeword swap flag – 1 bit

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- Precoding information – number of bits as specified in Table 5.3.3.1.5A-1

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-1.

In case one of the transport blocks is disabled, the transport block to codeword swap flag is reserved and the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2.

The precoding information field is defined according to Table 5.3.3.1.5A-2. For a single enabled codeword, index 1 in Table 5.3.3.1.5A-2 is only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers with large delay CDD.

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For transmission with 2 antenna ports, the precoding information field is not present. The number of transmission layers is equal to 2 if both codewords are enabled; transmit diversity is used if codeword 0 is enabled while codeword 1 is disabled.

If the number of information bits in format 2A carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2A.

Table 5.3.3.1.5A-1: Number of bits for precoding information.

Number of antenna ports at eNodeB	Number of bits for precoding information
2	0
4	2

Table 5.3.3.1.5A-2: Content of precoding information field for 4 antenna ports.

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	4 layers: Transmit diversity	0	2 layers: precoder cycling with large delay CDD
1	2 layers: precoder cycling with large delay CDD	1	3 layers: precoder cycling with large delay CDD
2	reserved	2	4 layers: precoder cycling with large delay CDD
3	reserved	3	reserved

5.3.3.1.5B Format 2B

The following information is transmitted by means of the DCI format 2B:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.
- Resource block assignment:
  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]
    - $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation
  - For resource allocation type 1 as defined in section 7.1.6.2 of [3]
    - $\left\lceil \log_2(P) \right\rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset
    - 1 bit indicates a shift of the resource allocation span
    - $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \left\lceil \log_2(P) \right\rceil - 1 \right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section [7.1.6.1] of [3]

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- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Scrambling identity– 1 bit as defined in section 6.10.3.1 of [2]

- SRS request – [0-1] bit. This field can only be present for TDD operation and if present is defined in section 8.2 of [3]

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled, the number of layers equals two; transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1. Antenna ports 7 and 8 are used for spatial multiplexing.

In case one of the transport blocks is disabled, the number of layers equals one; the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2; and the antenna port for single-antenna port transmission is according to Table 5.3.3.1.5B-1.

Table 5.3.3.1.5B-1: Antenna port for single-antenna port transmission (one transport block disabled).

New data indicator of the disabled transport block	Antenna port
0	7
1	8

If the number of information bits in format 2B carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2B.

5.3.3.1.5C Format 2C

The following information is transmitted by means of the DCI format 2C:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]

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- $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]

  - $\left\lceil \log_2(P) \right\rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

  - 1 bit indicates a shift of the resource allocation span

  - $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \left\lceil \log_2(P) \right\rceil - 1 \right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section [7.1.6.1] of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Antenna port(s), scrambling identity and number of layers – 3 bits as specified in Table 5.3.3.1.5C-1 where n_{SCID} is the scrambling identity for antenna ports 7 and 8 defined in section 6.10.3.1 of [2], or 4bits as specified in Table 5.3.3.1.5C-2 where n_{SCID} is the scrambling identity for antenna ports 7, 8, 11 and 13 defined in section 6.10.3.1 of [2] when higher layer parameter *Rel-13-DMRS-table* is set to 1.

- SRS request – [0-1] bit. This field can only be present for TDD operation and if present is defined in section 8.2 of [3]

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled; transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1.

In case one of the transport blocks is disabled; the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For the single enabled codeword, Value = 4, 5, 6 in Table 5.3.3.1.5C-1 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two, three or four layers, respectively.

If the number of information bits in format 2C carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2C.

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Table 5.3.3.1.5C-1: Antenna port(s), scrambling identity and number of layers indication

One Codeword: Codeword 0 enabled, Codeword 1 disabled		Two Codewords: Codeword 0 enabled, Codeword 1 enabled	
Value	Message	Value	Message
0	1 layer, port 7, n_{SCID}=0	0	2 layers, ports 7-8, n_{SCID}=0
1	1 layer, port 7, n_{SCID}=1	1	2 layers, ports 7-8, n_{SCID}=1
2	1 layer, port 8, n_{SCID}=0	2	3 layers, ports 7-9
3	1 layer, port 8, n_{SCID}=1	3	4 layers, ports 7-10
4	2 layers, ports 7-8	4	5 layers, ports 7-11
5	3 layers, ports 7-9	5	6 layers, ports 7-12
6	4 layers, ports 7-10	6	7 layers, ports 7-13
7	Reserved	7	8 layers, ports 7-14

Table 5.3.3.1.5C-2: Antenna port(s), scrambling identity and number of layers indication

One Codeword: Codeword 0 enabled, Codeword 1 disabled		Two Codewords: Codeword 0 enabled, Codeword 1 enabled	
Value	Message	Value	Message
0	1 layer, port 7, n_{SCID}=0 (OCC=2)	0	2 layer, port 7-8, n_{SCID}=0 (OCC=2)
1	1 layer, port 7, n_{SCID}=1 (OCC=2)	1	2 layer, port 7-8, n_{SCID}=1 (OCC=2)
2	1 layer, port 8, n_{SCID}=0 (OCC=2)	2	2 layer, port 7-8, n_{SCID}=0 (OCC=4)
3	1 layer, port 8, n_{SCID}=1 (OCC=2)	3	2 layer, port 7-8, n_{SCID}=1 (OCC=4)
4	1 layer, port 7, n_{SCID}=0 (OCC=4)	4	2 layer, port 11,13, n_{SCID}=0 (OCC=4)
5	1 layer, port 7, n_{SCID}=1 (OCC=4)	5	2 layer, port 11,13, n_{SCID}=1 (OCC=4)
6	1 layer, port 8, n_{SCID}=0 (OCC=4)	6	3 layer, port 7-9
7	1 layer, port 8, n_{SCID}=1 (OCC=4)	7	4 layer, port 7-10
8	1 layer, port 11, n_{SCID}=0 (OCC=4)	8	5 layer, port 7-11
9	1 layer, port 11, n_{SCID}=1 (OCC=4)	9	6 layer, port 7-12
10	1 layer, port 13, n_{SCID}=0 (OCC=4)	10	7 layers, ports 7-13
11	1 layer, port 13, n_{SCID}=1 (OCC=4)	11	8 layers, ports 7-14
12	2 layers, ports 7-8	12	Reserved
13	3 layers, ports 7-9	13	Reserved
14	4 layers, ports 7-10	14	Reserved
15	Reserved	15	Reserved

5.3.3.1.5D Format 2D

The following information is transmitted by means of the DCI format 2D:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.
- Resource block assignment:
  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]

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- $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]

- $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

- 1 bit indicates a shift of the resource allocation span

- $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section [7.1.6.1] of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Antenna port(s), scrambling identity and number of layers – 3 bits as specified in Table 5.3.3.1.5C-1 where n_{SCID} is the scrambling identity for antenna ports 7 and 8 defined in section 6.10.3.1 of [2], or 4bits as specified in Table 5.3.3.1.5C-2 where n_{SCID} is the scrambling identity for antenna ports 7, 8, 11 and 13 defined in section 6.10.3.1 of [2] when higher layer parameter *Rel-13-DMRS-table* is set to 1.

- SRS request – [0-1] bit. This field can only be present for TDD operation and if present is defined in section 8.2 of [3]

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- PDSCH RE Mapping and Quasi-Co-Location Indicator – 2 bits as defined in sections 7.1.9 and 7.1.10 of [3]

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled; transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1.

In case one of the transport blocks is disabled; the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For the single enabled codeword, Value = 4, 5, 6 in Table 5.3.3.1.5C-1 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two, three or four layers, respectively.

If the number of information bits in format 2D carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2D.

5.3.3.1.6 Format 3

DCI format 3 is used for the transmission of TPC commands for PUCCH and PUSCH with 2-bit power adjustments.

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The following information is transmitted by means of the DCI format 3:

- TPC command number 1, TPC command number 2,..., TPC command number N

where $N = \left\lfloor \frac{L_{\text{format 0}}}{2} \right\rfloor$, and where $L_{\text{format 0}}$ is equal to the payload size of format 0 before CRC attachment when format 0 is mapped onto the common search space, including any padding bits appended to format 0. The parameter *tpc-Index* or *tpc-Index-PUCCH-SCell-r13* provided by higher layers determines the index to the TPC command for a given UE.

If $\left\lfloor \frac{L_{\text{format 0}}}{2} \right\rfloor < \frac{L_{\text{format 0}}}{2}$, a bit of value zero shall be appended to format 3.

5.3.3.1.7 Format 3A

DCI format 3A is used for the transmission of TPC commands for PUCCH and PUSCH with single bit power adjustments.

The following information is transmitted by means of the DCI format 3A:

- TPC command number 1, TPC command number 2,..., TPC command number M

where $M = L_{\text{format 0}}$, and where $L_{\text{format 0}}$ is equal to the payload size of format 0 before CRC attachment when format 0 is mapped onto the common search space, including any padding bits appended to format 0. The parameter *tpc-Index* or *tpc-Index-PUCCH-SCell-r13* provided by higher layers determines the index to the TPC command for a given UE.

5.3.3.1.8 Format 4

DCI format 4 is used for the scheduling of PUSCH in one UL cell with multi-antenna port transmission mode,

The following information is transmitted by means of the DCI format 4:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Resource block assignment - $\max\left(\left\lceil \log_2(N_{\text{RB}}^{\text{UL}}(N_{\text{RB}}^{\text{UL}}+1)/2) \right\rceil, \left\lceil \log_2\left(\binom{\left\lceil N_{RB}^{UL}/P+1 \right\rceil}{4} \right) \right\rceil \right)$ bits, where P is the UL RBG size as defined in section 8.1.2 of [3]
- For resource allocation type 0:
  - The $\left(\left\lceil \log_2(N_{\text{RB}}^{\text{UL}}(N_{\text{RB}}^{\text{UL}}+1)/2) \right\rceil \right)$ LSBs provide the resource allocation in the UL subframe as defined in section 8.1.1 of [3]
- For resource allocation type 1:
  - The $\left\lceil \log_2\left(\binom{\left\lceil N_{RB}^{UL}/P+1 \right\rceil}{4} \right) \right\rceil$ LSBs provide the resource allocation in the UL subframe as defined in section 8.1.2 of [3]
- TPC command for scheduled PUSCH – 2 bits as defined in section 5.1.1.1 of [3]
- Cyclic shift for DM RS and OCC index – 3 bits as defined in section 5.5.2.1.1 of [2]
- UL index – 2 bits as defined in sections 5.1.1.1, 7.2.1, 8 and 8.4 of [3] (this field is present only for TDD operation with uplink-downlink configuration 0)

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- Downlink Assignment Index (DAI) – 2 bits as defined in section 7.3 of [3] (this field is present only for cases with TDD primary cell and either TDD operation with uplink-downlink configurations 1-6 or FDD operation)
- CSI request – 1, 2 or 3 bits as defined in section 7.2.1 of [3]. The 2-bit field applies to UEs configured with no more than five DL cells and to
  - UEs that are configured with more than one DL cell;
  - UEs that are configured by higher layers with more than one CSI process;
  - UEs that are configured with two CSI measurement sets by higher layers with the parameter *csi-MeasSubframeSet*;

  the 3-bit field applies to UEs that are configured with more than five DL cells;

  otherwise the 1-bit field applies
- SRS request – 2 bits as defined in section 8.2 of [3]
- Resource allocation type – 1 bit as defined in section 8.1 of [3]

In addition, for transport block 1:

- Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3]
- New data indicator – 1 bit

In addition, for transport block 2:

- Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3]
- New data indicator – 1 bit

Precoding information and number of layers: number of bits as specified in Table 5.3.3.1.8-1. Bit field as shown in Table 5.3.3.1.8-2 and Table 5.3.3.1.8- 3. Note that TPMI for 2 antenna ports indicates which codebook index is to be used in Table 5.3.3A.2-1 of [2], and TPMI for 4 antenna ports indicates which codebook index is to be used in Table 5.3.3A.2-2, Table 5.3.3A.2-3, Table 5.3.3A.2-4 and Table 5.3.3A.2-5 of [2]. If both transport blocks are enabled, transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1. In case one of the transport blocks is disabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For a single enabled codeword, indices 24 to 39 in Table 5.3.3.1.8-3 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers.

Table 5.3.3.1.8-1: Number of bits for precoding information.

Number of antenna ports at UE	Number of bits for precoding information
2	3
4	6

Table 5.3.3.1.8-2: Content of precoding information field for 2 antenna ports

One codeword: Codeword 0 enabled Codeword 1 disabled		Two codewords: Codeword 0 enabled Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	1 layer: TPMI=0	0	2 layers: TPMI=0
1	1 layer: TPMI=1	1-7	reserved
2	1 layer: TPMI=2		
...	...		
5	1 layer: TPMI=5		
6-7	reserved		

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Table 5.3.3.1.8-3: Content of precoding information field for 4 antenna ports

One codeword: Codeword 0 enabled Codeword 1 disabled		Two codewords: Codeword 0 enabled Codeword 1 enabled	
Bit field mapped to index	**Message**	**Bit field mapped to index**	**Message**
0	1 layer: TPMI=0	0	2 layers: TPMI=0
1	1 layer: TPMI=1	1	2 layers: TPMI=1
...	...	...	...
23	1 layer: TPMI=23	15	2 layers: TPMI=15
24	2 layers: TPMI=0	16	3 layers: TPMI=0
25	2 layers: TPMI=1	17	3 layers: TPMI=1
...	...	...	...
39	2 layers: TPMI=15	27	3 layers: TPMI=11
40-63	reserved	28	4 layers: TPMI=0
		29 - 63	Reserved

If the number of information bits in format 4 is equal to the payload size for DCI format 1, 2, 2A, 2B, 2C or 2D associated with the configured DL transmission mode in the same serving cell, one zero bit shall be appended to format 4.

5.3.3.1.9 Format 5

DCI format 5 is used for the scheduling of PSCCH, and also contains several SCI format 0 fields used for the scheduling of PSSCH.

The following information is transmitted by means of the DCI format 5:

- Resource for PSCCH – 6 bits as defined in section 14.2.1 of [3]

-TPC command for PSCCH and PSSCH – 1 bit as defined in sections 14.2.1 and 14.1.1 of [3]

- SCI format 0 fields according to 5.4.3.1.1:

  - Frequency hopping flag

  - Resource block assignment and hopping resource allocation

  - Time resource pattern

If the number of information bits in format 5 mapped onto a given search space is less than the payload size of format 0 for scheduling the same serving cell, zeros shall be appended to format 5 until the payload size equals that of format 0 including any padding bits appended to format 0.

5.3.3.2 CRC attachment

Error detection is provided on DCI transmissions through a Cyclic Redundancy Check (CRC).

The entire payload is used to calculate the CRC parity bits. Denote the bits of the payload by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the payload size and L is the number of parity bits.

The parity bits are computed and attached according to section 5.1.1 setting L to 16 bits, resulting in the sequence $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where $B = A + L$.

In the case where closed-loop UE transmit antenna selection is not configured or applicable, after attachment, the CRC parity bits are scrambled with the corresponding RNTI $x_{rnti,0}, x_{rnti,1}, ..., x_{rnti,15}$, where $x_{rnti,0}$ corresponds to the MSB of the RNTI, to form the sequence of bits $c_0, c_1, c_2, c_3, ..., c_{B-1}$. The relation between c_k and b_k is:

$c_k = b_k$ for $k = 0, 1, 2, ..., A-1$

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$$c_k = (b_k + x_{rnti,k-A}) \bmod 2 \quad \text{for } k = A, A+1, A+2, \ldots, A+15.$$

In the case where closed-loop UE transmit antenna selection is configured and applicable, after attachment, the CRC parity bits with DCI format 0 are scrambled with the antenna selection mask $x_{AS,0}, x_{AS,1}, \ldots, x_{AS,15}$ as indicated in Table 5.3.3.2-1 and the corresponding RNTI $x_{rnti,0}, x_{rnti,1}, \ldots, x_{rnti,15}$ to form the sequence of bits $c_0, c_1, c_2, c_3, \ldots, c_{B-1}$. The relation between c_k and b_k is:

$$c_k = b_k \qquad \text{for } k = 0, 1, 2, \ldots, A-1$$

$$c_k = (b_k + x_{rnti,k-A} + x_{AS,k-A}) \bmod 2 \qquad \text{for } k = A, A+1, A+2, \ldots, A+15.$$

Table 5.3.3.2-1: UE transmit antenna selection mask.

UE transmit antenna selection	Antenna selection mask $< x_{AS,0}, x_{AS,1}, \ldots, x_{AS,15} >$
UE port 0	<0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0>
UE port 1	<0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1>

5.3.3.3 Channel coding

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3, \ldots, c_{K-1}$, where K is the number of bits, and they are tail biting convolutionally encoded according to section 5.1.3.1.

After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, \ldots, d_{D-1}^{(i)}$, with $i = 0,1,$ and 2, and where D is the number of bits on the i-th coded stream, i.e., $D = K$.

5.3.3.4 Rate matching

A tail biting convolutionally coded block is delivered to the rate matching block. This block of coded bits is denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, \ldots, d_{D-1}^{(i)}$, with $i = 0,1,$ and 2, and where i is the coded stream index and D is the number of bits in each coded stream. This coded block is rate matched according to section 5.1.4.2.

After rate matching, the bits are denoted by $e_0, e_1, e_2, e_3, \ldots, e_{E-1}$, where E is the number of rate matched bits.

5.3.4 Control format indicator

Data arrives each subframe to the coding unit in the form of an indicator for the time span, in units of OFDM symbols, of the DCI carried by PDCCH in that subframe of the corresponding DL cell. The CFI takes values CFI = 1, 2 or 3. For system bandwidths $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, the span of the DCI carried by PDCCH in units of OFDM symbols, 1, 2 or 3, is given by the CFI. For system bandwidths $N_{\mathrm{RB}}^{\mathrm{DL}} \le 10$, the span of the DCI carried by PDCCH in units of OFDM symbols, 2, 3 or 4, is given by CFI+1.

The coding flow is shown in Figure 5.3.4-1.

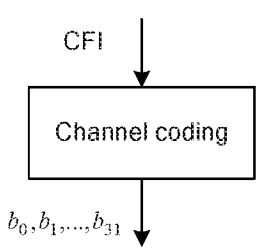


Figure 5.3.4-1 Coding for CFI.

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5.3.4.1 Channel coding

The control format indicator is coded according to Table 5.3.4-1.

Table 5.3.4-1: CFI code words.

CFI	CFI code word $< b_0, b_1, \ldots, b_{31} >$
1	<0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1>
2	<1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0>
3	<1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1>
4 (Reserved)	<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0>

5.3.5 HARQ indicator (HI)

Data arrives to the coding unit in the form of indicators for HARQ acknowledgement for one transport block.

The coding flow is shown in Figure 5.3.5-1.

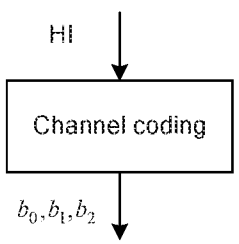


Figure 5.3.5-1 Coding for HI.

5.3.5.1 Channel coding

The HI is coded according to Table 5.3.5-1, where for a positive acknowledgement HI = 1 and for a negative acknowledgement HI = 0.

Table 5.3.5-1: HI code words.

HI	HI code word $< b_0, b_1, b_2 >$
0	< 0,0,0 >
1	< 1,1,1 >

5.4 Sidelink transport channels and control information

5.4.1 Sidelink broadcast channel

Figure 5.4.1-1 shows the processing structure for the SL-BCH transport channel. Data arrives to the coding unit in the form of a maximum of one transport block. The following coding steps can be identified:

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- Add CRC to the transport block
- Channel coding
- Rate matching

The coding steps for SL-BCH transport channel are shown in the figure below. In addition, after rate matching PUSCH interleaving is applied according to sections 5.2.2.7 and 5.2.2.8 without any control information in order to apply a time-first rather than frequency-first mapping, where $C_{mux} = 2 \cdot \left(N_{\text{symb}}^{\text{SL}} - 3\right)$ and the sequence of bits f is equal to e.

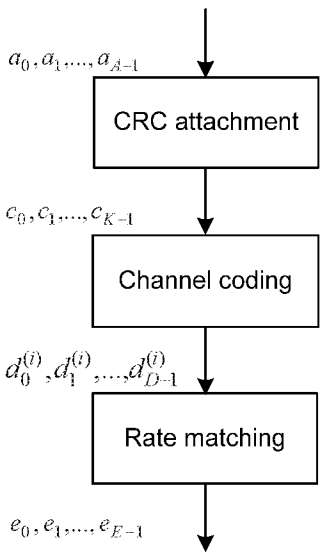


Figure 5.4.1-1: Transport channel processing for SL-BCH.

5.4.1.1 Transport block CRC attachment

Error detection is provided on transport blocks through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the size of the transport block and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in section 6.1.1 of [5].

The parity bits are computed and attached according to section 5.1.1 setting L to 16 bits, resulting in the sequence of bits $c_0, c_1, c_2, c_3, ..., c_{K-1}$ where $c_k = b_k$ for $k = 0, 1, 2, ..., K\text{-}1$ and $K = A + L$.

5.4.1.2 Channel coding

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits, and they are tail biting convolutionally encoded according to section 5.1.3.1.

After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, with $i = 0,1$, and 2, and where D is the number of bits on the i-th coded stream, i.e., $D = K$.

5.4.1.3 Rate matching

A tail biting convolutionally coded block is delivered to the rate matching block. This block of coded bits is denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, with $i = 0,1$, and 2, and where i is the coded stream index and D is the number of bits in each coded stream. This coded block is rate matched according to section 5.1.4.2.

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After rate matching, the bits are denoted by $e_0, e_1, e_2, e_3, ..., e_{E-1}$, where E is the number of rate matched bits as defined in section 9.6.1 of [2].

5.4.2 Sidelink shared channel

The processing of the sidelink shared channel follows the downlink shared channel according to section 5.3.2, with the following differences:

- Data arrives to the coding unit in the form of a maximum of one transport block every transmission time interval (TTI)
- In the step of code block concatenation, the sequence of coded bits corresponding to one transport block after code block concatenation is referred to as one codeword in section 9.3.1 of [2].
- PUSCH interleaving is applied according to sections 5.2.2.7 and 5.2.2.8 without any control information in order to apply a time-first rather than frequency-first mapping, where $C_{mux} = 2 \cdot \left(N_{\text{symb}}^{\text{SL}} - 1\right)$.

5.4.3 Sidelink control information

An SCI transports sidelink scheduling information for one destination ID.

The processing for one SCI follows the downlink control information according to section 5.3.3, with the following differences:

- In the step of CRC attachment, no scrambling is performed.
- PUSCH interleaving is applied according to sections 5.2.2.7 and 5.2.2.8 without any control information in order to apply a time-first rather than frequency-first mapping, where $C_{mux} = 2 \cdot \left(N_{\text{symb}}^{\text{SL}} - 1\right)$ and the sequence of bits f is equal to e.

5.4.3.1 SCI formats

The fields defined in the SCI formats below are mapped to the information bits a_0 to a_{A-1} as follows.

Each field is mapped in the order in which it appears in the description, with the first field mapped to the lowest order information bit a_0 and each successive field mapped to higher order information bits. The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to a_0.

5.4.3.1.1 SCI format 0

SCI format 0 is used for the scheduling of PSSCH.

The following information is transmitted by means of the SCI format 0:

- Frequency hopping flag – 1 bit as defined in section 14.1.1 of [3].
- Resource block assignment and hopping resource allocation – $\left\lceil \log_2(N_{\text{RB}}^{\text{SL}}(N_{\text{RB}}^{\text{SL}}+1)/2) \right\rceil$ bits
  - For PSSCH hopping:
    - N_{SL_hop} MSB bits are used to obtain the value of $\tilde{n}_{PRB}(i)$ as indicated in section 8.4 of [3]
    - $\left(\left\lceil \log_2(N_{\text{RB}}^{\text{SL}}(N_{\text{RB}}^{\text{SL}}+1)/2) \right\rceil - N_{\text{SL\_hop}} \right)$ bits provide the resource allocation in the subframe
  - For non-hopping PSSCH:

- $\left(\left\lceil \log_2\left(N_{\mathrm{RB}}^{\mathrm{SL}}\left(N_{\mathrm{RB}}^{\mathrm{SL}}+1\right)/2\right)\right\rceil\right)$ bits provide the resource allocation in the subframe as defined in section 8.1.1 of [3]

- Time resource pattern – 7 bits as defined in section 14.1.1 of [3].

- Modulation and coding scheme – 5 bits as defined in section 14.1.1 of [3]

- Timing advance indication – 11 bits as defined in section 14.2.1 of [3]

- Group destination ID – 8 bits as defined by higher layers

5.4.4 Sidelink discovery channel

The processing of the sidelink discovery channel follows the downlink shared channel according to section 5.3.2, with the following differences:

- Data arrives to the coding unit in the form of a maximum of one transport block every transmission time interval (TTI)

- In the step of code block concatenation, the sequence of coded bits corresponding to one transport block after code block concatenation is referred to as one codeword in section 9.5.1 of [2].

- PUSCH interleaving is applied according to sections 5.2.2.7 and 5.2.2.8 without any control information in order to apply a time-first rather than frequency-first mapping, where $C_{mux} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{SL}} - 1\right)$.

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Annex A (informative): Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2006-09					Skeleton		0.0.0
2006-10					Updated skeleton	0.0.0	0.0.1
2006-10					Endorsed skeleton	0.0.1	0.1.0
2006-11					Added TC. Added Broadcast, Paging and MBMS transport channels in Table 4.2-1.	0.1.0	0.1.1
2006-11					Endorsed v 0.2.0	0.1.1	0.2.0
2006-12					Added CC. Added type of coding for each transport channel or control information.	0.2.0	0.2.1
2007-01					Editor's version	0.2.1	0.2.2
2007-01					Endorsed v 0.3.0	0.2.2	0.3.0
2007-02					Added QPP turbo interleaver description.	0.3.0	0.3.1
2007-02					Editor's version	0.3.1	0.3.2
2007-02					Endorsed v 0.4.0	0.3.2	0.4.0
2007-02					Added CRC details for PDSCH, PDCCH and PUSCH. Added QPP turbo-interleaver parameters. Set Z to 6144. Added details on code block segmentation.	0.4.0	0.4.1
2007-02					Editor's version	0.4.1	0.4.2
2007-03	RAN#35	RP-070170			For information at RAN#35	0.4.2	1.0.0
2007-03					Editor's version	1.0.0	1.0.1
2007-03					Editor's version	1.0.1	1.1.0
2007-05					Editor's version	1.1.0	1.1.1
2007-05					Editor's version	1.1.1	1.1.2
2007-05					Editor's version	1.1.2	1.2.0
2007-06					Added circular buffer rate matching for PDSCH and PUSCH. Miscellaneous changes.	1.2.0	1.2.1
2007-06					Editor's version	1.2.1	1.2.2
2007-07					Editor's version	1.2.2	1.2.3
2007-07					Endorsed by email following decision taken at RAN1#49b	1.2.3	1.3.0
2007-08					Editor's version including decision from RAN1#49bis.	1.3.0	1.3.1
2007-08					Editor's version	1.3.1	1.3.2
2007-08					Editor's version	1.3.2	1.4.0
2007-09					Editor's version with decisions from RAN1#50	1.4.0	1.4.1
2007-09					Editor's version	1.4.1	1.4.2
10/09/07	RAN#37	RP-070730	-	-	For approval at RAN#37	1.4.2	2.0.0
12/09/07	RAN_37	RP-070730	-	-	Approved version	2.0.0	8.0.0
28/11/07	RAN_38	RP-070949	0001	-	Update of 36.212	8.0.0	8.1.0
05/03/08	RAN_39	RP-080145	0002	-	Update to 36.212 incorporating decisions from RAN1#51bis and RAN1#52	8.1.0	8.2.0
28/05/08	RAN_40	RP-080433	0003	-	Joint coding of CQI and ACK on PUCCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0004	1	ACK insertion into PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0005	1	Introduction of format 1C	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0006	1	Miscellaneous fixes to 36.212	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0008	1	On multiplexing scheme for indicators	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0009	1	On the soft buffer split of MIMO and TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0010	-	Resource assignment field for distributed VRB	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0011	-	Clarifying the use of the different DCI formats	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0012	1	Clarifying the value of N_L	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0013	-	Payload size for DCI formats 3 and 3A	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0014	-	Coding of ACK on PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0015	1	Coding of RI on PUSCH and mapping	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0016	-	CRC for control information on PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0017	-	Introduction of Downlink Assignment Index	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0018	-	Coding of CQI/PMI on PUSCH coming from PUCCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0019	-	Simultaneous transmission of aperiodic CQI and UL control	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0020	-	Encoding of antenna indicator on DCI format 0	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0021	-	PDCCH coverage in narrow bandwidths	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0022	-	Closed-loop and open-loop spatial multiplexing	8.2.0	8.3.0
28/05/08	RAN_40	RP-080457	0023	-	Formula for linkage between PUSCH MCS and amount of resources used for control	8.2.0	8.3.0
09/09/08	RAN_41	RP-080669	0026	-	Correction to PUSCH Channel Interleaver	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0028	-	Correction of mapping of ACK/NAK to binary bit values	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0029	-	Correction to bit collection, selection and transmission	8.3.0	8.4.0

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Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
09/09/08	RAN_41	RP-080669	0030	-	Padding one bit to DCI format 1 when format 1 and format 0/1A have the same size	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0031	-	Modification of M_limit	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0032	-	Definition of Formats 2 and 2A	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0033	2	Corrections to DCI formats	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0035	1	Format 1B confirmation flag	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0036	-	Corrections to Rank information scrambling in Uplink Shared Channel	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0037	2	Clarification of TPC commands signaled in DCI formats 3/3A	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0038	-	Clarification on UE transmit antenna selection mask	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0039	1	Linking of control resources in PUSCH to data MCS	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0041	-	Definition of Bit Mapping for DCI signalling	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0042	1	Clarification on resource allocation in DCI format 1/2/2A	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0043	-	DCI Format 1A changes needed for scheduling Broadcast Control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0044	-	DCI format1C	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0045	-	Miscellaneous corrections	8.3.0	8.4.0
11/09/08	RAN_41	RP-080736	0046	1	Correction on downlink multi-user MIMO	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0047	-	Corrections to DL DCI Formats in case of Ambiguous Payload Sizes	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0048	-	CR for RE provisioning for the control information in case of CQI-only transmission on PUSCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0091	2	Coding and multiplexing of multiple ACK/NACK in PUSCH	8.3.0	8.4.0
03/12/08	RAN_42	RP-080983	0050	2	Clarification of input bits corresponding to 2-bit HARQ-ACK and 2-bit RI	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0053	-	Editorial corrections to 36.212	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0055	-	Miscellaneous Corrections	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0057	-	Clarification of mapping of information bits	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0058	-	Completion of 36.212 CR47 (R1-083421) for "new" DCI Formats	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0059	-	Change for determining DCI format 1A TBS table column indicator for broadcast control	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0061	2	Defining DCI format 1A for downlink data arrival	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0063	1	ACK/NACK transmission on PUSCH for LTE TDD	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0065	-	Correction in 36.212 related to TDD downlink HARQ processes	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0067	1	Correction of control MCS offset and SRS symbol puncturing	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0068	1	DCI format 2/2A	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0069	-	Correction to zero padding in DCI format 1	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0071	-	Clarification of RI bit field mapping for PUCCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0072	-	Clarifying RNTI bit mapping for PDCCH CRC scrambling	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0073	-	Clarification on BCH transport block size	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0076	-	Clarification on the number of PUCCH-based CQI/PMI bits when reported on PUSCH	8.4.0	8.5.0
04/03/09	RAN_43	RP-090235	77	1	Corrections to Transmitted Rank Indication	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	79	1	Correction to the bundled ACK/NACK and DAI transmission	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	80	2	Corrections to transmission modes	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	81	1	Correction on ACKNACK transmission on PUSCH for LTE TDD	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	82	2	Corrections to CQI and RI fields description	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	83	-	Clarifying DCI format 1A and DCI Format 1B	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	92	1	Clarification on channel coding for UCI HARQ-ACK	8.5.0	8.6.0
27/05/09	RAN_44	RP-090528	87	-	Clarify some parameters for determining control resources on PUSCH	8.6.0	8.7.0
01/12/09	RAN_46	RP-091168	89	-	Clarification on bitwidth of RI	8.7.0	8.8.0
01/12/09	RAN_46	RP-091168	94	-	Correction to Channel interleaver for PUSCH RE Mapping	8.7.0	8.8.0
01/12/09	RAN_46	RP-091177	88	1	Editorial corrections to 36.212	8.8.0	9.0.0
01/12/09	RAN_46	RP-091257	95	1	Introduction of enhanced dual layer transmission	8.8.0	9.0.0
16/03/10	RAN_47	RP-100210	96	1	MCCH change notification using DCI format 1C	9.0.0	9.1.0
16/03/10	RAN_47	RP-100211	97	-	Addition of missing reference to DCI format 2B + typo corrections	9.0.0	9.1.0
01/06/10	RAN_48	RP-100589	98	-	Correction to TBS determination for DCI format 1C	9.1.0	9.2.0
14/09/10	RAN_49	RP-100899	99	-	Clarify soft buffer size determination for MCH	9.2.0	9.3.0
07/12/10	RAN_50	RP-101320	100	-	Introduction of Rel-10 LTE-Advanced features in 36.212	9.3.0	10.0.0
15/03/11	RAN_51	RP-110254	101	-	Correction on UE behavior upon receiving DCI format 1B	10.0.0	10.1.0
15/03/11	RAN_51	RP-110256	102	-	Corrections to Rel-10 LTE-Advanced features in 36.212	10.0.0	10.1.0
01/06/11	RAN_52	RP-110819	103	3	Correction of DCI format 0 and 4 resource allocation	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	104	2	Correction to Multi-cluster flag in DCI format 0	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	107	2	Corrections on HARQ-ACK Channel Coding in the PUSCH	10.1.0	10.2.0
01/06/11	RAN_52	RP-110820	108	3	A clarification for DCI format payload size	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	110	1	Correction the search space and RNTI for CQI and SRS request flag	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	111	-	Resource dimensioning for CQI only PUSCH transmission	10.1.0	10.2.0

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Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
01/06/11	RAN_52	RP-110820	112	1	Correction on bit representations of transport block processing for UL-SCH	10.1.0	10.2.0
01/06/11	RAN_52	RP-110818	113	-	Clarification on PMI indication in DCI format1B and format 2	10.1.0	10.2.0
01/06/11	RAN_52	RP-110820	114	1	Rate maching parameters for CA	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	116	-	HARQ-ACK on PUSCH for TDD with channel selection configured for 2 serving cells	10.1.0	10.2.0
01/06/11	RAN_52	RP-110823	117	-	Single codeword multiple layer transmission in uplink	10.1.0	10.2.0
15/09/11	RAN_53	RP-111228	119	1	Corrections on transport block processing for UL-SCH	10.2.0	10.3.0
15/09/11	RAN_53	RP-111230	120	2	On correction of channel coding of control information	10.2.0	10.3.0
15/09/11	RAN_53	RP-111230	122	1	Size adjustment of DCI format 0, 1A and 1	10.2.0	10.3.0
15/09/11	RAN_53	RP-111232	123	1	Corrections on *Nsrs*	10.2.0	10.3.0
15/09/11	RAN_53	RP-111232	124	2	Corrections on DCI format 1B/1D	10.2.0	10.3.0
15/09/11	RAN_53	RP-111228	125	-	Minor Correction on DCI Format 1 Description	10.2.0	10.3.0
15/09/11	RAN_53	RP-111226	127	-	Correction on ACK/NACK mapping	10.2.0	10.3.0
15/09/11	RAN_53	RP-111231	128	-	Corrections on channel coding of control information and DCI Format 4.	10.2.0	10.3.0
15/09/11	RAN_53	RP-111229	129	-	Clarification and correction to configuration signalling condition for channel quality information formats	10.2.0	10.3.0
05/12/11	RAN_54	RP-111667	130	1	Corrections on codebook index indication in DCI format 4	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	131	-	HARQ-ACK on UCI-only PUSCH without UL-SCH data	10.3.0	10.4.0
28/02/12	RAN_55	RP-120283	132	2	Corrections on payload size adjustment for DCI format 1A and 1	10.4.0	10.5.0
28/02/12	RAN_55	RP-120283	133	1	Correction of two HARQ-ACK feedback on PUSCH	10.4.0	10.5.0
28/02/12	RAN_55	RP-120285	134	1	Miscellaneous corrections	10.4.0	10.5.0
13/06/12	RAN_56	RP-120739	136	-	Correction to Data and control multiplexing	10.5.0	10.6.0
13/06/12	RAN_56	RP-120737	138	-	Correction to CSI request field size in DCI format 0 and DCI format 4	10.5.0	10.6.0
04/09/12	RAN_57	RP-121272	139	-	Introduction of Rel-11 LTE-Advanced features in 36.212	10.6.0	11.0.0
04/12/12	RAN_58	RP-121839	143	-	Correction to the parameter ue-Category-v10xy	11.0.0	11.1.0
04/12/12	RAN_58	RP-121846	144	-	Finalisation for introducing Rel-11 features	11.0.0	11.1.0
26/02/13	RAN_59	RP-130255	145	-	Additional clarifications/corrections for introducing Rel-11 features	11.1.0	11.2.0
11/06/13	RAN_60	RP-130751	147	2	Correction on the RI bit width	11.2.0	11.3.0
11/06/13	RAN_60	RP-130747	148	-	CR on DCI Format 4 payload size	11.2.0	11.3.0
11/06/13	RAN_60	RP-130752	149	-	Correction on the time span of the DCI	11.2.0	11.3.0
11/06/13	RAN_60	RP-130752	150	-	Correction on ARO bit setting for DL DCIs carried by EPDCCH	11.2.0	11.3.0
11/06/13	RAN_60	RP-130750	151	-	Clarification on DL DAI usage in inter-band TDD CA	11.2.0	11.3.0
11/06/13	RAN_60	RP-130749	153	-	Correction to bit padding of DCI format 1A for secondary cell without uplink component carrier	11.2.0	11.3.0
03/12/13	RAN_62	RP-131893	155	1	Correction on parameter ue-Category	11.3.0	11.4.0
03/12/13	RAN_62	RP-131896	154	3	Introduction of Rel 12 feature for Downlink MIMO Enhancement	11.4.0	12.0.0
10/06/14	RAN_64	RP-140858	156	-	Clarification on UE antenna port based CRC masking	12.0.0	12.1.0
10/06/14	RAN_64	RP-140859	157	1	Correction on UCI multiplexing on PUSCH	12.0.0	12.1.0
10/06/14	RAN_64	RP-140862	158	-	Introduction of Rel 12 features of TDD-FDD CA and eIMTA	12.0.0	12.1.0
10/06/14	RAN_64	RP-140858	159	-	Clarification of downlink subframes	12.0.0	12.1.0
10/09/14	RAN_65	RP-141485	161	-	CR for 36.212 on 256QAM and LC-MTC	12.1.0	12.2.0
08/12/14	RAN_66	RP-142106	163	3	CR for 36.212 on 256QAM and LC-MTC	12.2.0	12.3.0
08/12/14	RAN_66	RP-142098	164	3	Clarification of PUSCH rate matching with SRS	12.2.0	12.3.0
08/12/14	RAN_66	RP-142107	166	-	Introduction of Dual Connectivity feature into 36.212	12.2.0	12.3.0
09/03/15	RAN_67	RP-150366	162	3	Introduction of D2D feature into 36.212	12.3.0	12.4.0
15/06/15	RAN_68	RP-150936	169	-	Corrections on eIMTA RRC parameter naming	12.4.0	12.5.0
15/06/15	RAN_68	RP-150937	171	1	Correction for 36.212 on soft buffer assumption	12.4.0	12.5.0
14/09/15	RAN_69	RP-151466	174	1	Introducing 4-layer MIMO transmission in TM3 and TM4	12.5.0	12.6.0
14/09/15	RAN_69	RP-151467	175	2	Introduction of MIMO capability signalling for intra-band contiguous CA	12.50	12.6.0
07/12/15	RAN_70	RP-152038	177	-	Correction on rank indication bit widths	12.6.0	12.7.0
07/12/15	RAN_70	RP-152027	178	1	Introduction of Rel 13 feature of eCA	12.7.0	13.0.0
07/12/15	RAN_70	RP-152025	179	1	Introduction of EB/FD-MIMO	12.7.0	13.0.0
07/12/15	RAN_70	RP-152026	180	2	Introduction of Rel 13 feature of LAA	12.7.0	13.0.0
07/12/15	RAN_70	RP-152031	182	-	Introduction of Rel 13 features for SC-PTM	12.7.0	13.0.0

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Technical Specification

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Foreword

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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]

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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
CG	Cell Group
CIF	Carrier Indicator Field
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CRI	CSI-RS Resource Indicator
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
MCG	Master Cell Group
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
PSBCH	Physical Sidelink Broadcast Channel
PSCCH	Physical Sidelink Control Channel
PSCell	Primary Secondary cell
PSDCH	Physical Sidelink Discovery Channel
PSSCH	Physical Sidelink Shared Channel
PSSS	Primary Sidelink Synchronisation Signal
PUCCH	Physical Uplink Control Channel
PUCCH-SCell	PUCCH SCell
PUSCH	Physical Uplink Shared Channel
PTI	Precoding Type Indicator
RBG	Resource Block Group

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RE	Resource Element
RI	Rank Indication
RS	Reference Signal
SCG	Secondary Cell Group
SINR	Signal to Interference plus Noise Ratio
SPS C-RNTI	Semi-Persistent Scheduling C-RNTI
SR	Scheduling Request
SRS	Sounding Reference Symbol
SSSS	Secondary Sidelink Synchronisation Signal
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

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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.

If the UE is configured with a SCG [11], the downlink radio link quality of the PSCell [11] of the SCG 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 or PSCell, the UE shall adjust uplink transmission timing for PUCCH/PUSCH/SRS of the primary cell or PSCell 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. If the primary cell in a TAG has a frame structure type 1 and a secondary cell in the same TAG has a frame structure type 2, UE may assume that $N_{TA} \geq 624$.

If the UE is configured with a SCG, the UL transmission timing for PUSCH/SRS of a secondary cell other than the PSCell is the same as the PScell if the secondary cell and the PSCell belong to the same TAG.

Upon reception of a timing advance command for a TAG not containing the primary cell or PSCell, if all the serving cells in the TAG have the same frame structure type, 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.

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Upon reception of a timing advance command for a TAG not containing the primary cell or PSCell, if a serving cell in the TAG has a different frame structure type compared to the frame structure type of another serving cell in the same TAG, the UE shall adjust uplink transmission timing for PUSCH/SRS of all the secondary cells in the TAG by using $N_{TAoffset} = 624$ regardless of the frame structure type of the serving cells and 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. $N_{TAoffset}$ is described in [3].

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 $T_A = 0, 1, 2, ..., 256$ if the UE is configured with a SCG, and $T_A = 0, 1, 2, ..., 1282$ otherwise, 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 $n+8$.

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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].

For a serving cell with frame structure type 1, a UE is not expected to be configured with *UplinkPowerControlDedicated-v12x0*.

5.1.1 Physical uplink shared channel

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group

- When the procedures are applied for primary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the primary PUCCH group respectively.
- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the secondary PUCCH group respectively.

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

$$P_{\text{PUSCH},c}(i) = \min\begin{Bmatrix} P_{\text{CMAX},c}(i), \\ 10\log_{10}(M_{\text{PUSCH},c}(i)) + P_{\text{O\_PUSCH},c}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF},c}(i) + f_c(i) \end{Bmatrix} \text{ [dBm]}$$

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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 $P_{\text{CMAX},c}(i)$ assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR, A-MPR, P-MPR and ΔT_C are defined in [6].
- $\hat{P}_{\text{PUCCH}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$ defined in subclause 5.1.2.1
- $M_{\text{PUSCH},c}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for subframe i and serving cell c.
- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*,
  - when j=0, $P_{\text{O\_PUSCH},c}(0) = P_{\text{O\_UE\_PUSCH},c,2}(0) + P_{\text{O\_NOMINAL\_PUSCH},c,2}(0)$, where j=0 is used for PUSCH (re)transmissions corresponding to a semi-persistent grant. $P_{\text{O\_UE\_PUSCH},c,2}(0)$ and $P_{\text{O\_NOMINAL\_PUSCH},c,2}(0)$ are the parameters *p0-UE-PUSCH-Persistent-SubframeSet2-r12 and p0-NominalPUSCH-Persistent-SubframeSet2-r12* respectively provided by higher layers, for each serving cell c.
  - when j=1, $P_{\text{O\_PUSCH},c}(1) = P_{\text{O\_UE\_PUSCH},c,2}(1) + P_{\text{O\_NOMINAL\_PUSCH},c,2}(1)$, where j=1 is used for PUSCH (re)transmissions corresponding to a dynamic scheduled grant. $P_{\text{O\_UE\_PUSCH},c,2}(1)$ and $P_{\text{O\_NOMINAL\_PUSCH},c,2}(1)$ are the parameters *p0-UE-PUSCH-SubframeSet2-r12 and p0-NominalPUSCH-SubframeSet2-r12* respectively, provided by higher layers for serving cell c.
  - when j=2, $P_{\text{O\_PUSCH},c}(2) = P_{\text{O\_UE\_PUSCH},c}(2) + P_{\text{O\_NOMINAL\_PUSCH},c}(2)$ where $P_{\text{O\_UE\_PUSCH},c}(2) = 0$ and $P_{\text{O\_NOMINAL\_PUSCH},c}(2) = P_{\text{O\_PRE}} + \Delta_{PREAMBLE\_Msg3}$, where the parameter *preambleInitialReceivedTargetPower* [8] ($P_{\text{O\_PRE}}$) and $\Delta_{PREAMBLE\_Msg3}$ are signalled from higher layers for serving cell c, where j=2 is used for PUSCH (re)transmissions corresponding to the random access response grant.

  Otherwise

  - $P_{\text{O\_PUSCH},c}(j)$ is a parameter composed of the sum of a component $P_{\text{O\_NOMINAL\_PUSCH},c}(j)$ provided from higher layers for $j=0$ and 1 and a component $P_{\text{O\_UE\_PUSCH},c}(j)$ 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

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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 $j=2$. $P_{O\_UE\_PUSCH,c}(2) = 0$ and $P_{O\_NOMINAL\_PUSCH,c}(2) = P_{O\_PRE} + \Delta_{PREAMBLE\_Msg3}$, where the parameter *preambleInitialReceivedTargetPower* [8] (P_{O_PRE}) and $\Delta_{PREAMBLE\_Msg3}$ are signalled from higher layers for serving cell c.

- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*,
  - For j=0 or 1, $\alpha_c(j) = \alpha_{c,2} \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$. $\alpha_{c,2}$ is the parameter *alpha-SubframeSet2-r12* provided by higher layers for each serving cell c.
  - For j=2, $\alpha_c(j) = 1$.

  Otherwise
  - 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 path loss 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 containing the PSCell then, for the uplink of the PSCell, the PSCell is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP; for the uplink of the secondary cell other than PSCell, 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 or PSCell 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 β_{offset}^{PUSCH}, for each serving cell c, are computed as below. $K_S = 0$ for transmission mode 2.
  - $BPRE = O_{CQI} / N_{RE}$ for control data sent via PUSCH without UL-SCH data and $\sum_{r=0}^{C-1} K_r / N_{RE}$ for other cases.
    - where C is the number of code blocks, K_r is the size for code block r, O_{CQI} is the number of CQI/PMI bits including CRC bits and N_{RE} is the number of resource elements determined as $N_{RE} = M_{sc}^{PUSCH-initial} \cdot N_{symb}^{PUSCH\text{-}initial}$, where C, K_r, $M_{sc}^{PUSCH-initial}$ and $N_{symb}^{PUSCH\text{-}initial}$ 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.

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- $\delta_{\text{PUSCH},c}$ 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. If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*, the current PUSCH power control adjustment state for serving cell c is given by $f_{c,2}(i)$, and the UE shall use $f_{c,2}(i)$ instead of $f_c(i)$ to determine $P_{\text{PUSCH},c}(i)$. Otherwise, the current PUSCH power control adjustment state for serving cell c is given by $f_c(i)$. $f_{c,2}(i)$ and $f_c(i)$ are defined by:

  - $f_c(i) = f_c(i-1) + \delta_{\text{PUSCH},c}(i - K_{\text{PUSCH}})$ and $f_{c,2}(i) = f_{c,2}(i-1) + \delta_{\text{PUSCH},c}(i - K_{\text{PUSCH}})$ if accumulation is enabled based on the parameter *Accumulation-enabled* provided by higher layers or if the TPC command $\delta_{\text{PUSCH},c}$ 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 or FDD-TDD and serving cell frame structure type 1, $K_{PUSCH} = 4$
      - 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, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD and serving cell frame structure type 2, 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 or FDD-TDD and serving cell c frame structure type 2.
    - 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 δ_{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.

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- If UE has reached $P_{CMAX,c}(i)$ 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
- If the UE is not configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c, the UE shall reset accumulation
  - For serving cell c, when $P_{O\_UE\_PUSCH,c}$ value is changed by higher layers
  - For serving cell c, when the UE receives random access response message for serving cell c
- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c,
  - the UE shall reset accumulation corresponding to $f_c(*)$ for serving cell c
    - when $P_{O\_UE\_PUSCH,c}$ value is changed by higher layers
    - when the UE receives random access response message for serving cell c
  - the UE shall reset accumulation corresponding to $f_{c,2}(*)$ for serving cell c
    - when $P_{O\_UE\_PUSCH,c,2}$ value is changed by higher layers
- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and
  - if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12* $f_c(i) = f_c(i-1)$
  - if subframe i does not belong to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12* $f_{c,2}(i) = f_{c,2}(i-1)$
- $f_c(i) = \delta_{PUSCH,c}(i - K_{PUSCH})$ and $f_{c,2}(i) = \delta_{PUSCH,c}(i - K_{PUSCH})$ if accumulation is not enabled for serving cell c based on the parameter *Accumulation-enabled* provided by higher layers
  - where $\delta_{PUSCH,c}(i - K_{PUSCH})$ 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 or FDD-TDD and serving cell frame structure type 1, $K_{PUSCH} = 4$
    - 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, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, or FDD-TDD and serving cell frame structure type 2, 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.

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- 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.

- $f_c(i) = f_c(i-1)$ and $f_{c,2}(i) = f_{c,2}(i-1)$ 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 or FDD-TDD and serving cell c frame structure type 2.

- If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and

  - if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12* $f_c(i) = f_c(i-1)$

  - if subframe i does not belong to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12* $f_{c,2}(i) = f_{c,2}(i-1)$

- 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

      - $f_c(0) = \Delta P_{rampup,c} + \delta_{msg2,c}$, 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

$$\Delta P_{rampup,c} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \begin{pmatrix} 10\log_{10}(M_{PUSCH,c}(0)) \\ + P_{O\_PUSCH,c}(2) + \delta_{msg2} \\ + \alpha_c(2)\cdot PL + \Delta_{TF,c}(0) \end{pmatrix}\right)\right\},\right.$$

$$\left.\Delta P_{rampuprequested,c}\right]$$

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.

    - If $P_{\text{O\_UE\_PUSCH,c,2}}$ value is received by higher layers for a serving cell c.

      - $f_{c,2}(0) = 0$

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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 $\delta_{\text{PUSCH,c}}$ values

TPC Command Field in DCI format 0/3/4	Accumulated $\delta_{\text{PUSCH,c}}$ [dB]	Absolute $\delta_{\text{PUSCH,c}}$ [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 $\delta_{\text{PUSCH,c}}$ values

TPC Command Field in DCI format 3A	Accumulated $\delta_{\text{PUSCH,c}}$ [dB]
0	-1
1	1

If the UE is not configured with an SCG or a PUCCH-SCell, and if the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cell c in subframe i such that the condition

$$\sum_{c} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUCCH}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$, $\hat{P}_{\text{PUSCH},c}(i)$ is the linear value of $P_{\text{PUSCH},c}(i)$, $\hat{P}_{CMAX}(i)$ 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 $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c where $0 \le w(i) \le 1$. In case there is no PUCCH transmission in subframe i $\hat{P}_{\text{PUCCH}}(i) = 0$.

If the UE is not configured with an SCG or a PUCCH-Scell, and 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 $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cells without UCI in subframe i such that the condition

$$\sum_{c \ne j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$$

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 $\sum_{c \ne j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) = 0$ and the total transmit power of the UE still would exceed $\hat{P}_{CMAX}(i)$.

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For a UE not configured with a SCG or a PUCCH-SCell, 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 is not configured with an SCG or a PUCCH-SCell, and 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 $\hat{P}_{\mathrm{PUSCH},c}(i)$ according to

$$\hat{P}_{\mathrm{PUSCH},j}(i) = \min\left(\hat{P}_{\mathrm{PUSCH},j}(i), \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUCCH}}(i)\right)\right)$$

and

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \leq \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUCCH}}(i) - \hat{P}_{\mathrm{PUSCH},j}(i)\right)$$

If the UE is not configured with a SCG or a PUCCH-SCell, and

- 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.

If the UE is configured with a SCG, and if the higher layer parameter *phr-ModeOtherCG-r12* for a CG indicates 'virtual', for power headroom reports transmitted on that CG, the UE shall compute PH assuming that it does not transmit PUSCH/PUCCH on any serving cell of the other CG.

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If the UE is configured with a SCG,

- For computing power headroom for cells belonging to MCG, the term 'serving cell' in this subclause refers to serving cell belonging to the MCG.
- For computing power headroom for cells belonging to SCG, the term 'serving cell' in this subclause refers to serving cell belonging to the SCG. The term 'primary cell' in this subclause refers to the PSCell of the SCG.

If the UE is configured with a PUCCH-SCell,

- For computing power headroom for cells belonging to primary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the primary PUCCH group.
- For computing power headroom for cells belonging to secondary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the secondary PUCCH group. The term 'primary cell' in this subclause refers to the PUCCH-SCell of the secondary PUCCH group.

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 ΔT_C =0dB, where MPR , A-MPR, P-MPR and ΔT_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

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(10\log_{10}(M_{\text{PUSCH},c}(i)) + P_{\text{O\_PUSCH},c}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF},c}(i) + f_c(i)\right)/10} \\ + \ 10^{\left(P_{\text{O\_PUCCH}} + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i)\right)/10} \end{array}\right) \text{ [dB]}$$

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where, $P_{\mathrm{CMAX,c}}$, $M_{\mathrm{PUSCH,c}}(i)$, $P_{\mathrm{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\mathrm{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\mathrm{O\_PUCCH}}$, PL_c, $h(n_{CQI}, n_{HARQ}, n_{SR})$, $\Delta_{\mathrm{F\_PUCCH}}(F)$, $\Delta_{TxD}(F')$ 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

$$PH_{\mathrm{type2}}(i) = P_{\mathrm{CMAX,c}}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(10\log_{10}(M_{\mathrm{PUSCH,c}}(i)) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\mathrm{TF},c}(i) + f_c(i)\right)/10} \\ + \ 10^{\left(P_{\mathrm{O\_PUCCH}} + PL_c + g(i)\right)/10} \end{array}\right) \ [\mathrm{dB}]$$

where, $P_{\mathrm{CMAX,c}}(i)$, $M_{\mathrm{PUSCH,c}}(i)$, $P_{\mathrm{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\mathrm{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\mathrm{O\_PUCCH}}$, 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

$$PH_{\mathrm{type2}}(i) = P_{\mathrm{CMAX,c}}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(P_{\mathrm{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right)/10} \\ + \ 10^{\left(P_{\mathrm{O\_PUCCH}} + PL_c + h\left(n_{CQI}, n_{HARQ}, n_{SR}\right) + \Delta_{\mathrm{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i)\right)/10} \end{array}\right) \ [\mathrm{dB}]$$

where, $P_{\mathrm{O\_PUSCH,c}}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1, $P_{\mathrm{CMAX,c}}(i)$, $P_{\mathrm{O\_PUCCH}}$, PL_c, $h(n_{CQI}, n_{HARQ}, n_{SR})$, $\Delta_{\mathrm{F\_PUCCH}}(F)$, $\Delta_{TxD}(F')$ 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

$$PH_{\mathrm{type2}}(i) = \tilde{P}_{\mathrm{CMAX,c}}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(P_{\mathrm{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right)/10} \\ + \ 10^{\left(P_{\mathrm{O\_PUCCH}} + PL_c + g(i)\right)/10} \end{array}\right) \ [\mathrm{dB}]$$

where, $\tilde{P}_{CMAX,c}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR, A-MPR, P-MPR and ΔT_C are defined in [6], $P_{\mathrm{O\_PUSCH,c}}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\mathrm{O\_PUCCH}}$, PL_c and $g(i)$ are defined in subclause 5.1.2.1.

If the UE is unable to determine whether there is a PUCCH transmission corresponding to PDSCH transmission(s) or not, or which PUCCH resource is used, in subframe i for the primary cell, before generating power headroom for a Type 2 report, upon (E)PDCCH detection, with the following conditions:

- if both PUCCH format 1b with channel selection and *simultaneousPUCCH-PUSCH* are configured for the UE, or
- if PUCCH format 1b with channel selection is used for HARQ-ACK feedback for the UE configured with PUCCH format 3 and *simultaneousPUCCH-PUSCH* are configured,

then, UE is allowed to compute power headroom for a Type 2 using

$$PH_{\mathrm{type2}}(i) = P_{\mathrm{CMAX,c}}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(10\log_{10}(M_{\mathrm{PUSCH,c}}(i)) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\mathrm{TF},c}(i) + f_c(i)\right)/10} \\ + \ 10^{\left(P_{\mathrm{O\_PUCCH}} + PL_c + g(i)\right)/10} \end{array}\right) \ [\mathrm{dB}]$$

where, $P_{\mathrm{CMAX,c}}(i)$, $M_{\mathrm{PUSCH,c}}(i)$, $P_{\mathrm{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\mathrm{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in subclause 5.1.1.1 and $P_{\mathrm{O\_PUCCH}}$, PL_c and $g(i)$ are defined in subclause 5.1.2.1.

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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.

If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*, the UE shall use $f_{c,2}(i)$ instead of $f_c(i)$ to compute $PH_{\text{type1},c}(i)$ and $PH_{\text{type2},c}(i)$ for subframe i and serving cell c, where $f_{c,2}(i)$ is defined in subclause 5.1.1.1.

5.1.2 Physical uplink control channel

If the UE is configured with a SCG, the UE shall apply the procedures described in this subclause for both MCG and SCG.

- When the procedures are applied for MCG, the term 'serving cell' in this subclause refers to serving cell belonging to the MCG.

When the procedures are applied for SCG, the term 'serving cell' in this subclause refers to serving cell belonging to the SCG. The term 'primary cell' in this subclause refers to the PSCell of the SCG.If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this subclause for both primary PUCCH group and secondary PUCCH group.

- When the procedures are applied for the primary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the primary PUCCH group.
- When the procedures are applied for the secondary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the secondary PUCCH group. The term 'primary cell' in this subclause refers to the PUCCH-SCell of the secondary PUCCH group.

5.1.2.1 UE behaviour

If serving cell c is the primary cell, for PUCCH format 1/1a/1b/2/2a/2b/3, the setting of the UE Transmit power P_{PUCCH} for the physical uplink control channel (PUCCH) transmission in subframe i for serving cell c is defined by

$$P_{\text{PUCCH}}(i) = \min\left\{\begin{array}{l} P_{\text{CMAX},c}(i), \\ P_{0\_\text{PUCCH}} + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i) \end{array}\right\} \quad \text{[dBm]}$$

If serving cell c is the primary cell, for PUCCH format 4/5, the setting of the UE Transmit power P_{PUCCH} for the physical uplink control channel (PUCCH) transmission in subframe i for serving cell c is defined by

$$P_{\text{PUCCH}}(i) = \min\left\{\begin{array}{l} P_{\text{CMAX},c}(i), \\ P_{0\_\text{PUCCH}} + PL_c + 10\log_{10}(M_{\text{PUCCH},c}(i)) + \Delta_{\text{TF},c}(i) + \Delta_{\text{F\_PUCCH}}(F) + g(i) \end{array}\right\} \quad \text{[dBm]}$$

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_{PUCCH} for PUCCH in subframe i is computed by

$$P_{\text{PUCCH}}(i) = \min\{P_{\text{CMAX},c}(i), P_{0\_\text{PUCCH}} + PL_c + g(i)\} \quad \text{[dBm]}$$

where

- $P_{\text{CMAX},c}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell c. 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 ΔT_C =0dB, where MPR, A-MPR, P-MPR and ΔT_C are defined in [6].

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- The parameter $\Delta_{F\_PUCCH}(F)$ is provided by higher layers. Each $\Delta_{F\_PUCCH}(F)$ 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

$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} + n_{CQI} - 1}{2}$$

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- For PUCCH format 4, $M_{\mathrm{PUCCH},c}(i)$ is the bandwidth of the PUCCH format 4 expressed in number of resource blocks valid for subframe i and serving cell c. For PUCCH format 5, $M_{\mathrm{PUCCH},c}(i) = 1$.
- $\Delta_{TF,c}(i) = 10\log_{10}\left(2^{1.25 \cdot BPRE(i)} - 1\right)$ where $BPRE(i) = O_{\mathrm{UCI}}(i)/N_{\mathrm{RE}}(i)$,
  - $O_{\mathrm{UCI}}(i)$ is the number of HARQ-ACK/SR/RI/CQI/PMI bits including CRC bits transmitted on PUCCH format 4/5 in subframe i;
  - $N_{\mathrm{RE}}(i) = M_{\mathrm{PUCCH},c}(i) \cdot N_{sc}^{RB} \cdot N_{\mathrm{symb}}^{\mathrm{PUCCH}}$ for PUCCH format 4 and $N_{\mathrm{RE}}(i) = N_{sc}^{RB} \cdot N_{\mathrm{symb}}^{\mathrm{PUCCH}}/2$ for PUCCH format 5;
  - $N_{\mathrm{symb}}^{\mathrm{PUCCH}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right) - 1$ if shortened PUCCH format 4 or shortened PUCCH format 5 is used in subframe i and $N_{\mathrm{symb}}^{\mathrm{PUCCH}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right)$ otherwise.
- $P_{\mathrm{O\_PUCCH}}$ is a parameter composed of the sum of a parameter $P_{\mathrm{O\_NOMINAL\_PUCCH}}$ provided by higher layers and a parameter $P_{\mathrm{O\_UE\_PUCCH}}$ provided by higher layers.
- δ_{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 δ_{PUCCH} provided in that PDCCH/EPDCCH.

    Else
    - if the UE decodes a PDCCH with DCI format 3/3A, the UE shall use the δ_{PUCCH} provided in that PDCCH

    else the UE shall set δ_{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 or FDD-TDD and primary cell frame structure type 1, $M = 1$ and $k_0 = 4$.

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- For TDD, values of M and k_m are given in Table 10.1.3.1-1, where the "UL/DL configuration" in Table 10.1.3.1-1 corresponds to the *eimta-HARQ-ReferenceConfig-r12* for the primary cell when the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for the primary cell.

- The δ_{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 δ_{PUCCH} is 0dB.

- The δ_{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

    - δ_{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,

$$\Delta P_{rampup} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \left(\begin{array}{c} P_{0\_PUCCH} \\ + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) \\ + \Delta_{F\_PUCCH}(F) + \Delta_{TxD}(F') \end{array}\right)\right)\right\}, \Delta P_{rampuprequested}\right].$$

    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 $P_{\text{CMAX,c}}(i)$ 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 $P_{\text{O\_UE\_PUCCH}}$ 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 or FDD-TDD and primary cell frame structure type 2.

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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 δ_{PUCCH} values

TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2D/2/3	δ_{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 δ_{PUCCH} values

TPC Command Field in DCI format 3A	δ_{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_{SRS} for the SRS transmitted on subframe i for serving cell c is defined by

$$P_{\text{SRS},c}(i) = \min\left\{ P_{\text{CMAX},c}(i),\ P_{\text{SRS\_OFFSET},c}(m) + 10\log_{10}(M_{\text{SRS},c}) + P_{\text{O\_PUSCH},c}(j) + \alpha_c(j)\cdot PL_c + f_c(i) \right\} \quad \text{[dBm]}$$

where

- $P_{\text{CMAX},c}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell c.
- $P_{\text{SRS\_OFFSET},c}(m)$ 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 $m=1$.
- $M_{\text{SRS},c}$ 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.
- $P_{\text{O\_PUSCH},c}(j)$ and $\alpha_c(j)$ are parameters as defined in subclause 5.1.1.1 for subframe i, where $j=1$.

If the UE is not configured with an SCG or a PUCCH-SCell, and 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 $\hat{P}_{\text{SRS},c}(i)$ for the serving cell c and the SC-FDMA symbol in subframe i such that the condition

$$\sum_c w(i)\cdot \hat{P}_{\text{SRS},c}(i) \le \hat{P}_{CMAX}(i)$$

is satisfied where $\hat{P}_{\text{SRS},c}(i)$ is the linear value of $P_{\text{SRS},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of P_{CMAX} defined in [6] in subframe i and $w(i)$ is a scaling factor of $\hat{P}_{\text{SRS},c}(i)$ 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 not configured with an SCG or a PUCCH-SCell, and 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

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$\hat{P}_{\mathrm{SRS},c}(i)$ 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.

If the UE is configured with higher layer parameter *UplinkPowerControlDedicated-v12x0* for serving cell c and if subframe i belongs to uplink power control subframe set 2 as indicated by the higher layer parameter *tpc-SubframeSet-r12*, the UE shall use $f_{c,2}(i)$ instead of $f_c(i)$ to determine $P_{\mathrm{SRS},c}(i)$ for subframe i and serving cell c, where $f_{c,2}(i)$ is defined in subclause 5.1.1.1.

5.1.4 Power allocation for dual connectivity

If a UE is configured with multiple cell groups,

- if the UE supports synchronous dual connectivity but does not support asynchronous dual connectivity, or if the UE supports both synchronous dual connectivity and asynchronous dual connectivity and if the higher layer parameter *powerControlMode* indicates dual connectivity power control mode 1
  - if the maximum uplink timing difference between transmitted signals to different serving cells including serving cells belonging to different CGs is equal to or less than $T_{dc1\_threshold}$
    - The UE shall use the procedures described in sub clause 5.1.4.1.
    - If a PRACH transmission of the UE on the Pcell starting in subframe $i1$ of MCG overlaps in time domain with another PRACH transmission of the UE starting in subframe $i2$ of SCG, and if subframe $i1$ and subframe $i2$ overlap in time with more than one symbol, and if the total power of both the PRACH transmissions would exceed $\hat{P}_{\mathrm{CMAX}}(i1,i2)$, the UE shall transmit the PRACH on the Pcell using the preamble transmission power P_{PRACH} described in subclause 6.1. The UE may drop or adjust the power of the PRACH transmission in subframe $i2$ of SCG such that the total power does not exceed $\hat{P}_{\mathrm{CMAX}}(i1,i2)$, where $\hat{P}_{\mathrm{CMAX}}(i1,i2)$ is the linear value configured transmitted power for Dual Connectivity for the subframe pair $(i1,i2)$as described in [6]. If the UE drops the PRACH transmission, it sends power ramping suspension indicator to the higher layers. If the UE adjusts the power of PRACH transmission, it may send power ramping suspension indicator to the higher layers.
- if the UE supports both synchronous dual connectivity and asynchronous dual connectivity and if the higher layer parameter *powerControlMode* does not indicate dual connectivity power control mode 1
  - The UE shall use the procedures described in sub clause 5.1.4.2 .
  - If a PRACH transmission on the Pcell in subframe $i1$ of MCG overlaps in time another PRACH transmission in subframe $i2$ of SCG, and if the time difference between the start of the two PRACH transmissions is less than $30720 \cdot T_s$, and if the transmission timing of the PRACH on the Pcell (according to subclause 6.1.1) is such that the UE is ready to transmit the PRACH on Pcell at least one subframe before subframe $i1$ of MCG, and if the total power of both the PRACH transmissions exceeds $\hat{P}_{\mathrm{CMAX}}(i1,i2)$, the UE shall transmit the PRACH on the Pcell using the preamble transmission power P_{PRACH} described in subclause 6.1. The UE may drop or adjust the power of the PRACH transmission in subframe $i2$ of SCG such that the total power does not exceed $\hat{P}_{\mathrm{CMAX}}(i1,i2)$, where $\hat{P}_{\mathrm{CMAX}}(i1,i2)$ is the linear value

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configured transmitted power for Dual Connectivity for the subframe pair $(i1, i2)$ as described in [6]. If the UE drops the PRACH transmissions, it sends power ramping suspension indicator to the higher layers. If the UE adjusts the power of PRACH transmission, it may send power ramping suspension indicator to the higher layers.

5.1.4.1 Dual connectivity power control Mode 1

If the UE PUSCH/PUCCH transmission(s) in subframe $i1$ of CG1 overlap in time with PUSCH/PUCCH transmission(s) in more than one symbol of subframe $i2$ of CG2 or if at least the last symbol the UE PUSCH/PUCCH transmission(s) in subframe $i1$ of CG1 overlap in time with SRS transmission(s) of subframe $i2$, and

- if the UE has a PUCCH/PUSCH transmission with UCI including HARQ-ACK/SR in subframe $i1$ of CG1: If the UE has a PUCCH transmission with UCI including HARQ-ACK/SR in subframe $i1$ of CG1 and if $\hat{P}_{PUCCH\_CG1}(i1)$ would exceed $S1(i1)$, the UE scales $\hat{P}_{PUCCH\_CG1}(i1)$ such that the condition $\alpha 1(i1) \cdot \hat{P}_{PUCCH\_CG1}(i1) = \max\{0, S1(i1)\}$ is satisfied where $0 \le \alpha 1(i1) \le 1$ and $\hat{P}'_{PUCCH\_CG1}(i1) = \alpha 1(i1) \cdot \hat{P}_{PUCCH\_CG1}(i1)$. If $\hat{P}_{PUCCH\_CG1}(i1)$ would not exceed $S1(i1)$, $\hat{P}'_{PUCCH\_CG1}(i1) = \hat{P}_{PUCCH\_CG1}(i1)$. If the UE has a PUSCH transmission with UCI including HARQ-ACK in subframe $i1$ of serving cell $c_1 \in CG1$, and if $\hat{P}_{PUSCH,c_1}(i1)$ would exceed $S1(i1)$, the UE scales $\hat{P}_{PUSCH,c_1}(i1)$ such that the condition $\alpha 1(i1) \cdot \hat{P}_{PUSCH,c_1}(i1) = \max\{0, S1(i1)\}$ is satisfied where $0 \le \alpha 1(i1) \le 1$ and $\hat{P}'_{PUSCH,c_1}(i1) = \alpha 1(i1) \cdot \hat{P}_{PUSCH,c_1}(i1)$. If $\hat{P}_{PUSCH,c_1}(i1)$ would not exceed $S1(i1)$, $\hat{P}'_{PUSCH,c_1}(i1) = \hat{P}_{PUSCH,c_1}(i1)$.
  $S1(i1)$ is determined as follows

$$S1(i1) = \hat{P}_{\mathrm{CMAX}}(i1,i2) - \hat{P}_{u1}(i1) - \hat{P}_{q1}(i2) - \min\left\{ \begin{array}{l} \max\left\{ \begin{array}{l} 0, \\ \hat{P}_{\mathrm{CMAX}}(i1,i2) \cdot \frac{\gamma_{CG2}}{100} - \hat{P}_{q1}(i2) \end{array} \right\}, \\ \hat{P}'_{q1}(i2) \end{array} \right\};$$

  where

  - $\hat{P}_{u1}(i1) = \hat{P}_{PRACH\_CG1}(i1)$;
  - if CG1 is MCG and CG2 is SCG,
    - $\hat{P}_{q1}(i2) = \hat{P}_{PRACH\_CG2}(i2)$;
    - $\hat{P}'_{q1}(i2) = \hat{P}_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$;
  - if CG1 is SCG and CG2 is MCG
    - if the UE has a PUCCH transmission with UCI including HARQ-ACK/SR subframe $i2$ of CG2,
      - $\hat{P}_{q1}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2)$;
      - $\hat{P}'_{q1}(i2) = \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$
    - else if the UE has a PUSCH transmission with UCI including HARQ-ACK in subframe $i2$ of serving cell $j_2 \in CG2$,

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- $\hat{P}_{q1}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUSCH,j_2}(i2)$;
- $\hat{P}'_{q1}(i2) = \sum_{c_2 \in CG2, c_2 \neq j_2} \hat{P}_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}_{SRS,c_2}(i2)$;

- otherwise,
  - $\hat{P}_{q1}(i2) = \hat{P}_{PRACH\_CG2}(i2)$;
  - $\hat{P}'_{q1}(i2) = \hat{P}_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$

- if the UE has a PUCCH/PUSCH transmission with UCI not including HARQ-ACK/SR in subframe $i1$ of CG1:
  If the UE has a PUCCH transmission with UCI not including HARQ-ACK/SR in subframe $i1$ of CG1 and if $\hat{P}_{PUCCH\_CG1}(i1)$ would exceed $S2(i1)$, the UE scales $\hat{P}_{PUCCH\_CG1}(i1)$ such that the condition $\alpha 2(i1) \cdot \hat{P}_{PUCCH\_CG1}(i1) = \max\{0, S2(i1)\}$ is satisfied where $0 \le \alpha 2(i1) \le 1$ and $\hat{P}'_{PUCCH\_CG1}(i1) = \alpha 2(i1) \cdot \hat{P}_{PUCCH\_CG1}(i1)$. If $\hat{P}_{PUCCH\_CG1}(i1)$ would not exceed $S2(i1)$, $\hat{P}'_{PUCCH\_CG1}(i1) = \hat{P}_{PUCCH\_CG1}(i1)$. If the UE has a PUSCH transmission with UCI not including HARQ-ACK in subframe $i1$ of serving cell $c_1 \in CG1$, and if $\hat{P}_{PUSCH,c_1}(i1)$ would exceed $S2(i1)$, the UE scales $\hat{P}_{PUSCH,c_1}(i1)$ such that the condition $\alpha 2(i1) \cdot \hat{P}_{PUSCH,c_1}(i1) = \max\{0, S2(i1)\}$ is satisfied where $0 \le \alpha 2(i1) \le 1$ and $\hat{P}'_{PUSCH,c_1}(i1) = \alpha 2(i1) \cdot \hat{P}_{PUSCH,c_1}(i1)$. If $\hat{P}_{PUSCH,c_1}(i1)$ would not exceed $S2(i1)$, $\hat{P}'_{PUSCH,c_1}(i1) = \hat{P}_{PUSCH,c_1}(i1)$.
  $S2(i1)$ is determined as follows

$$S2(i1) = \hat{P}_{\text{CMAX}}(i1,i2) - \hat{P}_{u2}(i1) - \hat{P}_{q2}(i2) - \min\left\{ \begin{array}{l} \max\left\{ \begin{array}{l} 0, \\ \hat{P}_{\text{CMAX}}(i1,i2) \cdot \frac{\gamma_{CG2}}{100} - \hat{P}_{q2}(i2) \end{array} \right\} \\ \hat{P}'_{q2}(i2) \end{array} \right\}$$

  where

  - $\hat{P}_{u2}(i1) = \hat{P}_{PRACH\_CG1}(i1) + \hat{P}'_{PUCCH\_CG1}(i1)$ if the UE has a PUCCH transmission with HARQ-ACK/SR and a PUSCH transmission with UCI not including HARQ-ACK in subframe $i1$ of CG1, otherwise, $\hat{P}_{u2}(i1) = \hat{P}_{PRACH\_CG1}(i1)$.

- if CG1 is MCG and CG2 is SCG
  - if the UE has a PUCCH transmission with UCI including HARQ-ACK/SR in subframe $i2$ of CG2,
    - $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2)$
    - $\hat{P}'_{q2}(i2) = \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$;
  - else if the UE has a PUSCH transmission with UCI including HARQ-ACK in subframe $i2$ of serving cell $j_2 \in CG2$,

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- $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUSCH,j_2}(i2)$
- $\hat{P}'_{q2}(i2) = \sum_{c_2 \in CG2, c_2 \neq j_2} \hat{P}_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}_{SRS,c_2}(i2)$;

- otherwise,
  - $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2)$
  - $\hat{P}'_{q2}(i2) = \hat{P}_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$

- if CG1 is SCG and CG2 is MCG
  - if the UE has a PUCCH transmission in subframe $i2$ of CG2 and/or a PUSCH transmission with UCI in in subframe $i2$ of serving cell $j_2 \in CG2$
    - $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2) + \hat{P}'_{PUSCH,j_2}(i2)$
    - $\hat{P}'_{q2}(i2) = \sum_{c_2 \in CG2, c_2 \neq j_2} \hat{P}_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}_{SRS,c_2}(i2)$

    where, $\hat{P}_{PUCCH\_CG2}(i2) = 0$ if the UE does not have a PUCCH transmission in subframe $i2$ of CG2; $\hat{P}_{PUSCH,j_2}(i2) = 0$ if the UE does not have a PUSCH transmission with UCI in subframe $i2$ of CG2;
  - otherwise
    - $\hat{P}_{q2}(i2) = \hat{P}_{PRACH\_CG2}(i2)$
    - $\hat{P}'_{q2}(i2) = \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$

- If the UE has PUSCH transmission(s) without UCI in subframe $i1$ of CG1, the UE shall determine

$$S3(i1) = \hat{P}_{\mathrm{CMAX}}(i1,i2) - \hat{P}_{u3}(i1) - \hat{P}_{q3}(i2) - \min\left\{ \begin{array}{l} \max\left\{ \begin{array}{l} 0, \\ \hat{P}_{\mathrm{CMAX}}(i1,i2) \cdot \frac{\gamma_{CG2}}{100} - \hat{P}_{q3}(i2) \end{array} \right\} \\ \hat{P}'_{q3}(i2) \end{array} \right\}$$

where

- if the UE has a PUCCH transmission in subframe $i1$ of CG1 and/or a PUSCH transmission with UCI in in subframe $i1$ of serving cell $j_1 \in CG1$ $\hat{P}_{u3}(i1) = \hat{P}_{PRACH\_CG1}(i1) + \hat{P}'_{PUCCH\_CG1}(i1) + \hat{P}'_{PUSCH,j_1}(i1)$, where $\hat{P}_{PUCCH\_CG1}(i1) = 0$ if the UE does not have a PUCCH transmission in subframe $i1$ of CG1, $\hat{P}_{PUSCH,j_1}(i1) = 0$ if the UE does not have a PUSCH transmission with UCI in subframe $i1$ of CG1; otherwise $\hat{P}_{u3}(i1) = \hat{P}_{PRACH\_CG1}(i1)$;
- if CG1 is MCG and CG2 is SCG

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- if the UE has a PUCCH transmission in subframe $i2$ of CG2 and/or a PUSCH transmission with UCI in in subframe $i2$ of serving cell $j_2 \in CG2$
  - $\hat{P}_{q3}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2) + \hat{P}'_{PUSCH,j_2}(i2)$
  - $\hat{P}'_{q3}(i2) = \sum_{c_2 \in CG2, c_2 \neq j_2} \hat{P}_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}_{SRS,c_2}(i2)$

  where, $\hat{P}_{PUCCH\_CG2}(i2) = 0$ if the UE does not have a PUCCH transmission in subframe $i2$ of CG2; $\hat{P}_{PUSCH,j_2}(i2) = 0$ if the UE does not have a PUSCH transmission with UCI in subframe $i2$ of CG2;
- otherwise
  - $\hat{P}_{q3}(i2) = \hat{P}_{PRACH\_CG2}(i2)$
  - $\hat{P}'_{q3}(i2) = \sum_{c_2 \in CG2} \left(\hat{P}_{PUSCH,c_2}(i2) + \hat{\tilde{P}}_{SRS,c_2}(i2) \right)$;
- if CG1 is SCG and CG2 is MCG
  - $\hat{P}_{q3}(i2) = \hat{P}_{PRACH\_CG2}(i2) + \hat{P}'_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \hat{P}'_{PUSCH,c_2}(i2)$
  - $\hat{P}'_{q3}(i2) = \sum_{c_2 \in CG2} \hat{\tilde{P}}_{SRS,c_2}(i2)$;

- If the total transmit power of all the PUSCH transmission(s) without UCI in subframe $i1$ of CG1 would exceed $S3(i1)$, the UE scales $\hat{P}_{\mathrm{PUSCH},c1}(i1)$ for each serving cell $c_1 \in CG1$ with a PUSCH transmission without UCI in subframe $i1$ such that the condition $\sum_{c_1 \in CG1} w(i1) \cdot \hat{P}_{\mathrm{PUSCH},c_1}(i1) \leq \max\{0, S3(i1)\}$ is satisfied, where $\hat{P}'_{\mathrm{PUSCH},c_1}(i1) = w(i1) \cdot \hat{P}_{\mathrm{PUSCH},c_1}(i1)$, and where $w(i1)$ is a scaling factor of $\hat{P}_{\mathrm{PUSCH},c_1}(i1)$ for serving cell c_1 where $0 \leq w(i1) \leq 1$. Note that $w(i1)$ values are the same across serving cells within a cell group when $w(i1) > 0$ but for certain serving cells within the cell group $w(i1)$ may be zero. If the total transmit power of all the PUSCH transmission(s) without UCI in subframe $i1$ of CG1 would not exceed $S3(i1)$, $\hat{P}'_{\mathrm{PUSCH},c_1}(i1) = \hat{P}_{\mathrm{PUSCH},c_1}(i1)$.

where

- $\hat{P}_{\mathrm{CMAX}}(i1,i2)$ is the linear value of configured transmitted power for Dual Connectivity for the subframe pair $(i1,i2)$ as described in [6];
- if CG1 is MCG and CG2 is SCG
  - $\hat{P}_{\mathrm{PUCCH\_CG1}}(i1)$ is the linear value of $P_{\mathrm{PUCCH}}(i1)$ corresponding to PUCCH transmission on the primary cell ; $\hat{P}_{\mathrm{PUCCH\_CG2}}(i2)$ is the linear value of $P_{\mathrm{PUCCH}}(i2)$ corresponding to PUCCH transmission on the PSCell.
  - $\gamma_{CG1} = \gamma_{MCG}$;

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- if CG1 is SCG and CG2 is MCG;
  - $\hat{P}_{\text{PUCCH\_CG1}}(i1)$ is the linear value of $P_{\text{PUCCH}}(i1)$ corresponding to PUCCH transmission on the PSCell; $\hat{P}_{\text{PUCCH\_CG2}}(i2)$ is the linear value of $P_{\text{PUCCH}}(i2)$ corresponding to PUCCH transmission on the primary cell.
  - $\gamma_{CG1} = \gamma_{SCG}$;
- $\hat{P}_{\text{PUSCH},c_1}(i1)$ is the linear value of $P_{\text{PUSCH},c_1}(i1)$ for subframe $i1$ of serving cell of serving cell $c_1 \in CG1$, and $\hat{P}_{\text{PUSCH},c_2}(i2)$ is the linear value of $P_{\text{PUSCH},c_2}(i2)$ for subframe $i2$ of serving cell of serving cell $c_2 \in CG2$.
- γ_{MCG} and γ_{SCG} are given by Table 5.1.4.2-1 according to higher layer parameters p-MeNB and p-SeNB respectively;
- If the UE has a PRACH transmission for CG1 overlapping with subframe $i1$ of CG1, $\hat{P}_{PRACH\_CG1}(i1)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{PRACH\_CG1}(i1) = 0$;
- If the UE has a PRACH transmission for CG2 overlapping with subframe $i2$ of CG2, $\hat{P}_{PRACH\_CG2}(i2)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{PRACH\_CG2}(i2) = 0$.
- $\hat{\hat{P}}_{SRS,c_2}(i2)$ is determined as follows
  - if the PUSCH/PUCCH is not transmitted in the last symbol of subframe $i1$ of CG1, or if the UE does not have an SRS transmission in subframe $i2$ of serving cell $c_2 \in CG2$ or if the UE drops SRS transmission in subframe $i2$ of serving cell $c_2 \in CG2$ due to collision with PUCCH in subframe $i2$ of serving cell $c_2 \in CG2$
    - $\hat{\hat{P}}_{SRS,c_2}(i2) = 0$;
  - if the UE has an SRS transmission and does not have a PUCCH/PUSCH transmission in subframe $i2$ of serving cell $c_2 \in CG2$
    - $\hat{\hat{P}}_{SRS,c_2}(i2) = \hat{P}_{SRS,c_2}(i2)$;
  - if the UE has an SRS transmission and a has PUCCH transmission, and does not have a PUSCH transmission in subframe $i2$ of serving cell $c_2 \in CG2$

$$\hat{\hat{P}}_{SRS,c_2}(i2) = \max\left\{0, \hat{P}_{SRS,c_2}(i2) - \hat{P}_{PUCCH\_CG2}(i2)\right\}$$

  - if the UE has an SRS transmission and a has PUSCH transmission, and does not have a PUCCH transmission in subframe $i2$ of serving cell $c_2 \in CG2$

$$\hat{\hat{P}}_{SRS,c_2}(i2) = \max\left\{0, \hat{P}_{SRS,c_2}(i2) - \hat{P}_{PUSCH,c_2}(i2)\right\}$$

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- if the UE has an SRS transmission and has a PUSCH transmission and a PUCCH transmission in in subframe $i2$ of serving cell $c_2 \in CG2$

$$\hat{\tilde{P}}_{SRS,c_2}(i2) = \max\left\{0, \hat{P}_{SRS,c_2}(i2) - \hat{P}_{PUSCH,c_2}(i2) - \hat{P}_{PUCCH\_CG2}(i2)\right\}$$

If the total transmit power for the Sounding Reference Symbol in an SC-FDMA symbol across all the serving cells within a TAG of a cell group CG1 would exceed $S4(i1)$, the UE scales $\hat{P}_{\mathrm{SRS},c_1}(i1)$ for the serving cell $c_1 \in CG1$ and the SC-FDMA symbol in subframe $i1$ such that the condition $\sum_{c_1 \in CG1} v(i1) \cdot \hat{P}_{\mathrm{SRS},c_1}(i1) \le S4(i1)$ is satisfied, where $\hat{P}'_{\mathrm{SRS},c_1}(i1) = v(i1) \cdot \hat{P}_{\mathrm{SRS},c_1}(i1)$ is the transmission power of SRS after scaling and where $\hat{P}_{\mathrm{SRS},c_1}(i1)$ is the linear value of $P_{\mathrm{SRS},c_1}(i1)$ described in section 5.1.3.1, and $v(i)$ is a scaling factor of $\hat{P}_{\mathrm{SRS},c_1}(i1)$ for serving cell $c_1 \in CG1$ where $0 < v(i) \le 1$. Note that $v(i)$ values are the same across serving cells within the same CG.

If the UE is configured with multiple TAGs within CG1 and the SRS transmission of the UE in an SC-FDMA symbol for a serving cell in subframe $i1$ in a TAG belonging to CG1 overlaps with the SRS transmission in another SC-FDMA symbol in subframe $i1$ for a serving cell in another TAG belonging to CG1, and if the total transmit power of the UE for the Sounding Reference Symbol in the overlapped portion would exceed $S4(i1)$, the UE scales $\hat{P}_{\mathrm{SRS},c_1}(i1)$ for the serving cell $c_1 \in CG1$ and each of the overlapped SRS SC-FDMA symbols in subframe $i1$ such that the condition $\sum_{c_1 \in CG1} v(i1) \cdot \hat{P}_{\mathrm{SRS},c_1}(i1) \le S4(i1)$ is satisfied, where $\hat{P}'_{\mathrm{SRS},c_1}(i1) = v(i1) \cdot \hat{P}_{\mathrm{SRS},c_1}(i1)$ is the transmission power of SRS after scaling, and where $v(i1)$ is a scaling factor of $\hat{P}_{\mathrm{SRS},c_1}(i1)$ for serving cell c_1 where $0 \le v(i1) \le 1$. Note that $v(i1)$ values are the same across serving cells within a cell group.

$S4(i1)$ is determined as follows

$$S4(i1) = \hat{P}_{\mathrm{CMAX}}(i1,i2) - \hat{P}_{q4}(i2) - \min\left\{\max\left\{0, \hat{P}_{\mathrm{CMAX}}(i1,i2) \cdot \frac{\gamma_{CG2}}{100} - \hat{P}_{q4}(i2)\right\}, \hat{P}'_{q4}(i2)\right\}$$

where

- if CG1 is MCG and CG2 is SCG

$$\hat{P}_{q4}(i2) = \hat{\tilde{P}}_{PRACH\_CG2}(i2) + \hat{\tilde{P}}'_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}'_{PUSCH,c_2}(i2)$$

$$\hat{P}'_{q4}(i2) = \sum_{c_2 \in CG2} \hat{P}_{SRS,c_2}(i2)$$

- if CG1 is SCG and CG2 is MCG

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$$\hat{P}_{q4}(i2) = \hat{\tilde{P}}_{PRACH\_CG2}(i2) + \hat{\tilde{P}}'_{PUCCH\_CG2}(i2) + \sum_{c_2 \in CG2} \hat{\tilde{P}}'_{PUSCH,c_2}(i2) + \sum_{c_2 \in CG2} \hat{P}'_{SRS,c_2}(i2)$$

-

- $\hat{P}'_{q4}(i2) = 0$

- if the UE has no PUCCH transmission or has a shortened PUCCH transmission in subframe $i2$ of CG2, $\hat{\tilde{P}}'_{PUCCH\_CG2}(i2) = 0$; otherwise $\hat{\tilde{P}}'_{PUCCH\_CG2}(i2) = \hat{P}'_{PUCCH\_CG2}(i2)$

- if the UE has no PUSCH transmission in the last symbol of subframe $i2$ of serving cell $c_2 \in CG2$, $\hat{\tilde{P}}'_{PUSCH,c_2}(i2) = 0$; otherwise $\hat{\tilde{P}}'_{PUSCH,c_2}(i2) = \hat{P}'_{PUSCH,c_2}(i2)$

- if the UE has PRACH transmission in CG2 that overlaps with the last symbol of subframe $i2$ of CG2, $\hat{\tilde{P}}_{PRACH\_CG2}(i2) = \hat{P}_{PRACH\_CG2}(i2)$; otherwise $\hat{\tilde{P}}_{PRACH\_CG2}(i2) = 0$

For both cell groups

- if the PUCCH/PUSCH transmission of the UE on subframe $i1$ for a given serving cell in a TAG of CG1 overlaps some portion of the first symbol of the PUSCH transmission on subframe $i1+1$ for a different serving cell in another TAG of CG1 and/or overlaps with the PUCCH/PUSCH transmission on subframe $i2+1$ for a serving cell in another TAG of CG2, the UE shall adjust its total transmission power of all CGs such that the total transmission power of the UE across all CGs does not exceed P_{CMAX} on any overlapped portion.

- if the PUSCH transmission of the UE on subframe $i1$ for a given serving cell in a TAG of CG1 overlaps some portion of the first symbol of the PUCCH transmission on subframe $i1+1$ for a different serving cell in another TAG of CG1 and/or overlaps with the PUCCH/PUSCH transmission on subframe $i2+1$ for a serving cell in another TAG of CG2, the UE shall adjust its total transmission power of all CGs such that the total transmission power of the UE across all CGs does not exceed P_{CMAX} on any overlapped portion.

- if the SRS transmission of the UE in a symbol on subframe $i1$ for a given serving cell in a TAG of CG1 overlaps with the PUCCH/PUSCH transmission on subframe $i1$ or subframe $i1+1$ for a different serving cell in the same or another TAG of CG1 and/or overlaps with the PUCCH/PUSCH transmission on subframe $i2+1$ for a serving cell of CG2, the UE shall drop the SRS in CG1 if its total transmission power across all CGs exceeds P_{CMAX} on any overlapped portion of the symbol.

- if the SRS transmission of the UE in a symbol on subframe $i1$ for a given serving cell in CG1 overlaps with the SRS transmission on subframe $i1$ for a different serving cell(s) in CG1 or overlaps with SRS transmission on subframe $i2$ for a serving cell(s) in CG2, and if the SRS transmissions overlap with PUSCH/PUCCH transmission on subframe $i1$ or subframe $i1+1$ for another serving cell(s) in CG1, and/or if the SRS transmissions overlap with PUSCH/PUCCH transmission on subframe $i2+1$ for a serving cell of CG2, the UE shall drop the SRS transmissions in CG1 if its total transmission power across all CGs exceeds P_{CMAX} on any overlapped portion of the symbol.

- UE shall, when requested by higher layers, to transmit PRACH on subframe $i1$ or subframe $i1+1$ in a secondary serving cell in CG1 and/or to transmit PRACH on subframe $i2+1$ in a serving cell in CG2 in parallel with SRS transmission in a symbol on subframe $i1$ of a different serving cell belonging to a different TAG of CG1, drop SRS in CG1 if its total transmission power across all CGs exceeds P_{CMAX} on any overlapped portion of the symbol.

- UE shall, when requested by higher layers, to transmit PRACH on subframe $i1+1$ in a secondary serving cell in CG1 and/or to transmit PRACH on subframe $i2+1$ in a serving cell in CG2 in parallel with

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PUSCH/PUCCH on subframe $i1$ in a different serving cell belonging to a different TAG of CG1, adjust the transmission power of PUSCH/PUCCH in CG1 so that the total transmission power of the UE across all CGs does not exceed P_{CMAX} on the overlapped portion.

5.1.4.2 Dual connectivity power control Mode 2

If subframe $i1$ of CG1 overlaps in time with subframe $i2-1$ and subframe $i2$ of CG2, and if the UE has transmission(s) in subframe $i1$ of CG1,

- if the UE determines based on higher layer signalling that transmission(s) in subframe $i1$ of CG1 cannot overlap in time with transmission(s) in subframe $i2$ of CG2, the UE shall determine

$$\hat{P}^1_{CG1}(i1) = \min\left\{\begin{array}{l}\hat{P}_{q1}(i1),\\ \hat{P}_{\text{CMAX}}(i1,i2-1) - \hat{P}_{\text{PRACH\_CG1}}(i1) - \hat{P}^1_{CG2}(i2-1) - \hat{P}_{\text{PRACH\_CG2}}(i2-1)\end{array}\right\}$$

- Otherwise, the UE shall determine

$$\hat{P}^1_{CG1}(i1) = \min\left\{\begin{array}{l}\hat{P}_{q1}(i1),\\ \hat{P}_{\text{CMAX}}(i1,i2-1) - \hat{P}_{\text{PRACH\_CG1}}(i1) - \max\left\{\begin{array}{l}\hat{P}_{\text{CMAX}}(i1,i2-1)\cdot\frac{\gamma_{CG2}}{100},\\ \hat{P}^1_{CG2}(i2-1) + \hat{P}_{\text{PRACH\_CG2}}(i2-1),\\ \hat{P}_{\text{PRACH\_CG2}}(i2)\end{array}\right\}\end{array}\right\}$$

where,

- $\hat{P}_{q1}(i1) = \hat{P}_{PUCCH\_CG1}(i1) + \sum_{c\in CG1}\left(\hat{P}_{PUSCH,c}(i1) + \hat{\tilde{P}}_{SRS,c}(i1)\right)$
- $\hat{P}_{\text{CMAX}}(i1,i2-1)$ is the linear value of configured transmitted power for Dual Connectivity for the subframe pair $(i1,i2-1)$, as described in [6];
- $\hat{P}_{PUSCH,c}(i1) = 0$, if the UE does not have a PUSCH transmission in serving cell $c \in CG1$;
- $\hat{P}_{PUCCH\_CG1}(i1) = 0$ if the UE does not have a PUCCH transmission in CG1;
- $\hat{P}^1_{CG2}(i2-1) = 0$ if the UE has no transmission of PUCCH, PUSCH, or SRS in subframe $i2-1$ of CG2;
- $\gamma_{CG1} = \gamma_{MCG}$, and $\gamma_{CG2} = \gamma_{SCG}$ if CG1 is MCG and CG2 is SCG;
- $\gamma_{CG1} = \gamma_{SCG}$, and $\gamma_{CG2} = \gamma_{MCG}$, if CG1 is SCG and CG2 is MCG;
- γ_{MCG} and γ_{SCG} are given by Table 5.1.4.2-1 according to higher layer parameters *p-MeNB* and *p-SeNB* respectively;
- If the UE has a PRACH transmission for CG1 overlapping with subframe $i1$ of CG1, $\hat{P}_{PRACH\_CG1}(i1)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{PRACH\_CG1}(i1) = 0$.

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- If the UE has a PRACH transmission for CG2 overlapping with subframe $i2$ of CG2, and if the transmission timing of the PRACH transmission (according to subclause 6.1.1) is such that the UE is ready to transmit the PRACH at least one subframe before subframe $i2$ of CG2, $\hat{P}_{PRACH\_CG2}(i2)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{PRACH\_CG2}(i2) = 0$.

- If the UE has a PRACH transmission for CG2 overlapping with subframe $i2-1$ of CG2, $\hat{P}_{\text{PRACH\_CG2}}(i2-1)$ is the linear value of the transmission power of that PRACH transmission; otherwise, $\hat{P}_{\text{PRACH\_CG2}}(i2-1) = 0$.

- $\hat{\tilde{P}}_{SRS,c}(i1)$ is determined as follows

  - if the UE does not have an SRS transmission in subframe $i1$ of serving cell $c \in CG1$ or if the UE drops the SRS transmission in subframe $i1$ of serving cell $c \in CG1$ due to collision with a PUCCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = 0$;

  - if the UE has an SRS transmission and does not have a PUCCH/PUSCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = \hat{P}_{SRS,c}(i1)$;

  - if the UE has an SRS transmission and a has PUCCH transmission, and does not have a PUSCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = \max\left\{\begin{matrix}0,\\ \hat{P}_{SRS,c}(i1) - \hat{P}_{PUCCH\_CG1}(i1)\end{matrix}\right\}$

  - if the UE has an SRS transmission and a has PUSCH transmission, and does not have a PUCCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = \max\left\{\begin{matrix}0,\\ \hat{P}_{SRS,c}(i1) - \hat{P}_{PUSCH,c}(i1)\end{matrix}\right\}$

  - if the UE has an SRS transmission and has a PUSCH transmission and a PUCCH transmission in subframe $i1$ of serving cell $c \in CG1$

    - $\hat{\tilde{P}}_{SRS,c}(i1) = \max\left\{\begin{matrix}0,\\ \hat{P}_{SRS,c}(i1) - \hat{P}_{PUSCH,c}(i1) - \hat{P}_{PUCCH\_CG1}(i1)\end{matrix}\right\}$

    where $\hat{P}_{SRS,c}(i1)$ is the linear value of $P_{SRS,c}(i1)$ described in section 5.1.3.1.

If $\hat{P}_{\text{PUCCH\_CG1}}(i)$ would exceed $\hat{P}^1_{CG1}(i)$, the UE scales $\hat{P}_{PUCCH\_CG1}(i)$ such that the condition $\alpha 1(i) \cdot \hat{P}_{PUCCH\_CG1}(i) \le \hat{P}^1_{CG1}(i)$ is satisfied where

- if CG1 is MCG, $\hat{P}_{\text{PUCCH\_CG1}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$ corresponding to PUCCH transmission on the primary cell, in case there is no PUCCH transmission in subframe i on the primary cell $\hat{P}_{\text{PUCCH\_CG1}}(i) = 0$.
- if CG1 is SCG, $\hat{P}_{\text{PUCCH\_CG1}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$ corresponding to PUCCH transmission on PSCell, in case there is no PUCCH transmission in subframe i on the PSCell $\hat{P}_{\text{PUCCH\_CG1}}(i) = 0$.
  $\hat{P}_{\text{PUSCH},c}(i)$ is the linear value of $P_{\text{PUSCH},c}(i)$
- $0 \le \alpha 1(i) \le 1$ is a scaling factor of $\hat{P}_{\text{PUCCH\_CG1}}(i)$.

If the UE has PUSCH transmission with UCI on serving cell $j \in CG1$, and $\hat{P}_{\text{PUSCH},j}(i)$ would exceed $\hat{P}^1_{CG1}(i)$ the UE scales $\hat{P}_{\text{PUSCH},j}(i)$ such that the condition $\alpha 2(i) \cdot \hat{P}_{\text{PUSCH},j}(i) \le \hat{P}^1_{CG1}(i)$ is satisfied where $\hat{P}_{\text{PUSCH},j}(i)$ is the linear value of the PUSCH transmit power for the cell with UCI, and $0 \le \alpha 2(i) \le 1$ is a scaling factor of $\hat{P}_{\text{PUSCH},j}(i)$ for serving cell $j \in CG1$.

If the total transmit power across all the serving cells of a cell group CG1 would exceed $\hat{P}^1_{CG1}(i)$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cell $c \in CG1$ in subframe i such that the condition $\sum_{c \in CG1} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}^1_{CG1}(i) - \hat{P}_{\text{PUCCH\_CG1}}(i)\right)$ is satisfied; and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c where $0 \le w(i) \le 1$.

If the UE has PUSCH transmission with UCI on serving cell $j \in CG1$ and PUSCH without UCI in any of the remaining serving cells belonging to CG1, and the total transmit power across all the serving cells of CG1 would exceed $\hat{P}^1_{CG1}(i)$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cells belonging to CG1 without UCI in subframe i such that the condition $\sum_{c \in CG1, c \ne j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}^1_{CG1}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$ 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 $\sum_{c \in CG1, c \ne j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) = 0$ and the total transmit power across all of the serving cells of the CG1 still would exceed $\hat{P}^1_{CG1}(i)$.

If the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell $j \in CG1$ and PUSCH transmission without UCI in any of the remaining serving cells belonging to CG1, and the total transmit power across all the serving cells of the CG1 would exceed $\hat{P}^1_{CG1}(i)$, the UE obtains $\hat{P}_{\text{PUSCH},c}(i)$ according to $\hat{P}_{\text{PUSCH},j}(i) = \min\left(\hat{P}_{\text{PUSCH},j}(i), \left(\hat{P}^1_{CG1}(i) - \hat{P}_{\text{PUCCH\_CG1}}(i)\right)\right)$ and $\sum_{c \in CG1, c \ne j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}^1_{CG1}(i) - \hat{P}_{\text{PUCCH\_CG1}}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$

where

- if CG1 is MCG, $\hat{P}_{\text{PUCCH\_CG1}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$ corresponding to PUCCH transmission on the primary cell.

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- if CG1 is SCG, $\hat{P}_{\text{PUCCH\_CG1}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$ corresponding to PUCCH transmission on PSCell.

Note that $w(i)$ values are the same across serving cells within a cell group when $w(i) > 0$ but for certain serving cells within the cell group $w(i)$ may be zero.

If the total transmit power for the Sounding Reference Symbol in an SC-FDMA symbol across all the serving cells within a TAG of a cell group CG1 would exceed $\hat{P}^1_{CG1}(i)$, the UE scales $\hat{P}_{\text{SRS},c}(i)$ for the serving cell $c \in CG1$ and the SC-FDMA symbol in subframe i such that the condition

$$\sum_{c \in CG1} v(i) \cdot \hat{P}_{\text{SRS},c}(i) \le \hat{P}^1_{CG1}(i)$$

is satisfied where $\hat{P}_{\text{SRS},c}(i)$ is the linear value of $P_{\text{SRS},c}(i)$ described in section 5.1.3.1, and $v(i)$ is a scaling factor of $\hat{P}_{\text{SRS},c}(i)$ for serving cell $c \in CG1$ where $0 < v(i) \le 1$. Note that $v(i)$ values are the same across serving cells within the same CG.

If the UE is configured with multiple TAGs within CG1 and the SRS transmission of the UE in an SC-FDMA symbol for a serving cell in subframe i in a TAG belonging to CG1 overlaps with the SRS transmission in another SC-FDMA symbol in subframe i for a serving cell in another TAG belonging to CG1, and if the total transmit power of the UE for the Sounding Reference Symbol in the overlapped portion would exceed $\hat{P}^1_{CG1}(i)$, the UE scales $\hat{P}_{\text{SRS},c}(i)$ for the serving cell $c \in CG1$ and each of the overlapped SRS SC-FDMA symbols in subframe i such that the condition

$$\sum_{c \in CG1} v(i) \cdot \hat{P}_{\text{SRS},c}(i) \le \hat{P}^1_{CG1}(i)$$

is satisfied where $\hat{P}_{\text{SRS},c}(i)$ is the linear value of $P_{\text{SRS},c}(i)$ described in section 5.1.3.1, and $v(i)$ is a scaling factor of $\hat{P}_{\text{SRS},c}(i)$ for serving cell $c \in CG1$ where $0 < v(i) \le 1$. Note that $v(i)$ values are the same across serving cells within the same CG.

For a cell group CG1

- if the UE is configured with multiple TAGs within CG1, and if the PUCCH/PUSCH transmission of the UE on subframe i for a given serving cell in a TAG of CG1 overlaps some portion of the first symbol of the PUSCH transmission on subframe $i+1$ for a different serving cell in another TAG of CG1, the UE shall adjust its total transmission power of CG1 to not exceed $\hat{P}^1_{CG1}$ on any overlapped portion.

- if the UE is configured with multiple TAGs within CG1, and if the PUSCH transmission of the UE on subframe i for a given serving cell in a TAG of CG1 overlaps some portion of the first symbol of the PUCCH transmission on subframe $i+1$ for a different serving cell in another TAG of CG1 the UE shall adjust its total transmission power of CG1 to not exceed $\hat{P}^1_{CG1}$ on any overlapped portion.

- if the UE is configured with multiple TAGs within CG1, and if the SRS transmission of the UE in a symbol on subframe i for a given serving cell in a TAG of CG1 overlaps with the PUCCH/PUSCH transmission on subframe i or subframe $i+1$ for a different serving cell in the same or another TAG of CG1 the UE shall drop SRS if its total transmission power of CG exceeds $\hat{P}^1_{CG1}$ on any overlapped portion of the symbol.

- if the UE is configured with multiple TAGs within CG1 and more than 2 serving cells within CG1, and if the SRS transmission of the UE in a symbol on subframe i for a given serving cell in the CG1 overlaps with the SRS transmission on subframe i for a different serving cell(s) in CG1 and with PUSCH/PUCCH transmission on subframe i or subframe $i+1$ for another serving cell(s) in CG1, the UE shall drop the SRS transmissions in CG1 if the total transmission power of CG1 exceeds $\hat{P}^1_{CG1}$ on any overlapped portion of the symbol.

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- if the UE is configured with multiple TAGs within CG1, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in CG1 in parallel with SRS transmission in a symbol on a subframe of a different serving cell belonging to a different TAG of CG1, drop SRS in CG1 if the total transmission power of CG1 exceeds $\hat{P}_{CG1}^{1}$ on any overlapped portion in the symbol.

- if the UE is configured with multiple TAGs within CG1, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in CG1 in parallel with PUSCH/PUCCH in a different serving cell belonging to a different TAG in CG1, adjust the transmission power of PUSCH/PUCCH in CG1 so that its total transmission power of CG1 does not exceed $\hat{P}_{CG1}^{1}$ on the overlapped portion.

Table 5.1.4.2-1: γ_{MCG} (or γ_{SCG}) values for determining power allocation for dual connectivity

p-MeNB (or p-SeNB)	γ_{MCG} (or γ_{SCG}) Value (in %)
0	0
1	5
2	10
3	15
4	20
5	30
6	37
7	44
8	50
9	56
10	63
11	70
12	80
13	90
14	95
15	100

5.1.5 Power allocation for PUCCH-SCell

If a UE is configured with a PUCCH-SCell, power allocation for serving cells in the primary PUCCH group and secondary PUCCH group is performed according to section 5.1.4.1, with the following exceptions:

- the term 'MCG' is replaced by 'primary PUCCH group';
- the term 'SCG' is replaced by 'secondary PUCCH group';
- $i1 = i2 = i$ and $\hat{P}_{\text{CMAX}}(i1, i2) = \hat{P}_{\text{CMAX}}(i)$ is the linear value of the UE total configured maximum output power P_{CMAX} defined in [6] in subframe i; and
- $\gamma_{\text{MCG}} = \gamma_{\text{SCG}} = 0$.

5.2 Downlink power allocation

The eNodeB determines the downlink transmit energy per resource element.

For the purpose of RSRP and RSRQ measurements, the UE may assume downlink cell-specific RS EPRE is constant across the downlink system bandwidth and constant across all subframes with discovery signal transmissions until different cell-specific RS power information is received.

For a cell that is not a LAA Scell, the 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.

For a LAA SCell, the UE may assume that the EPRE of downlink cell-specific RS in subframe n is same as the EPRE of downlink cell-specific RS in subframe n-1, if all OFDM symbols of at least the second slot of subframe n-1, are occupied.

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 ρ_A or ρ_B according to the OFDM symbol index as given by Table 5.2-2 and Table 5.2-3. In addition, ρ_A and ρ_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, or 256QAM, spatial multiplexing with more than one layer or for PDSCH transmissions associated with the multi-user MIMO transmission scheme,

- ρ_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];
- ρ_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 a UE configured with higher layers parameter *servCellp-a-r12*, and the UE in transmission modes 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 QPSK and transmission with single-antenna port or transmit diversity transmission schemes or spatial multiplexing using a single transmission layer, and the PDSCH transmission is not associated with the multi-user MIMO transmission scheme, and the PDSCH is scheduled by a PDCCH/EPDCCH with CRC scrambled by C-RNTI,

- ρ_A is equal to $P_A' + 10 \cdot \log_{10}(2)$ [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];
- ρ_A is equal to P_A' [dB] otherwise

and where P_A' is given by the parameter *servCellp-a-r12*.

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, 64QAM, or 256QAM, 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].

For the purpose of RSRP and RSRQ measurements on CSI-RS of a discovery signal the UE may assume that the EPRE of CSI-RS is constant across the downlink system bandwidth and constant across all subframes with discovery signal transmissions for each CSI-RS resource.

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If a serving cell is not configured for a UE as a LAA Scell, and if CSI-RS is configured in the serving cell then the UE shall assume downlink CSI-RS EPRE is constant across the downlink system bandwidth and constant across all subframes for each CSI-RS resource.

If a serving cell is configured for a UE as a LAA Scell, the UE may assume that EPRE of CSI-RS in subframe n2 is same as EPRE of CSI-RS in earlier subframe n1, if all OFDM symbols of subframe n1 and all subframes between subframe n1 and subframe n2, are occupied.

The cell-specific ratio ρ_B / ρ_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 ρ_B / ρ_A for 1, 2, or 4 cell specific antenna ports

P_B	ρ_B / ρ_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, 64QAM, or 256QAM, 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 ρ_A or ρ_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 ρ_A		OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_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 ρ_A or ρ_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 ρ_A				OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_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 $n_{PRB} = 0,\ldots,N_{RB}^{DL}-1$; $RNTP_{threshold}$ 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

$$E_{\max\_nom}^{(p)} = \frac{P_{\max}^{(p)} \cdot \frac{1}{\Delta f}}{N_{RB}^{DL} \cdot N_{SC}^{RB}}$$

where $P_{\max}^{(p)}$ is the base station maximum output power described in [7], and Δf, N_{RB}^{DL} and N_{SC}^{RB} are defined in [3].

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6 Random access procedure

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG

Prior to initiation of the non-synchronized physical random access procedure, Layer 1 shall receive the following information from the higher layers:

- Random access channel parameters (PRACH configuration and frequency position)
- 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:

- Layer 1 procedure is triggered upon request of a preamble transmission by higher layers.
- 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.
- 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 path loss estimate calculated in the UE for serving cell c .
- A preamble sequence is selected from the preamble sequence set using the preamble index.
- A single preamble is transmitted using the selected preamble sequence with transmission power P_{PRACH} on the indicated PRACH resource.
- 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, where for TDD serving cell, the first UL subframe for PUSCH transmission is determined based on the UL/DL configuration (i.e., the

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parameter *subframeAssignment*) indicated by higher layers. 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

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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 δ_{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 δ_{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, RI, and CRI 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 TDD, FDD and FDD-TDD 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

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG unless stated otherwise

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells', 'serving cell', and 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell or serving cells belonging to the MCG respectively unless stated otherwise. The terms 'subframe' and 'subframes' refer to subframe or subframes belonging to MCG.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell' and 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PSCell), serving cell, serving cells belonging to the SCG respectively unless stated otherwise. The term 'primary cell' in this clause refers to the PSCell of the SCG. The terms 'subframe' and 'subframes' refer to subframe or subframes belonging to SCG

If a UE is configured with a LAA Scell, the UE shall apply the procedures described in this clause assuming frame structure type 1 for the LAA Scell unless stated otherwise.

For FDD, there shall be a maximum of 8 downlink HARQ processes per serving cell.

For FDD-TDD and primary cell frame structure type 1, there shall be a maximum of 8 downlink HARQ processes per serving cell.

For TDD and a UE not configured with the parameter *EIMTA-MainConfigServCell-r12* for any serving cell,, 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, 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, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD and primary cell frame structure type 2 and serving cell frame structure type 2, 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).

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For FDD-TDD and primary cell frame structure type 2 and serving cell frame structure type 1, the maximum number of downlink HARQ processes for the serving cell shall be determined by the DL-reference UL/DL configuration for the serving cell (as defined in subclause 10.2), as indicated in Table 7-2.

The dedicated broadcast HARQ process defined in [8] is not counted as part of the maximum number of HARQ processes for FDD, TDD and FDD-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

Table 7-2: Maximum number of DL HARQ processes for FDD-TDD, primary cell frame structure type 2, and serving cell frame structure type 1

DL-reference UL/DL Configuration	Maximum number of HARQ processes
0	10
1	11
2	12
3	15
4	16
5	16
6	12

7.1 UE procedure for receiving the physical downlink shared channel

Except the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* or by *mbsfn-SubframeConfigList-v12x0* or by *laa-SCellSubframeConfig* 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.

If a UE is configured with more than one serving cell and if the frame structure type of any two configured serving cells is different, then the UE is considered to be configured for FDD-TDD carrier aggregation.

Except for MBMS reception, the UE is not required to monitor PDCCH with CRC scrambled by the SI-RNTI on the PSCell.

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.

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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.

The UE is not required to monitor PDCCH with CRC scrambled by the P-RNTI on the PSCell.

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)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the G-RNTI or SC-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-4.
The scrambling initialization of PDSCH corresponding to these PDCCHs is by G-RNTI or SC-RNTI.

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Table 7.1-4: PDCCH and PDSCH configured by G-RNTI or SC-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 LAA Scells, the UE is not expected to receive PDSCH data transmissions signalled via PDCCH/EPDCCH according to transmission modes 5,6,7.

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.

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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 downlink subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* or by *mbsfn-SubframeConfigList-v12x0* or by *laa-SCellSubframeConfig* 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.

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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 and 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) • 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, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, single-antenna port, port 7 or 8 (see subclause 7.1.1) otherwise
Mode 10	DCI format 1A	Common and 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) • 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, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, single-antenna port, port 7 or 8 (see subclause 7.1.1) otherwise

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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) • 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, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, single-antenna port, port 7 or 8 (see subclause 7.1.1) otherwise
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) • 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, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, single-antenna port, port 7 or 8 (see subclause 7.1.1) otherwise

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.

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When a UE is configured in transmission mode 9 or 10, in the downlink subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* or by *mbsfn-SubframeConfigList-v12x0* 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_{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, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, Single-antenna port, port 7 or 8, (see subclause 7.1.1) otherwise
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, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, Single-antenna port, port 7 or 8, (see subclause 7.1.1) otherwise

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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, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, Single-antenna port, port 7 or 8, (see subclause 7.1.1) otherwise
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, 8, 11, or 13 (see subclause 7.1.1) if UE is configured with higher layer parameter *dmrs-tableAlt*, Single-antenna port, port 7 or 8, (see subclause 7.1.1) otherwise

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 0/5/7/8/11/13) 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].

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If the UE is not configured with higher layer parameter *dmrs-tableAlt*, and 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.

If the UE is configured with higher layer parameter *dmrs-tableAlt*, and in case of single layer transmission scheme on antenna port $p \in \{7,8,11,13\}$ corresponding to one codeword values 5-11 in Table 5.3.3.1.5C-2 [4] is used, the UE cannot assume that the other antenna ports in the set $\{7,8,11,13\}$ 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].

If the UE is configured with higher layer parameter *dmrs-tableAlt*, and in case of dual layer transmission scheme on antenna ports $\{7,8\}$ or $\{11,13\}$ corresponding to two codewords values 2-5 in Table 5.3.3.1.5C-2 [4]] s used, the UE cannot assume that the other antenna ports in the set $\{7,8,11,13\}$ is not associated with transmission of PDSCH to another UE.

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.

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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.

A UE may assume, for any PDSCH transmission scheduled by a cell with physical cell identity given in *NAICS-AssistanceInfo-r12* and the PDSCH transmission mode belonging to *transmissionModeList-r12* associated with the cell except spatial multiplexing using up to 8 transmission layers in transmission mode 10, that the resource allocation granularity and precoding granularity in terms of PRB pairs in the frequency domain are both given by N, where N is given by the higher layer parameter *resAllocGranularity-r12* associated with the cell. The first set of N consecutive PRB pairs of the resource allocation starts from the lowest frequency of the system bandwidth and the UE may assume the same precoding applies to all PRB pairs within a set.

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_{RBG}) for downlink system bandwidth of $N_{\mathrm{RB}}^{\mathrm{DL}}$ is given by $N_{RBG} = \lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \rceil$ where $\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P \rfloor$ of the RBGs are of size P and if $N_{\mathrm{RB}}^{\mathrm{DL}} \bmod P > 0$ then one of the RBGs is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - P \cdot \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P \rfloor$. The bitmap is of size N_{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 $N_{\mathrm{RBG}} - 1$ 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 $N_{\mathrm{RB}}^{\mathrm{DL}}$	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_{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.

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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 $N_{\mathrm{RB}}^{\mathrm{TYPE1}}$ and is defined as

$$N_{\mathrm{RB}}^{\mathrm{TYPE1}} = \left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \left\lceil \log_2(P) \right\rceil - 1$$

The addressable VRB numbers of a selected RBG subset start from an offset, $\Delta_{\mathrm{shift}}(p)$ 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 $\Delta_{\mathrm{shift}}(p) = 0$. Otherwise, the offset for RBG subset p is given by $\Delta_{\mathrm{shift}}(p) = N_{\mathrm{RB}}^{\mathrm{RBG\,subset}}(p) - N_{\mathrm{RB}}^{\mathrm{TYPE1}}$, where the LSB of the bitmap is justified with the highest VRB number within the selected RBG subset. $N_{\mathrm{RB}}^{\mathrm{RBG\,subset}}(p)$ 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.

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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 $L_{CRBs} \ge 1$ 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 $(L'_{CRBs}-1) \le \lfloor N'^{DL}_{VRB}/2 \rfloor$ 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,

$L'_{CRBs} \ge 1$ 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 $l_{\mathrm{DataStart}}$.

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,

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- 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 $N_{\text{RB}}^{\text{DL}} \le 10$.

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
  - $l_{\text{DataStart}}$ 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,
    - $l_{\text{DataStart}} = \min(2, l'_{\text{DataStart}})$.

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- 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 $N_{\text{RB}}^{\text{DL}} - P'\left\lfloor N_{\text{RB}}^{\text{DL}} / P' \right\rfloor$. 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_{RB}^{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_{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_{PRB} to N_{PRB}^{1A} 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'_{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 $N_{PRB} = \max\left\{\left\lfloor N'_{PRB} \times 0.375 \right\rfloor, \quad 1\right\}$
  - for other special subframe configurations:
    - set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = \max\left\{\left\lfloor N'_{PRB} \times 0.75 \right\rfloor, \quad 1\right\}$,

  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 0.931, 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,

- if the higher layer parameter *altCQI-Table-r12* is configured, and if the PDSCH is assigned by a PDCCH/EPDCCH with DCI format 1/1B/1D/2/2A/2B/2C/2D with CRC scrambled by C-RNTI,
  - the UE shall use I_{MCS} and Table 7.1.7.1-1A to determine the modulation order (Q_m) used in the physical downlink shared channel.
- else
  - the UE shall use I_{MCS} and Table 7.1.7.1-1 to determine the modulation order (Q_m) used in the physical downlink shared channel.

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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	26/26A
29	2	reserved
30	4	
31	6	

Table 7.1.7.1-1A. Modulation and TBS index table 2 for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
0	2	0
1	2	2
2	2	4
3	2	6
4	2	8
5	4	10
6	4	11
7	4	12
8	4	13
9	4	14
10	4	15
11	6	16
12	6	17
13	6	18
14	6	19
15	6	20

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
16	6	21
17	6	22
18	6	23
19	6	24
20	8	25
21	8	27
22	8	28
23	8	29
24	8	30
25	8	31
26	8	32
27	8	33/33A
28	2	reserved
29	4	
30	6	
31	8	

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 $0 \le I_{TBS} \le 26$.
- 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 if the higher layer parameter *altCQI-Table-r12* is configured, then

- for DCI format 1A with CRC scrambled by C-RNTI and for DCI format 1/1A/2/2A/2B/2C/2D with CRC scrambled by SPS C-RNTI:
  - 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 $29 \le I_{MCS} \le 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH/EPDCCH for the same transport block using $0 \le I_{TBS} \le 33$. If there is no PDCCH/EPDCCH for the same transport block using $0 \le I_{TBS} \le 26$, 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.
- for DCI format 1/1B/1D/2/2A/2B/2C/2D with CRC scrambled by C-RNTI

- for $0 \le I_{MCS} \le 27$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 7.1.7.1-1A except if the transport block is disabled in DCI formats 2, 2A, 2B, 2C and 2D as specified below. When $I_{MCS} = 27$, if the UE is scheduled by DCI formats 2C/2D and is configured with a33 in *tbsTableAlt*, I_{TBS} is 33A; otherwise I_{TBS} is 33. 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 $28 \le I_{MCS} \le 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH/EPDCCH for the same transport block using $0 \le I_{MCS} \le 27$.
- 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.

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. When $I_{MCS} = 28$, if the UE is scheduled by DCI formats 2C/2D and is configured with a26 in *tbsTableAlt*, I_{TBS} is 26A; otherwise I_{TBS} is 26. 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 34×110)

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

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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
26A	632	1288	1928	2600	3240	3880	4584	5160	5992	6456

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
26A	7224	7736	8504	9144	9912	10296	11064	11832	12576	12960

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
26A	13536	14112	15264	15840	16416	16992	17568	18336	19080	19848

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
26A	20616	20616	21384	22152	22920	23688	24496	24496	25456	26416

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

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26A	26416	27376	27376	29296	29296	29296	30576	30576	31704	32856

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
26A	32856	34008	34008	35160	36696	36696	36696	37888	37888	39232

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
26A	40576	40576	40576	40576	42368	42368	43816	43816	45352	45352

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

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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
26A	45352	46888	46888	48936	48936	48936	51024	51024	51024	52752

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
26A	52752	52752	55056	55056	55056	55056	57336	57336	57336	59256

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
26A	59256	59256	59256	61664	61664	61664	63776	63776	63776	66592

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
26A	66592	66592	66592	68808	68808	68808	71112	71112	71112	71112

I_{TBS}	N_{PRB}									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
27	648	1320	1992	2664	3368	4008	4584	5352	5992	6712
28	680	1384	2088	2792	3496	4264	4968	5544	6200	6968
29	712	1480	2216	2984	3752	4392	5160	5992	6712	7480
30	776	1544	2344	3112	3880	4776	5544	6200	6968	7736
31	808	1608	2472	3240	4136	4968	5736	6456	7480	8248
32	840	1672	2536	3368	4264	5160	5992	6712	7736	8504
33	968	1992	2984	4008	4968	5992	6968	7992	8760	9912
33A	840	1736	2600	3496	4392	5160	5992	6968	7736	8760

I_{TBS}	N_{PRB}									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
27	7224	7992	8504	9144	9912	10680	11448	11832	12576	12960
28	7736	8504	9144	9912	10680	11064	11832	12576	13536	14112
29	8248	8760	9528	10296	11064	11832	12576	13536	14112	14688
30	8504	9528	10296	11064	11832	12576	13536	14112	14688	15840
31	9144	9912	10680	11448	12216	12960	14112	14688	15840	16416
32	9528	10296	11064	11832	12960	13536	14688	15264	16416	16992
33	10680	11832	12960	13536	14688	15840	16992	17568	19080	19848
33A	9528	10296	11448	12216	12960	14112	14688	15840	16416	17568

I_{TBS}	N_{PRB}									
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
27	14112	14688	15264	15840	16416	16992	17568	18336	19080	19848

28	14688	15264	16416	16992	17568	18336	19080	19848	20616	21384
29	15840	16416	16992	17568	18336	19080	19848	20616	21384	22152
30	16416	16992	18336	19080	19848	20616	21384	22152	22920	23688
31	17568	18336	19080	19848	20616	21384	22152	22920	23688	24496
32	17568	19080	19848	20616	21384	22152	22920	23688	24496	25456
33	20616	21384	22920	23688	24496	25456	26416	27376	28336	29296
33A	18336	19080	19848	20616	22152	22920	23688	24496	25456	26416

I_{TBS}	N_{PRB}									
	31	32	33	34	35	36	37	38	39	40
27	20616	21384	22152	22920	22920	23688	24496	25456	25456	26416
28	22152	22152	22920	23688	24496	25456	26416	26416	27376	28336
29	22920	23688	24496	25456	26416	26416	27376	28336	29296	29296
30	24496	25456	25456	26416	27376	28336	29296	29296	30576	31704
31	25456	26416	27376	28336	29296	29296	30576	31704	31704	32856
32	26416	27376	28336	29296	29296	30576	31704	32856	32856	34008
33	30576	31704	32856	34008	35160	35160	36696	37888	39232	39232
33A	27376	27376	29296	29296	30576	30576	31704	32856	34008	35160

I_{TBS}	N_{PRB}									
	41	42	43	44	45	46	47	48	49	50
27	27376	27376	28336	29296	29296	30576	31704	31704	32856	32856
28	29296	29296	30576	30576	31704	32856	32856	34008	34008	35160
29	30576	31704	31704	32856	34008	34008	35160	35160	36696	36696
30	31704	32856	34008	34008	35160	36696	36696	37888	37888	39232
31	34008	35160	35160	36696	36696	37888	39232	39232	40576	40576
32	35160	35160	36696	37888	37888	39232	40576	40576	42368	42368
33	40576	40576	42368	43816	43816	45352	46888	46888	48936	48936
33A	35160	36696	36696	37888	39232	40576	40576	40576	42368	43816

I_{TBS}	N_{PRB}									
	51	52	53	54	55	56	57	58	59	60
27	34008	34008	35160	35160	36696	36696	37888	37888	39232	39232
28	35160	36696	36696	37888	39232	39232	40576	40576	42368	42368
29	37888	39232	39232	40576	40576	42368	42368	43816	43816	45352
30	40576	40576	42368	42368	43816	43816	45352	45352	46888	46888
31	42368	42368	43816	45352	45352	46888	46888	46888	48936	48936
32	43816	43816	45352	46888	46888	46888	48936	48936	51024	51024
33	51024	51024	52752	52752	55056	55056	57336	57336	59256	59256
33A	43816	45352	45352	46888	48936	48936	48936	51024	51024	52752

I_{TBS}	N_{PRB}									
	61	62	63	64	65	66	67	68	69	70
27	40576	40576	42368	42368	43816	43816	43816	45352	45352	46888
28	42368	43816	43816	45352	45352	46888	46888	46888	48936	48936
29	45352	45352	46888	46888	48936	48936	48936	51024	51024	52752
30	46888	48936	48936	51024	51024	51024	52752	52752	55056	55056
31	51024	51024	52752	52752	52752	55056	55056	55056	57336	57336
32	52752	52752	52752	55056	55056	57336	57336	57336	59256	59256
33	59256	61664	61664	63776	63776	63776	66592	66592	68808	68808
33A	52752	55056	55056	55056	57336	57336	57336	59256	59256	61664

I_{TBS}	N_{PRB}									
	71	72	73	74	75	76	77	78	79	80
27	46888	46888	48936	48936	48936	51024	51024	51024	52752	52752
28	48936	51024	51024	52752	52752	52752	55056	55056	55056	57336
29	52752	52752	55056	55056	55056	57336	57336	57336	59256	59256
30	55056	57336	57336	57336	59256	59256	59256	61664	61664	63776
31	59256	59256	59256	61664	61664	63776	63776	63776	66592	66592
32	61664	61664	61664	63776	63776	63776	66592	66592	66592	68808
33	71112	71112	71112	73712	75376	76208	76208	76208	78704	78704
33A	61664	61664	63776	63776	66592	66592	66592	68808	68808	68808

I_{TBS}	N_{PRB}									
	81	82	83	84	85	86	87	88	89	90
27	52752	55056	55056	55056	57336	57336	57336	59256	59256	59256
28	57336	57336	59256	59256	59256	61664	61664	61664	61664	63776
29	59256	61664	61664	61664	63776	63776	63776	66592	66592	66592

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30	63776	63776	63776	66592	66592	66592	68808	68808	68808	71112
31	66592	68808	68808	68808	71112	71112	71112	73712	73712	73712
32	68808	71112	71112	71112	73712	73712	73712	75376	76208	76208
33	81176	81176	81176	81176	84760	84760	84760	87936	87936	87936
33A	71112	71112	71112	73712	75376	75376	76208	76208	78704	78704

I_{TBS}	N_{PRB}									
	91	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**
27	59256	61664	61664	61664	63776	63776	63776	63776	66592	66592
28	63776	63776	66592	66592	66592	66592	68808	68808	68808	71112
29	66592	68808	68808	68808	71112	71112	71112	73712	73712	73712
30	71112	71112	73712	73712	75376	75376	76208	76208	78704	78704
31	75376	76208	76208	78704	78704	78704	81176	81176	81176	81176
32	78704	78704	78704	81176	81176	81176	84760	84760	84760	84760
33	90816	90816	90816	93800	93800	93800	93800	97896	97896	97896
33A	78704	81176	81176	81176	81176	84760	84760	84760	84760	87936

I_{TBS}	N_{PRB}									
	101	**102**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**
27	66592	66592	68808	68808	68808	71112	71112	71112	71112	73712
28	71112	71112	73712	73712	73712	75376	75376	76208	76208	76208
29	75376	76208	76208	76208	78704	78704	78704	81176	81176	81176
30	78704	81176	81176	81176	81176	84760	84760	84760	84760	87936
31	84760	84760	84760	84760	87936	87936	87936	87936	90816	90816
32	87936	87936	87936	87936	90816	90816	90816	93800	93800	93800
33	97896	97896	97896	97896	97896	97896	97896	97896	97896	97896
33A	87936	87936	87936	90816	90816	90816	93800	93800	93800	97896

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
76208	152976	81176	161760	87936	175600	93800	187712
78704	157432	84760	169544	90816	181656	97896	195816

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

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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		
76208	230104	81176	245648	87936	266440	93800	284608
78704	236160	84760	254328	90816	275376	97896	293736

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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		
76208	305976	81176	324336	87936	351224	93800	375448
78704	314888	84760	339112	90816	363336	97896	391656

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

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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

For FDD, TDD and FDD-TDD, if the UE is configured with more than one serving cell or if the UE is configured with a SCG, then for each serving cell, for at least $K_{\mathrm{MIMO}} \cdot \min(M_{\mathrm{DL\_HARQ}}, M_{\mathrm{limit}})$ 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:

$$n_{SB} = \min\left(N_{cb}, \left\lfloor \frac{N'_{soft}}{C \cdot N_{cells}^{DL} \cdot K_{\mathrm{MIMO}} \cdot \min(M_{\mathrm{DL\_HARQ}}, M_{\mathrm{limit}})} \right\rfloor\right),$$

w_k, C, N_{cb}, K_{MIMO}, ,and M_{limit} are defined in subclause 5.1.4.1.2 of [4].

$M_{\mathrm{DL\_HARQ}}$ is the maximum number of DL HARQ processes.

If the UE is configured with a SCG

- N_{cells}^{DL} is the number of configured serving cells across both MCG and SCG.

else

- N_{cells}^{DL} is the number of configured serving cells.

If the UE signals *ue-CategoryDL-r12*, N'_{soft} is the total number of soft channel bits [12] according to the UE category indicated by *ue-CategoryDL-r12* [11]. Else if the UE signals *ue-Category-v1170* and not *ue-CategoryDL-r12*, 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* and not *ue-CategoryDL-r12*, 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

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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.*
- *zeroTxPowerCSI-RS2-r12* if the UE is configured with higher layer parameter *CSI-Reporting-Type* for TDD serving cell.

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 – 30 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 – 30 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 – 30 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.

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7.2 UE procedure for reporting Channel State Information (CSI)

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group unless stated otherwise

- When the procedures are applied for the primary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', and 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell or serving cells belonging to the primary PUCCH group respectively unless stated otherwise.
- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell' and 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PUCCH-SCell), serving cell, serving cells belonging to the secondary PUCCH group respectively unless stated otherwise. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group.

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), CSI-RS resource indicator (CRI), 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.

For a UE in transmission mode 10,

- If a UE is not configured with higher layer parameter *CSI-Reporting-Type*, 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 UE can be configured with up to two CSI-IM resources for a CSI process if the UE is configured with CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ by the higher layer parameter *csi-SubFramePatternConfig-r12* for the CSI process.
- If the UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS A', each CSI process is associated with one or more CSI-RS resource (defined in subclause 7.2.5) and a CSI-interference measurement (CSI-IM) resource (defined in subclause 7.2.6). A UE can be configured with up to two CSI-IM resources for a CSI process if the UE is configured with CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ by the higher layer parameter *csi-SubFramePatternConfig-r12* for the CSI process.
- If the UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', each CSI process is associated with one or more CSI-RS resource (defined in subclause 7.2.5) and one or more CSI-interference measurement (CSI-IM) resource (defined in subclause 7.2.6). Each CSI-RS resource is associated with a CSI-IM resource by higher layers. For a CSI process with one CSI-RS resource, a UE can be configured with CSI-IM resource for each CSI subframe sets if the UE is configured with CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ by the higher layer parameter *csi-SubFramePatternConfig-r12* for the CSI process.

For a UE in transmission mode 10, 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.

For UE in transmission mode 9 and the UE configured with higher layer parameter *CSI-Reporting-Type*, the term 'CSI process' in this subclause refers to the CSI configured for the UE.

For a UE in transmission mode 9, and if the UE is configured with higher layer parameter *CSI-Reporting-Type*, and,

- *CSI-Reporting-Type* is set to 'CLASS A', each CSI process is associated with one or more CSI-RS resource (defined in subclause 7.2.5).
- *CSI-Reporting-Type* is set to 'CLASS B', each CSI process is associated with one or more CSI-RS resource (defined in subclause 7.2.5).

For a CSI process, and if a UE is configured in transmission mode 9 or 10, and UE is not configured with higher layer parameter *pmi-RI-Report*, and UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-*

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Type is set to 'CLASS B', and the number of CSI-RS antenna ports in each of the one or more configured CSI-RS resource is more than one, the UE is considered to be configured without PMI reporting.

A UE is configured with resource-restricted CSI measurements if the subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers.

For a serving cell with frame structure type 1, a UE is not expected to be configured with *csi-SubframePatternConfig-r12*.

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.

Table 7.2-1: Void

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.

If the higher layer parameter *altCQI-Table-r12* is configured and is set to *allSubframes-r12*,

- the UE shall report CQI according to Table 7.2.3-2.

Else if the higher layer parameter *altCQI-Table-r12* is configured and is set to *csi-SubframeSet1-r12* or *csi-SubframeSet2-r12*,

- the UE shall report CQI according to Table 7.2.3-2 for the corresponding CSI subframe set configured by *altCQI-Table-r12*
- the UE shall report CQI for the other CSI subframe set according to Table 7.2.3-1.

Else

- the UE shall report CQI according to Table 7.2.3-1.

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.

For a UE configured in transmission mode 9 or 10, when reporting CRI the UE reports a single instance of a selected CSI-RS resource. For each CRI reporting interval when a UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one for a CSI process, the UE shall determine a CRI from the supported set of CRI values as defined in subclause 5.2.2.6 of [4] and report the number in each CRI report.

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_{RB}^{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 one or more bitmap parameter(s) *codebookSubsetRestriction, codebookSubsetRestriction-1, codebookSubsetRestriction-2, codebookSubsetRestriction-3* configured by higher layer signalling.

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For a UE configured in transmission mode 10 and the UE not configured with higher layer parameter *CSI-Reporting-Type* for a CSI process, or for a UE configured in transmission mode 9 or 10 and the UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2' for a CSI process, the bitmap parameter *codebookSubsetRestriction* is configured for each CSI process and each subframe sets (if subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers) by higher layer signaling.

For a UE configured in transmission mode 9 or 10, and for a CSI process and UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting Type* is set to 'CLASS A', the bitmap parameters *codebookSubsetRestriction-1, codebookSubsetRestriction-2* is configured for the CSI process and each subframe sets (if subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers) by higher layer signaling.

For a UE configured in transmission mode 9 or 10, and for a CSI process and UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1', the bitmap parameter *codebookSubsetRestriction-3* is configured for the CSI process and each subframe sets (if subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers) by higher layer signaling.

For a UE configured in transmission mode 9 or 10, and for a CSI process and UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and more than one CSI-RS resource configured, the bitmap parameter *codebookSubsetRestriction* is configured for each CSI-RS resource of the CSI process and each subframe sets (if subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ 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, and transmission mode 9 and 10 without PMI reporting. The resulting number of bits for each transmission mode are given in Table 7.2-1b, Table 7.2-1d, Table 7.2-1e, and Table 7.2-1f. The bitmap parameter *codebookSubsetRestriction, codebookSubsetRestriction-1* or *codebookSubsetRestriction-3* forms the bit sequence $a_{A_c-1},\ldots,a_3,a_2,a_1,a_0$ 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 bitmap parameter *codebookSubsetRestriction-2* forms the bit sequence $b_{B_c-1},\ldots,b_3,b_2,b_1,b_0$ where b_0 is the LSB and b_{B_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 υ 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 υ 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 υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].
3. Transmission modes 5 and 6

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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 except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3], $\upsilon = 1,2$.

c. 4 antenna ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured: bit $a_{16(\upsilon-1)+i_1}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2\}$) and codebook index i_1 and bit $a_{32+16(\upsilon-1)+i_2}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2\}$) and codebook index i_2. Codebook indices i_1 and i_2 are given in Table 7.2.4-0A or 7.2.4-0B, for υ=1 or 2 respectively.

5. Transmission modes 9 and 10

a. 2 antenna ports except when a UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1' for a CSI process: see Table 7.2-1c

b. 4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured or for a CSI process the UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1': bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].

c. 4 antenna ports with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured except when a UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1' for a CSI process: bit $a_{16(\upsilon-1)+i_1}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2\}$) and codebook index i_1 and bit $a_{32+16(\upsilon-1)+i_2}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4\}$) and codebook index i_2. Codebook indices i_1 and i_2 are given in Table 7.2.4-0A, 7.2.4-0B, 7.2.4-0C or 7.2.4-0D, for υ=1,2,3 or 4 respectively.

d. 8 antenna ports except when a UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS A', or for when a UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1' for a CSI process: bit $a_{f1(\upsilon-1)+i_1}$ is associated with the precoder for υ 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 υ 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 υ=1,2,3,4,5,6,7, or 8 respectively.

e. 8, 12, and 16 antenna ports and for a CSI process the UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS A': bit $a_{N_2O_2l+m}$ is associated with the precoder based on the quantity $v_{l,m}$ $l = 0,1,\ldots,N_1O_1-1$, $m = 0,1,\ldots,N_2O_2-1$ and bit $a_{N_1O_1N_2O_2+\upsilon-1}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4,5,6,7,8\}$). The quantity $v_{l,m}$ is defined in

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subclause 7.2.4. Bit $b_{g(\upsilon-1)+i_2}$ is associated with the precoder for υ layers ($\upsilon \in \{1,2,3,4\}$) and codebook index i_2 where $g(\cdot)$ is given in Table 7.2-1g. Codebook index i_2 is given in Table 7.2.4-10, 7.2.4-11, 7.2.4-12, 7.2.4-13, 7.2.4-14, 7.2.4-15, 7.2.4-16, or 7.2.4-17, for υ=1,2,3,4,5,6,7, or 8 respectively.

f. 2, 4, or 8 antenna ports and for a CSI process the UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1': bit $a_{f(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and codebook index i_c where $\upsilon \in \{1,2\}$ and $f(\cdot) = \{0,4\}$ for 2 antenna ports, $\upsilon \in \{1,2,3,4\}$ and $f(\cdot) = \{0,8,16,20\}$ for 4 antenna ports, and $\upsilon \in \{1,2,3,4,5,6,7,8\}$ and $f(\cdot) = \{0,16,32,48,56,57,58,59\}$ for 8 antenna ports. Codebook index i_c is given in Table 7.2.4-18, 7.2.4-19, or 7.2.4-20, for 2, 4, or 8 antenna ports respectively.

Table 7.2-1b: Number of bits in codebook subset restriction *codebookSubsetRestriction* 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	64 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, otherwise 32	
Transmission modes 9 and 10	6	96 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, otherwise 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 υ	
	1	2
0	a_0	-
1	a_1	a_4
2	a_2	a_5
3	a_3	-

Table 7.2-1d: Number of bits in codebook subset restriction *codebookSubsetRestriction1* bitmap for applicable transmission modes

	Number of bits A_c
Transmission modes 9 and 10	$N_1O_1N_2O_2+8$

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Table 7.2-1e: Number of bits in codebook subset restriction *codebookSubsetRestriction2* bitmap for applicable transmission modes

	Value of Codebook-Config	Number of bits A_c
Transmission modes 9 and 10	1	12
	2	56
	3	56
	4	56

Table 7.2-1f: Number of bits in codebook subset restriction *codebookSubsetRestriction3* bitmap for applicable transmission modes

	Number of bits A_c		
	2 antenna ports	4 antenna ports	8 antenna ports
Transmission modes 9 and 10	6	22	60

Table 7.2-1g: $g(\cdot)$ for a CSI process with *CSI-Reporting-Type* set to 'CLASS A'

Value of Codebook-Config	$g(\cdot)$
1	$\{0,4,8,10\}$
2	$\{0,16,32,48\}$
3	$\{0,16,32,48\}$
4	$\{0,16,32,48\}$

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 $N = \lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k \rceil$. 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, transmission modes 8, 9 and 10 with PMI/RI reporting and RI=1, and transmission modes 9 and 10 without PMI reporting and RI=1, a single 4-bit wideband CQI is reported.
- For transmission modes 3 and 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, and transmission modes 9 and 10 without PMI 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, and transmission modes 9 and 10 without PMI reporting, PUSCH based triggered reporting includes reporting a wideband CQI which comprises:
  - A 4-bit wideband CQI for codeword 0
  - A 4-bit wideband CQI for codeword 1
- For RI > 1 with transmission mode 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, and transmission modes 9 and 10 without PMI reporting, PUCCH based reporting includes reporting a 4-bit wideband CQI for codeword 0 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.

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- 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

The term "UL/DL configuration" in this subclause refers to the higher layer parameter *subframeAssignment* unless specified otherwise.

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 and the UE is not configured with *csi-SubframePatternConfig-r12* for any serving cell, 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 and the UE is not configured with *csi-SubframePatternConfig-r12* for any serving cell, 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 and the UE is not configured with *csi-SubframePatternConfig-r12* for any serving cell, 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 and the UE is not configured with *csi-SubframePatternConfig-r12* for any serving cell, a report is triggered according to the value in Table 7.2.1-1B corresponding to aperiodic CSI reporting.

If the CSI request field is 1 bit and the UE is configured with the higher layer parameter *csi-SubframePatternConfig-r12* for at least one serving cell, - a report is triggered for a set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) for serving cell c corresponding to the higher layer configured set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) associated with the value of CSI request field of '01' in Table 7.2.1-1C, if the CSI request field is set to '1'.

If the CSI request field size is 2 bits and the UE is configured with the higher layer parameter *csi-SubframePatternConfig-r12* for at least one serving cell, a report is triggered according to the value in Table 7.2.1-1C corresponding to aperiodic CSI reporting.

If the CSI request field size is 3 bits and the UE is not configured with the higher layer parameter *csi-SubframePatternConfig-r12* for any serving cell, a report is triggered according to the value in Table 7.2.1-1D corresponding to aperiodic CSI reporting.

If the CSI request field size is 3 bits and the UE is configured with the higher layer parameter *csi-SubframePatternConfig-r12* for at least one serving cell, a report is triggered according to the value in Table 7.2.1-1E 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, Table 7.2.1-1C, Table 7.2.1-1D, and Table 7.2.1-1E 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 be configured by higher layers with more than 5 CSI processes and/or {CSI process, CSI subframe set}-pair(s) in each of the 1st and 2nd set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) in Table 7.2.1-1C. A UE is not expected to be configured by higher layers with more than one instance of the same CSI process in each of the higher layer configured sets associated with the value of CSI request field of '01', '10', and '11' in Table 7.2.1-1B and Table 7.2.1-1C respectively. A UE is not expected to be configured by higher layers with more than 32 CSI processes in each of the 1st to 6th set of CSI process(es) in Table 7.2.1-1D. A UE is not expected to be configured by higher layers with more than 32 CSI processes and/or {CSI process, CSI subframe set}-pair(s) in each of the 1st to 6th set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) in Table 7.2.1-1E. A UE is not expected to be configured by higher layers with more than one instance of the same CSI process in each of the higher layer configured sets associated with the value of CSI request field of '001', '010', '011', '100', '101', '110' and '111' in Table 7.2.1-1D and Table 7.2.1-1E respectively.

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 serving cell $N_x = N_{CSI-P}$;
- for TDD serving cell
  - 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.

If a UE is configured with multiple cell groups, and if the UE receives multiple aperiodic CSI report requests in a subframe for different cell groups triggering more than one CSI report, the UE is not required to update CSI for more than 5 CSI processes from the CSI processes corresponding to all the triggered CSI reports.

If a UE is configured with a PUCCH-SCell, and if the UE receives multiple aperiodic CSI report requests in a subframe for both the primary PUCCH group and the secondary PUCCH group triggering more than one CSI report, the UE is not required to update CSI for more than 5 CSI processes from the CSI processes corresponding to all the triggered CSI reports, in case the total number of serving cells in the primary and secondary PUCCH group is no more than 5. If a UE is configured with more than 5 serving cells, and if the UE receives aperiodic CSI report request in a subframe triggering more than N_y CSI reports, the UE is not required to update CSI for more than N_y CSI processes from the CSI processes corresponding to all the triggered CSI reports, where the value of N_y is given by *maxNumberUpdatedCSI-Proc-r13*.

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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

Table 7.2.1-1C: 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) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers for serving cell c
'10'	Aperiodic CSI report is triggered for a 1st set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2nd set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers

Table 7.2.1-1D: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'000'	No aperiodic CSI report is triggered
'001'	Aperiodic CSI report is triggered for a set of CSI process(es) configured by higher layers for serving cell c
'010'	Aperiodic CSI report is triggered for a 1st set of CSI process(es) configured by higher layers
'011'	Aperiodic CSI report is triggered for a 2nd set of CSI process(es) configured by higher layers
'100'	Aperiodic CSI report is triggered for a 3rd set of CSI process(es) configured by higher layers
'101'	Aperiodic CSI report is triggered for a 4th set of CSI process(es) configured by higher layers
'110'	Aperiodic CSI report is triggered for a 5th set of CSI process(es) configured by higher layers
'111'	Aperiodic CSI report is triggered for a 6th set of CSI process(es) configured by higher layers

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Table 7.2.1-1E: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'000'	No aperiodic CSI report is triggered
'001'	Aperiodic CSI report is triggered for a set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers for serving cell c
'010'	Aperiodic CSI report is triggered for a 1st set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'011'	Aperiodic CSI report is triggered for a 2nd set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'100'	Aperiodic CSI report is triggered for a 3rd set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'101'	Aperiodic CSI report is triggered for a 4th set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'110'	Aperiodic CSI report is triggered for a 5th set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) configured by higher layers
'111'	Aperiodic CSI report is triggered for a 6th set of CSI process(es) and/or {CSI process, CSI subframe set}-pair(s) 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, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, or for FDD-TDD and serving cell frame structure type 2, 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 and CRI 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 and CRI 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 1-0	Mode 1-1	Mode 1-2
	UE Selected (subband CQI)	Mode 2-0		Mode 2-2
	Higher Layer-configured (subband CQI)	Mode 3-0	Mode 3-1	Mode 3-2

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, 1-0
Transmission mode 2 : Modes 2-0, 3-0, 1-0
Transmission mode 3 : Modes 2-0, 3-0, 1-0

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Transmission mode 4 : Modes 1-2, 2-2, 3-1, 3-2, 1-1
Transmission mode 5 : Mode 3-1, 1-1
Transmission mode 6 : Modes 1-2, 2-2, 3-1, 3-2, 1-1
Transmission mode 7 : Modes 2-0, 3-0, 1-0
Transmission mode 8 : Modes 1-2, 2-2, 3-1, 3-2, 1-1 if the UE is configured with PMI/RI reporting; modes 2-0, 3-0, 1-0 if the UE is configured without PMI/RI reporting
Transmission mode 9 : Modes 1-2, 2-2, 3-1, 3-2, 1-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0, 1-0 if the UE is configured without PMI/RI reporting or without PMI reporting or number of CSI-RS ports=1
Transmission mode 10 : Modes 1-2, 2-2, 3-1, 3-2, 1-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0, 1-0 if the UE is configured without PMI/RI reporting or without PMI 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, and transmission modes 9 and 10 without PMI 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 or CQI report without PMI reporting for that serving cell on that aperiodic reporting mode.

For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with parameter *CSI-Reporting-Type* configured by higher layers, and *CSI-Reporting-Type* is set to 'CLASS B' and the number of configured CSI-RS resources is more than one, and the total number of antenna ports across all configured CSI-RS resources is more than 15, the UE on reception of an aperiodic CSI report request triggering a CSI report in uplink subframe n is not expected to update CRI corresponding to the CSI process if CRI for the CSI process has been reported on or after subframe $n-5$.

- Wideband feedback
  - Mode 1-2 description:

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- For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set S subbands.
- 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 or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 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, if the UE is not configured with higher layer parameter *CSI-Reporting-Type*, or UE reports CRI, or UE is configured in transmission mode 9 or 10, and with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2'.
  - UE is configured in transmission mode 9 or 10, and with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS A', 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. If CRI is reported, the reported PMI, CQI, and RI values are calculated conditioned on the reported CRI.

- Mode 1-1 description:
  - 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
  - The UE shall report the selected single precoding matrix indicator except with 8 CSI-RS ports configured for transmission modes 9 and 10 or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 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.
- Mode 1-0 description:
  - A UE shall report a 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 value is 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:

- If a UE is configured in transmission mode 9 or 10, and UE is configured with higher layer parameter *CSI-Reporting-Type* for a CSI process, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of CSI-RS antenna ports in each of the one or more configured CSI-RS resource is more than one,
  - If the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
  - 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 selected precoding matrix, and reported CQI values are calculated conditioned on the reported RI. If CRI is reported, the selected precoding matrix, reported CQI, and RI values are calculated conditioned on the reported CRI

  otherwise,
  - For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
  - 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. If CRI is reported, the reported CQI values are calculated conditioned on the reported CRI.
- Mode 3-1 description:
  - For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set *S* subbands.
  - 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,

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- 8 CSI-RS ports configured for transmission modes 9 and 10 or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, in which case a first and second precoding matrix indicator are reported corresponding to the selected single precoding matrix, if the UE is not configured with higher layer parameter *CSI-Reporting-Type*, or UE reports CRI, or UE is configured in transmission mode 9 or 10, and with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2'.
- UE is configured in transmission mode 9 or 10, and with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS A', 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. If CRI is reported, the reported PMI, CQI, and RI values are calculated conditioned on the reported CRI.

- Mode 3-2 description:

  - For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set S subbands.
  - 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.
  - A UE shall report the selected single precoding matrix indicator for each set S subband except with,
    - 8 CSI-RS ports configured for transmission mode 9 and 10, or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, in which case the UE shall report a first precoding matrix indicator for all set S subbands and also report a second precoding matrix indicator for each set S subband, if the UE is not configured with higher layer parameter *CSI-Reporting-Type*, or UE reports CRI, or UE is configured in transmission mode 9 or 10, and with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2'.
    - UE is configured in transmission mode 9 or 10, and with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS A', 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.
  - A UE shall report one subband CQI value per codeword for each set S subband reflecting transmission over the single subband and using the selected precoding matrix in the corresponding subband.
  - For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For transmission mode 6 they are reported conditioned on rank 1. If CRI is reported, the reported PMI, CQI, and RI values are calculated conditioned on the reported CRI.

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- 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:
    - If a UE is configured in transmission mode 9 or 10, and UE is configured with higher layer parameter *CSI-Reporting-Type* for a CSI process,, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of CSI-RS antenna ports in each of the one or more configured CSI-RS resource is more than one,
      - If the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set S subbands.
      - 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.
      - 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
      - The selected precoding matrix, and reported CQI values are calculated conditioned on the reported RI. If CRI is reported, the selected precoding matrix, reported CQI, and RI values are calculated conditioned on the reported CRI.
    - otherwise,

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- For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set S subbands.
- 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. If CRI is reported, the reported CQI values are calculated conditioned on the reported CRI.

- Mode 2-2 description:
  - For a UE configured in transmission mode 9 or 10, and for a CSI process, if a UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the UE shall report one wideband CRI which is calculated assuming transmission on set S subbands.
  - 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.
  - 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
  - The UE shall report the selected single precoding matrix indicator preferred for the M selected subbands and the selected single precoding matrix indicator for all set S subbands except with,
    - 8 CSI-RS ports configured for transmission modes 9 and 10 or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, in which case the UE shall report a first precoding matrix indicator for all set S subbands, a second precoding matrix indicator for all set S subbands and another second precoding matrix indicator for the M selected subbands, if the UE is not configured with higher layer parameter *CSI-Reporting-Type*, or UE reports CRI, or UE is configured in transmission mode 9 or 10, and with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2'.
    - UE is configured in transmission mode 9 or 10, and with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS A', in which case the UE shall report a first precoding matrix indicator i_1 for all set S subbands, a second precoding matrix indicator i_2 for all set S subbands

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and another second precoding matrix indicator i_2 for or the M selected 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. If CRI is reported, the reported PMI, CQI, and RI values are calculated conditioned on the reported CRI.

- 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

  - $r = \sum_{i=0}^{M-1} \left\langle \begin{matrix} N - s_i \\ M - i \end{matrix} \right\rangle$

  - 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 $\left\langle \begin{matrix} x \\ y \end{matrix} \right\rangle = \begin{cases} \binom{x}{y} & x \ge y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label $r \in \left\{0, \cdots, \binom{N}{M} - 1\right\}$.

- 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 $L = \left\lceil \log_2 \binom{N}{M} \right\rceil$.

Table 7.2.1-5: Subband Size (k) and Number of Subbands (M) in S vs. Downlink System Bandwidth

System Bandwidth N_{RB}^{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, CRI, 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 without PMI 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 without PMI 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 UE in transmission mode 9 and the UE configured with higher layer parameter *CSI-Reporting-Type*, the term 'CSI process' in this subclause refers to the CSI configured for the UE.

For a UE configured with transmission mode 9 or 10, and with 8 CSI-RS ports, if the UE is not configured with parameter *CSI-Reporting-Type* by higher layers , or UE is configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and parameter *PMI-Config* is set to '2', or UE is configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS B', and more than one CSI-RS resource configured, and each CSI-RS resource 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 a UE configured with transmission mode 8, 9 or 10, and with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, if the UE is not configured with higher layer parameter *CSI-Reporting-Type*, or UE is configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and parameter *PMI-Config* is set to '2', or UE is configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS B', and more than one CSI-RS resource configured, and each CSI-RS resource with 4 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

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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_{RB}^{DL} where $\lfloor N_{RB}^{DL}/k \rfloor$ subbands are of size k. If $\lceil N_{RB}^{DL}/k \rceil - \lfloor N_{RB}^{DL}/k \rfloor > 0$ then one of the subbands is of size $N_{RB}^{DL} - k \cdot \lfloor N_{RB}^{DL}/k \rfloor$.
- A bandwidth part j is frequency-consecutive and consists of N_j subbands where J bandwidth parts span S or N_{RB}^{DL} as given in Table 7.2.2-2. If $J=1$ then N_j is $\lceil N_{RB}^{DL}/k/J \rceil$. If $J>1$ then N_j is either $\lceil N_{RB}^{DL}/k/J \rceil$ or $\lceil N_{RB}^{DL}/k/J \rceil - 1$, depending on N_{RB}^{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 $L = \lceil \log_2 \lceil N_{RB}^{DL}/k/J \rceil \rceil$.

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
- Type 7 report support CRI and RI feedback
- Type 8 report supports CRI, RI and wideband PMI feedback
- Type 9 report supports CRI, RI and PTI feedback
- Type 10 report supports CRI 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 or for FDD-TDD with primary cell frame structure 1 and Table 7.2.2-1C for TDD or for FDD-TDD and primary cell frame structure type 2. 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. For a UE configured in transmission mode 9 and for each serving cell, or for a UE configured in transmission mode 10 and for each CSI process in each serving cell, if the UE is configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one, the periodicity M_{CRI} for CRI reporting is given by the parameter *cri-ConfigIndex* (I_{CRI}). The parameters *cqi-pmi-ConfigIndex*, *ri-ConfigIndex*, and *cri-ConfigIndex* are configured by higher layer signalling. The relative reporting offset for RI $N_{OFFSET,RI}$ takes values from the set $\{0,-1,\ldots,-(N_{pd}-1)\}$. If a UE is configured to report for more than one CSI

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subframe set then parameter *cqi-pmi-ConfigIndex*, *ri-ConfigIndex* and *cri-ConfigIndex* respectively correspond to the CQI/PMI, RI, and CRI periodicity and relative reporting offset for subframe set 1 and *cqi-pmi-ConfigIndex2*, *ri-ConfigIndex2* and *cri-ConfigIndex2* respectively correspond to the CQI/PMI, RI , and CRI periodicity and relative reporting offset for subframe set 2. For a UE configured with transmission mode 10, the parameters *cqi-pmi-ConfigIndex* , *ri-ConfigIndex*, *cri-ConfigIndex*, *cqi-pmi-ConfigIndex2*, *ri-ConfigIndex2*, and *cri-ConfigIndex2* 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 $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (N_{pd}) = 0$.

- For a UE configured in transmission mode 9 or 10, and UE configured with the parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* set to 'CLASS A', the reporting interval of wideband first PMI reporting is an integer multiple H' of period N_{pd} (in subframes).

  - The reporting instances for wideband first PMI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (H' \cdot N_{pd}) = 0$.

- 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 case CRI reporting is configured,

  - if the number of antenna ports in each configured CSI-RS resource is one,

    - the reporting interval of the CRI reporting is an integer multiple M_{CRI} of period N_{pd} (in subframes)

    - The reporting instances for CRI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (N_{pd} \cdot M_{CRI}) = 0$.

  - otherwise

    - the reporting interval of the CRI reporting is an integer multiple M_{CRI} of period $N_{pd} \cdot M_{RI}$ (in subframes).

    - The reporting instances for CRI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}) \bmod (N_{pd} \cdot M_{RI} \cdot M_{CRI}) = 0$.

In the case where both wideband CQI/PMI and subband CQI (or subband CQI/second PMI for transmission modes 9 and 10) reporting are configured:

- The reporting instances for wideband CQI/PMI and subband CQI (or subband CQI/second PMI for transmission modes 9 and 10) 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 modes 8 and 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 8, 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

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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 8, 9 and 10) reports, the remaining $J \cdot K$ reporting instances are used in sequence for subband CQI (or subband CQI/second PMI for transmission modes 9 and 10) 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 (or subband CQI/second PMI for transmission modes 9 and 10) 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 8, 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 modes 8 and 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 CRI reporting is configured,

  - if the number of antenna ports in each configured CSI-RS resource is one,

    - the reporting interval of the CRI reporting is M_{CRI} times the wideband CQI/PMI period $H \cdot N_{pd}$,

    - The reporting instances for CRI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (H \cdot N_{pd} \cdot M_{CRI}) = 0$.

  - otherwise

    - the reporting interval of the CRI reporting is M_{CRI} times the RI period $H.N_{pd} \cdot M_{RI}$ (in subframes).

    - The reporting instances for CRI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}) \bmod (H \cdot N_{pd} \cdot M_{RI} \cdot M_{CRI}) = 0$

If a UE is not configured with higher layer parameter *CSI-Reporting-Type*, or for a CSI process a UE is configured with higher layer parameter *CSI-Reporting-Type* and *CSI-Reporting-Type* is set to 'CLASS A', or for a CSI process a UE is configured with higher layer parameter *CSI-Reporting-Type* and *CSI-Reporting-Type* is set to 'CLASS B', and one

configured CSI-RS resource, 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 CSI process, if a UE is configured with higher layer parameter *CSI-Reporting-Type* and *CSI-Reporting-Type* is set to 'CLASS B', and more than one configured CSI-RS resources, in case of collision of a CSI report with PUCCH reporting type 7, 8, 9, or 10 of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2a, 2b, 2c, 3, 4, 5, or 6 of the same serving cell the latter CSI report with PUCCH reporting type (1, 1a, 2, 2a, 2b, 2c, 3, 4, 5, or 6) 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 *csi-ProcessId-r11* are dropped.

For a serving cell and UE configured in transmission mode 1-9 and configured with CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ by the higher layer parameter *csi-SubframePatternConfig-r12* for the serving cell, in case of collision between CSI reports of same serving cell with PUCCH reporting type of the same priority, the CSI report corresponding to CSI subframe set $C_{CSI,1}$ is dropped.

For a serving cell and UE configured in transmission mode 10 and configured with CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ by the higher layer parameter *csi-SubframePatternConfig-r12* for the serving cell, 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 CSI processes with same *csi-ProcessId-r11*, the CSI report corresponding to CSI subframe set $C_{CSI,1}$ is dropped.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*,and 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 7, 8, 9, or 10 of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2a, 2b, 2c, 3, 4, 5 or 6 of another serving cell, the latter CSI with PUCCH reporting type (1, 1a, 2, 2a, 2b, 2c, 3, 4, 5 or 6) has lower priority and is dropped. 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.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, 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.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, 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.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, 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.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, for a given subframe, in case of collision between CSI report of a given serving cell with UE

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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.

If a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, 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 a UE is not configured with higher layer parameter *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, and

- 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.

If a UE is configured with *format4-MultiCSI-resourceConfiguration* or *format5-MultiCSI-resourceConfiguration*, for a subframe in which only periodic CSI is transmitted,

- if there is only one CSI report in the subframe, 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 there are more than one CSI reports in the subframe,
  - if the UE is configured with a single PUCCH format 4 resource $n_{\mathrm{PUCCH}}^{(4)}$ according to higher layer parameter *format4-MultiCSI-resourceConfiguration*, the PUCCH format 4 resource $n_{\mathrm{PUCCH}}^{(4)}$ is used for transmission of the CSI report(s);
  - if the UE is configured with a PUCCH format 5 resource $n_{\mathrm{PUCCH}}^{(5)}$ according to higher layer parameter *format5-MultiCSI-resourceConfiguration*, the PUCCH format 5 resource $n_{\mathrm{PUCCH}}^{(5)}$ is used for transmission of the CSI report(s);
  - if the UE is configured with two PUCCH format 4 resources $n_{\mathrm{PUCCH},1}^{(4)}$ and $n_{\mathrm{PUCCH},2}^{(4)}$ according to higher layer parameter *format4-MultiCSI-resourceConfiguration*, if $O_{\mathrm{P\text{-}CSI}} \le \min\left(M_{\mathrm{RB},1}^{\mathrm{PUCCH4}}, M_{\mathrm{RB},2}^{\mathrm{PUCCH4}}\right) \cdot N_{sc}^{RB} \cdot N_{\mathrm{symb}}^{\mathrm{PUCCH4}} \cdot r$, the PUCCH format 4 resource with the smaller $M_{\mathrm{RB},i}^{\mathrm{PUCCH4}}$ between $n_{\mathrm{PUCCH},1}^{(4)}$ and $n_{\mathrm{PUCCH},2}^{(4)}$ is used for transmission of the CSI report(s); otherwise, the PUCCH format 4 resource with the larger $M_{\mathrm{RB},i}^{\mathrm{PUCCH4}}$ between $n_{\mathrm{PUCCH},1}^{(4)}$ and $n_{\mathrm{PUCCH},2}^{(4)}$ is used for transmission of the CSI report(s), where
    - $O_{\mathrm{P\text{-}CSI}}$ is the total number of CSI report bits in the subframe;
    - $M_{\mathrm{RB},i}^{\mathrm{PUCCH4}}$, $i = 1,2$, is the number of PRBs for $n_{\mathrm{PUCCH},1}^{(4)}$ and $n_{\mathrm{PUCCH},2}^{(4)}$ respectively, according to higher layer parameter *numberOfPRB-format4-r13* according to Table 10.1.1-2;
    - $N_{\mathrm{symb}}^{\mathrm{PUCCH4}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right) - 1$ if shortened PUCCH format 4 is used in the subframe and $N_{\mathrm{symb}}^{\mathrm{PUCCH4}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right)$ otherwise; and
    - r is the code rate given by higher layer parameter *maximumPayloadCoderate-r13* according to Table 10.1.1-1.

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If a UE transmits periodic CSI only using either a PUCCH format 4 $n_{\mathrm{PUCCH}}^{(4)}$ or PUCCH format 5 $n_{\mathrm{PUCCH}}^{(5)}$ in a subframe and if $O_{\mathrm{P-CSI}} > N_{\mathrm{RE}} \cdot r$, the UE shall select $N_{\mathrm{CSI,reported}}$ CSI report(s) for transmission in ascending order of $\mathrm{Pri}_{CSI}(y,s,c,t)$, where:

- $O_{\mathrm{P-CSI}}$ is the total number of CSI report bits in the subframe;
- $N_{\mathrm{RE}} = M_{\mathrm{RB}}^{\mathrm{PUCCH4}} \cdot N_{sc}^{RB} \cdot N_{\mathrm{symb}}^{\mathrm{PUCCH}}$ for PUCCH format 4 and $N_{\mathrm{RE}} = N_{sc}^{RB} \cdot N_{\mathrm{symb}}^{\mathrm{PUCCH}} / 2$ for PUCCH format 5, where $N_{\mathrm{symb}}^{\mathrm{PUCCH}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right) - 1$ if shortened PUCCH format 4 or shortened PUCCH format 5 is used in the subframe and $N_{\mathrm{symb}}^{\mathrm{PUCCH}} = 2 \cdot \left(N_{\mathrm{symb}}^{\mathrm{UL}} - 1\right)$ otherwise;
- r is the code rate given by higher layer parameter *maximumPayloadCoderate-r13* according to Table 10.1.1-1;
- for a CSI report of a serving cell, $\mathrm{Pri}_{CSI}(y,s,c,t)$ for the CSI report is defined as $\mathrm{Pri}_{CSI}(y,s,c,t) = y \cdot 4 \cdot 32 \cdot 2 + s \cdot 32 \cdot 2 + c \cdot 2 + t$, where
  - $y = 0$ for CSI report type 3/5/6/2a, $y = 1$ for CSI report type 2/2b/2c/4, and $y = 2$ for CSI report type 1/1a;
  - s is the CSI process ID according to *csi-ProcessId-r11* if the serving cell is configured with transmission mode 10, and $s = 1$ if the serving cell configured with transmission mode 1-9;
  - c is the serving cell index;
  - $t = 0$ and $t = 1$ for CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ respectively if CSI subframe sets are configured for the serving cell, and $t = 0$ otherwise.
- The value of $N_{\mathrm{CSI,reported}}$ satisfies $\sum_{n=1}^{N_{\mathrm{CSI,reported}}} O_{P-CSI,n} \le N_{\mathrm{RE}} \cdot r$ and $\sum_{n=1}^{N_{\mathrm{CSI,reported}}+1} O_{P-CSI,n} > N_{\mathrm{RE}} \cdot r$, and $O_{P-CSI,n}$ is the number of CSI report bits for the nth CSI report in ascending order of $\mathrm{Pri}_{CSI}(y,s,c,t)$.

Table 7.2.2-1A: Mapping of $I_{CQI/PMI}$ to N_{pd} and $N_{OFFSET,CQI}$ for FDD or for FDD-TDD and primary cell frame structure type 1

$I_{CQI/PMI}$	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	

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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 or for FDD-TDD and primary cell frame structure type 2

$I_{CQI/PMI}$	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 or FDD-TDD and primary cell frame structure type 2 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], where the UL/DL configuration corresponds to the *eimta-HARQ-ReferenceConfig-r12* for the primary cell if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for the primary cell:

- 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 for 8 CSI-RS ports 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 for 8 CSI-RS ports is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 for 8 CSI-RS ports is defined in Table 7.2.2-1F for PUCCH Reporting Type 1a.

For a UE configured with transmission mode 9 or 10, , and the UE configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS A', and PUCCH Reporting Type 1a, the sub-sampled

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codebook for PUCCH mode 2-1 for value of parameter *Codebook-Config* set to 2, 3, or 4 is defined in Table 7.2.2-1F, for value of parameter *Codebook-Config* set to 1, the value of the second PMI, I_{PMI2}, is set to i_2.

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

The sub-sampled codebook for PUCCH mode 1-1 submode 2 for transmission modes 8, 9 and 10 configured with *alternativeCodeBookEnabledFor4TX-r12=TRUE* is defined in Table 7.2.2-G 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 for transmission modes 8, 9 and 10 configured with *alternativeCodeBookEnabledFor4TX-r12=TRUE* is defined in

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Table 7.2.2-1H. The sub-sampled codebook for PUCCH mode 2-1 for transmission modes 8, 9 and 10 configured with *alternativeCodeBookEnabledFor4TX-r12=TRUE* is defined in Table 7.2.2-1I for PUCCH Reporting Type 1a.

Table 7.2.2-1G: PUCCH mode 1-1 submode 2 codebook subsampling with 4 antenna ports

	Relationship between the first PMI value and codebook index i_1		Relationship between the second PMI value and codebook index i_2		total
RI	Value of the first PMI I_{PMI1}	Codebook index i_1	Value of the second PMI I_{PMI2}	Codebook index i_2	#bits
1	0-3	$4I_{PMI1}$	0-3	$2I_{PMI2}+4\cdot\lfloor I_{PMI2}/2\rfloor$	4
2	0-3	$4I_{PMI1}$	0-3	$I_{PMI2}+2\cdot\lfloor I_{PMI2}/2\rfloor$	4
3	0	0	0-15	I_{PMI2}	4
4	0	0	0-15	I_{PMI2}	4

Table 7.2.2-1 H: Joint encoding of RI and for PUCCH mode 1-1 submode 1 with 4 antenna ports

Value of joint encoding of RI and the first PMI $I_{RI/PMI1}$	RI	Codebook index i_1
0-7	1	$I_{RI/PMI1}$
8-15	2	$I_{RI/PMI1}-8$
16	3	0
17	4	0
18-31	reserved	NA

Table 7.2.2-1 I: PUCCH mode 2-1 codebook subsampling with 4 antenna ports

	Relationship between the second PMI value and codebook index i_2	
RI	Value of the second PMI I_{PMI2}	Codebook index i_2
1	0-15	I_{PMI2}
2	0-3	$I_{PMI2}+2\cdot\lfloor I_{PMI2}/2\rfloor$
3	0-3	$2I_{PMI2}+4\cdot\lfloor I_{PMI2}/2\rfloor$
4	0-3	$2I_{PMI2}+4\cdot\lfloor I_{PMI2}/2\rfloor$

An CRI or 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

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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.

If a UE is configured for CRI reporting,

- For the calculation of CQI/PMI/RI conditioned on the last reported CRI, in the absence of a last reported CRI the UE shall conduct the CQI/PMI/RI calculation conditioned on the lowest possible CRI. If reporting for more than one CSI subframe set is configured, CQI/PMI/RI is conditioned on the last reported CRI linked to the same subframe set as the CSI report.
- For the calculation of CQI/PMI conditioned on the last reported RI and CRI, in the absence of a last reported RI and CRI, the UE shall conduct the CQI/PMI calculation conditioned on the lowest possible RI associated with the lowest possible CRI and as given by the bitmap parameter *codebookSubsetRestriction* and the parameter *alternativeCodeBookEnabledFor4TX-r12* if configured. If reporting for more than one CSI subframe set is configured, CQI/PMI is conditioned on the last reported RI associated with the last reported CRI and linked to the same subframe set as the CSI report

otherwise,

- 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* and the parameter *alternativeCodeBookEnabledFor4TX-r12* if configured. 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, and transmission mode 9 or 10 without PMI reporting):
        - 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, for transmission mode 3 the UE shall determine a RI assuming transmission on set S subbands, and for transmission mode 9 or 10 without PMI reporting, the UE shall determine a RI assuming transmission on set S subbands conditioned on the last reported periodic CRI.
        - The UE shall report a type 3 report consisting of one RI.
      - In the subframe where RI and CRI is reported (only for transmission mode 9 or 10 without PMI reporting and number of configured CSI-RS resources more than one):
        - A UE shall determine a CRI assuming transmission on set S subbands.

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- 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 conditioned on the reported CRI.
- The UE shall report a type 7 report consisting of one RI and one CRI.

- In the subframe where CRI is reported (only for transmission mode 9 or 10 with CRI reporting and the number of antenna ports in at least one configured CSI-RS resource is one):
  - A UE shall determine a CRI assuming transmission on set S subbands.
  - The UE shall report a type10 report consisting of one CRI.
- In the subframe where CQI is reported:
  - If the UE is configured without PMI reporting (only for transmission mode 9 or 10):
    - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands.
    - A UE shall report a type 4 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.
      - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
    - If the UE is configured with CRI reporting,
      - 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 selected precoding matrix 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 and last reported periodic CRI for the CSI process; otherwise the selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI and the last reported periodic CRI.
    - otherwise,
      - 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 selected precoding matrix 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 selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI.
  - otherwise,
    - A UE shall report a type 4 report consisting of one wideband CQI value which is calculated assuming transmission on set S subbands.

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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. If the UE is configured with CRI reporting, the CQI is calculated conditioned on the last reported periodic CRI.

- Mode 1-1 description:
  - In the subframe where RI is reported (only for transmission modes 4, 8, 9 and 10):
    - If the UE is configured with CRI reporting,
      - 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 conditioned on the last reported periodic CRI.
    - otherwise,
      - 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 CRI is reported for transmission modes 9 and 10:
    - A UE shall determine a CRI 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 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 conditioned on the reported CRI for the CSI process.
    - The UE shall report a type 7 report consisting of one RI and one CRI.
  - In the subframe where RI and a first PMI are reported for transmission modes 9 and 10 configured with submode 1 and 8 CSI-RS ports, and for transmission modes 8, 9 and 10 configured with submode 1 and *alternativeCodeBookEnabledFor4TX-r12=TRUE*:
    - If the UE is configured with CRI reporting,
      - 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 conditioned on the last reported periodic CRI.
    - otherwise,
      - 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

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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 with CRI reporting,
  - 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 and last reported periodic CRI.
- otherwise,
  - 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 CRI, RI and a first PMI are reported for transmission modes 9 and 10 configured with submode 1 and 8 CSI-RS ports, and for transmission modes 9 and 10 configured with submode 1 and *alternativeCodeBookEnabledFor4TX-r12=TRUE*:
  - A UE shall determine a CRI 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 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 conditioned on the reported CRI.
  - The UE shall report a type 8 report consisting of jointly coded CRI, 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 and last reported periodic CRI conditioned on the reported CRI.
- In the subframe where the wideband first PMI is reported, for transmission modes 9 and 10 with higher layer parameter *CSI-Reporting-Type* configured, and *CSI-Reporting Type* set to 'CLASS A',
  - A set of precoding matrices corresponding to the wideband first PMI is selected from the codebook assuming transmission on set S subbands.
  - A UE shall report a type 2a report consisting of the wideband first PMI corresponding to the selected set of precoding matrices.

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- 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 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 the wideband first PMI value is calculated conditioned on the last reported periodic RI.

- In the subframe where CQI/PMI is reported for all transmission modes except with,
  - UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting Type* is set to 'CLASS A', or
  - 8 CSI-RS ports configured for transmission modes 9 and 10, or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, if the UE is not configured with higher layer parameter *CSI-Reporting-Type*, or UE configured with CRI reporting, or UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2':
    - 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.
    - If the UE is configured with CRI reporting,
      - 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 and the last reported periodic CRI.
    - otherwise,
      - 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.

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- In the subframe where wideband CQI/second PMI is reported for transmission modes 9 and 10 with 8 CSI-RS ports and submode 1 configured and for transmission modes 8, 9 and 10 with submode 1 and *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, and for transmission modes 9 and 10 with higher layer parameter *CSI-Reporting-Type* configured, and *CSI-Reporting Type* set to 'CLASS A':
  - 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 the UE is configured with CRI reporting,
    - 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 and the last reported periodic CRI 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 and the last reported periodic CRI for the CSI process.
    - Otherwise,
      - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI and the last reported periodic CRI.
      - The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI and the last reported periodic CRI.
  - .otherwise,
    - 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 with 8 CSI-RS ports and submode 2 configured, and for transmission modes 8, 9 and 10 with submode 2 and *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured:
  - 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 the UE is configured with CRI reporting,
    - 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 and the last reported periodic CRI 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 and the last reported periodic CRI.
  - otherwise
    - 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, and transmission mode 9 or 10 without PMI reporting):
      - 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

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RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, for transmission mode 3 the UE shall determine a RI assuming transmission on set S subbands, and for transmission mode 9 or 10 without PMI reporting, the UE shall determine a RI assuming transmission on set S subbands conditioned on the last reported periodic CRI.

- The UE shall report a type 3 report consisting of one RI.

- In the subframe where RI and CRI is reported (only for transmission mode 9 or 10 without PMI reporting and number of configured CSI-RS resources more than one):
  - A UE shall determine a CRI 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 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 conditioned on the reported CRI.
  - The UE shall report a type 7 report consisting of one RI and one CRI.
- In the subframe where CRI is reported (only for transmission mode 9 or 10 with CRI reporting and the number of antenna ports in at least one configured CSI-RS resource is one):
  - A UE shall determine a CRI assuming transmission on set S subbands.
  - The UE shall report a type10 report consisting of one CRI.
- In the subframe where wideband CQI is reported:
  - If the UE is configured without PMI reporting (only for transmission mode 9 or 10):
    - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands.
    - A UE shall report a type 4 report on each respective successive reporting opportunity 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.
      - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
    - If the UE is configured with CRI reporting,
      - 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, selected precoding matrix 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 and the last reported periodic CRI for the CSI process; otherwise the subband selection, selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI and the last reported periodic CRI.
    - otherwise

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- 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, selected precoding matrix 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 subband selection, selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI.

- otherwise,

  - 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. If the UE is configured with CRI reporting, the CQI is calculated conditioned on the last reported periodic CRI.

- In the subframe where CQI for the selected subbands is reported:

  - If the UE is configured without PMI reporting (only for transmission mode 9 or 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.

    - A single precoding matrix is selected from the codebook subset assuming transmission on on the selected subband within the applicable bandwidth part.

    - 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.

      - The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.

    - If the UE is configured with CRI reporting,

      - 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 selected precoding matrix and CQI for the CSI process are calculated conditioned on the reported periodic RI for the

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configured "RI-reference CSI process" in the most recent RI reporting instance for the CSI process and the last reported periodic CRI for the CSI process; otherwise the selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI and the last reported periodic CRI.

- otherwise,
  - 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 selected precoding matrix 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 selected precoding matrix and CQI are calculated conditioned on the last reported periodic RI.

- otherwise,
  - 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. If the UE is configured with CRI reporting, the preferred subband selection and CQI values are calculated conditioned on the last reported periodic CRI.

- Mode 2-1 description:
  - In the subframe where RI is reported for transmission mode 4, transmission mode 8 except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, transmission modes 9 and 10 with 2 CSI-RS ports, and transmission modes 9 and 10 with 4 CSI-RS ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured, and for transmission modes 9 and 10 with higher layer parameter *CSI-Reporting-Type* configured, *CSI-Reporting-Type* set to 'CLASS B', one CSI-RS resource configured, higher layer parameter *PMI-Config* set to '1':
    - If a UE is configured with CRI reporting,
      - 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 conditioned on the last reported periodic CRI.
    - otherwise,
      - 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

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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 with 8 CSI-RS ports configured and higher layer parameter *CSI-Reporting-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2', or for transmission modes 9 and 10 with higher layer parameter *CSI-Reporting-Type* configured, and *CSI-Reporting Type* set to 'CLASS A',or for transmission modes 8, 9 and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured then:
  - If a UE is configured with CRI reporting,
    - 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 conditioned on the last reported periodic CRI.
    - 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) conditioned on the last reported periodic CRI.
  - otherwise,
    - 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 PTI for the CSI process shall be equal to 1 if the RI reported jointly with the PTI is greater than 2 for transmission modes 8, 9, 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured.
  - The UE shall report a type 6 report consisting of one RI and the PTI.
- In the subframe where RI and CRI is reported for transmission modes 9 and 10 with parameter *CSI-Reporting-Type* configured by higher layers, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one:
  - A UE shall determine a CRI 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 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 conditioned on the reported CRI for the CSI process.
  - If the configured CSI-RS resource corresponding to the determined CRI comprises 2 CSI-RS ports, or 4 CSI-RS ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured,
    - The UE shall report a type 7 report consisting of one RI and one CRI.

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- otherwise,
  - 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) conditioned on the reported CRI for the CSI process.
  - The PTI for the CSI process shall be equal to 1 if the RI reported jointly with the PTI is greater than 2 for transmission modes 9, 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured.
  - The UE shall report a type 9 report consisting of one CRI, RI, and the PTI.

- In the subframe where wideband CQI/PMI is reported for all transmission modes except with
  - UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting Type* is set to 'CLASS A', or
  - 8 CSI-RS ports configured for transmission modes 9 and 10, or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, if the UE is not configured with higher layer parameter *CSI-Reporting-Type*, or UE is configured with CRI reporting, or UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2':
    - 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.
  - If the UE is configured with CRI reporting,
    - 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 and the last reported periodic CRI for the CSI process; otherwise the PMI and CQI values are calculated conditioned on the last reported periodic RI and the last reported periodic CRI.
  - otherwise,
    - 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

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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 with 8 CSI-RS ports configured and higher layer parameter *CSI-Reporting-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2', or for transmission modes 9 and 10 with higher layer parameter *CSI-Reporting-Type* configured, and *CSI-Reporting Type* set to 'CLASS A', or for transmission modes 8, 9 and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* 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 the UE is configured with CRI reporting,
    - 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 and the last reported periodic CRI 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 and the last reported periodic CRI.
  - otherwise,
    - 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 with 8 CSI-RS ports configured and higher layer parameter *CSI-Reporting-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2', or for transmission modes 9 and 10 with higher layer parameter *CSI-Reporting-Type* configured, and *CSI-Reporting Type* set to 'CLASS A',or for transmission modes 8,9, and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured:

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- 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 the UE is configured with CRI reporting,
  - 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 and the last reported periodic CRI 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 and the last reported periodic CRI 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 and the last reported periodic CRI.
    - The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI and the last reported periodic CRI.
- otherwise,
  - 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

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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
  - UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting Type* is set to 'CLASS A', or
  - 8 CSI-RS ports configured for transmission modes 9 and 10, or with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured for transmission modes 8, 9 and 10, if the UE is not configured with higher layer parameter *CSI-Reporting-Type*, or UE is configured with CRI reporting, or UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2':
    - 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.

- If the UE is configured with CRI reporting,
  - F 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 and the last reported periodic CRI for the CSI process; otherwise the subband selection and CQI

values are calculated conditioned on the last reported periodic wideband PMI, RI and CRI.

- otherwise,
  - 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 with 8 CSI-RS ports configured and higher layer parameter *CSI-Reporting-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2', or for transmission modes 9 and 10 with higher layer parameter *CSI-Reporting-Type* configured, and *CSI-Reporting Type* set to 'CLASS A',or for transmission modes 8, 9 and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* 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 the UE is configured with CRI reporting,
    - 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

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wideband first PMI for the CSI process and the last reported periodic CRI 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 and the last reported periodic CRI 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 and the last reported periodic CRI.
  - The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI process and the last reported periodic CRI.

- otherwise,
  - 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 with 8 CSI-RS ports configured and higher layer parameter *CSI-Reporting-Type* not configured, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with CRI reporting, or for transmission modes 9 and 10 with 8 CSI-RS ports configured and UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '2', or for transmission modes 9 and 10 with higher layer parameter *CSI-Reporting-Type* configured, and *CSI-Reporting Type* set to 'CLASS A',or for transmission modes 8, 9 and 10 with *alternativeCodeBookEnabledFor4TX-r12=TRUE* 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.

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- 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 the UE is configured with CRI reporting,
  - 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 and the last reported periodic CRI 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 and the last reported periodic CRI 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 and the last reported periodic CRI.
    - The subband selection and CQI values are calculated conditioned on the selected precoding matrix and the last reported periodic RI and the last reported periodic CRI.
- otherwise,
  - 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,

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- 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_{RB}^{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.

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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[1] 7+L[2]
1a	Sub-band CQI / second PMI	8 antenna ports or 8/12/16 antenna ports with *Codebook-Config*={2,3,4}, RI = 1	NA	8+L	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *Codebook-Config*={2,3,4}, 1 < RI < 5	NA	9+L	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *Codebook-Config*={1,2,3,4} RI > 4	NA	7+L	NA	NA
		8/12/16 antenna ports with *Codebook-Config*=1, RI = 1	NA	6+L	NA	NA
		8/12/16 antenna ports with *Codebook-Config*=1, RI = 2	NA	9+L	NA	NA
		8/12/16 antenna ports with *Codebook-Config*=1, 2<RI<5	NA	8+L	NA	NA
		4 antenna ports RI=1	NA	8+L	NA	NA
		4 antenna ports 1<RI≤4	NA	9+L	NA	NA
2	Wideband CQI/PMI	2 antenna ports RI = 1	6	6	NA	NA
		4 antenna ports RI = 1, Note[5]	8	8	NA	NA
		2 antenna ports RI > 1	8	8	NA	NA
		4 antenna ports RI > 1, Note[5]	11	11	NA	NA
		4 antenna ports RI = 1, Note[6]	7	7	NA	NA
		4 antenna ports RI = 2, Note[6]	10	10	NA	NA
		4 antenna ports RI = 3, Note[6]	9	9	NA	NA
		4 antenna ports RI = 4, Note[6]	8	8	NA	NA
		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
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
		4 antenna ports 1≤RI≤2	NA	4	NA	NA
		4 antenna ports 2≤RI≤4	NA	NA	NA	NA
		8/12/16 antenna ports with *Codebook-Config*=1, 1≤RI≤8	Note[3]	Note[3]	NA	NA
		8/12/16 antenna ports with *Codebook-Config*={2,3,4}	Note[4]	Note[4]	NA	NA
2b	Wideband CQI / second PMI	8 antenna ports or 8/12/16 antenna ports with *Codebook-Config* = {2,3,4}, RI = 1	8	8	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *Codebook-Config* = {2,3,4}, 1 < RI < 4	11	11	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *Codebook-Config* = {2,3,4}, RI = 4	10	10	NA	NA
		8 antenna ports or 8/12/16 antenna ports with *Codebook-Config* = {1,2,3,4}, RI > 4	7	7	NA	NA
		4 antenna ports RI=1	8	8	NA	NA
		4 antenna port 1<RI≤4	11	11	NA	NA
		8/12/16 antenna ports with *Codebook-Config*=1, RI = 1	6	6	NA	NA
		8/12/16 antenna ports with *Codebook-Config*=1, RI = 2	9	9	NA	NA
		8/12/16 antenna ports with *Codebook-Config*=1, 2<RI<5	8	8	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
		4 antenna ports RI=1	8	NA	NA	NA
		4 antenna port 1<RI≤4	11	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[1] 1[2]	NA[1] 1[2]
		4 antenna ports, 4-layer spatial multiplexing	2	2	2	2
		8 antenna ports, 4-layer spatial multiplexing	2	NA	NA[1] 2[2]	NA[1] 2[2]

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		8-layer spatial multiplexing	3	NA	NA[1] 3[2]	NA[1] 3[2]
		12/16 antenna ports, 2-layer spatial multiplexing	1	NA	NA	NA
		12/16 antenna ports, 4-layer spatial multiplexing	2	NA	NA	NA
		12/16 antenna ports, 8-layer spatial multiplexing	3	NA	NA	NA
4	**Wideband CQI**	RI = 1 or RI>1, without PMI/RI reporting	NA	NA	4	4
		RI = 1 without PMI reporting	NA	NA	4	4
		RI>1 without PMI reporting	NA	NA	7	7
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			
		4 antenna ports, 2-layer spatial multiplexing	4			
		4 antenna ports, 4-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
		4 antenna ports, 2-layer spatial multiplexing	NA	2	NA	NA
		4 antenna ports, 4-layer spatial multiplexing	NA	3	NA	NA
7	CRI/RI	2-layer spatial multiplexing	k+1	k+1	k+1	k+1
		4-layer spatial multiplexing	k+2	k+2	k+2	k+2
		8-layer spatial multiplexing	k+3	k+3	k+3	k+3
8	CRI/RI/first PMI	2-layer spatial multiplexing	k+4	NA	NA	NA
		4 and 8-layer spatial multiplexing	k+5	NA	NA	NA
9	CRI/RI/PTI	2-layer spatial multiplexing	NA	k+2	NA	NA
		4-layer spatial multiplexing	NA	k+3	NA	NA
		8-layer spatial multiplexing	NA	k+4	NA	NA
10	CRI	Without PMI/RI reporting	NA	NA	k	k

NOTE *: For wideband CQI reporting types, the stated payload size applies to the full bandwidth.
NOTE 1: Without PMI/RI reporting
NOTE 2: Without PMI reporting $k = \lceil \log_2(K) \rceil$ where K is the number of configured CSI-RS resources
NOTE 3: Sum of Wideband first PMI i1,1 bit width and Wideband first PMI i1,2 bit width in Table 5.2.3.3.2-3B-1 of [4] with PTI=0
NOTE 4: Sum of Wideband first PMI i1,1 bit width and Wideband first PMI i1,2 bit width in Table 5.2.3.3.2-3B-2 of [4] with PTI=0
NOTE 5: Not configured with parameter *CSI-Reporting-Type* by higher-layers
NOTE 6: Configured with parameter *CSI-Reporting-Type* by higher-layers

7.2.3 Channel Quality Indicator (CQI) definition

The CQI indices and their interpretations are given in Table 7.2.3-1 for reporting CQI based on QPSK, 16QAM and 64QAM. The CQI indices and their interpretations are given in Table 7.2.3-2 for reporting CQI based on QPSK, 16QAM, 64QAM and 256QAM.

Based on an unrestricted observation interval in time unless specified otherwise in this subclause, and an unrestricted observation interval in 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 or Table 7.2.3-2 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 $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers, each CSI reference resource belongs to either $C_{CSI,0}$ or $C_{CSI,1}$ but not to both. When CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ 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 and parameter *CSI-Reporting-Type* is not 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, when parameter *CSI-Reporting-Type* is not configured by higher layers, 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 9 and the UE configured with parameter *CSI-Reporting-Type* by higher layers, the term 'CSI process' in this clause refers to the CSI configured for the UE.

For a UE in transmission mode 9 or 10 and for a CSI process, if the UE is configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS A', and one CSI-RS resource configured, or the UE is configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS B', and parameter *channelMeasRestriction* is not configured by higher layers, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe n and corresponding to the 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 9 or 10 and for a CSI process, if the UE is configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS A' and more than one CSI-RS resources configured, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe n and corresponding to the CSI process, based on only the non-zero power CSI-RS (defined in [3]) within each configured CSI-RS resource associated with the CSI process.

For a UE in transmission mode 9 or 10 and for a CSI process, if the UE is configured with parameter *CSI-Reporting-Type* by higher layers, and *CSI-Reporting-Type* is set to 'CLASS B', and parameter *channelMeasRestriction* is configured by higher layers, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe n and corresponding to the CSI process, based on only the most recent, no later than the CSI reference resource, 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, when parameter *CSI-Reporting-Type* is not configured by higher layers, 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 configured CSI-IM resource associated with the CSI process.

For a UE in transmission mode 10 and for a CSI process, when parameters *CSI-Reporting-Type* and *interferenceMeasRestriction* is configured by higher layers, the UE shall derive the interference measurements for computing the CQI value reported in uplink subframe n and corresponding to the CSI process, based on only the most recent, no later than the CSI reference resource, configured CSI-IM resource associated with the CSI process.

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For a UE in transmission mode 9 and for a CSI process, when parameters *CSI-Reporting-Type* and *interferenceMeasRestriction* is configured by higher layers, the UE shall derive the interference measurements for computing the CQI value reported in uplink subframe n and corresponding to the CSI process, based on only the CSI reference resource subframe.

If the UE in transmission mode 10 is configured by higher layers for CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ 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.

For a UE configured with the parameter *EIMTA-MainConfigServCell-r12* for a serving cell, configured CSI-IM resource(s) within only downlink subframe(s) of a radio frame that are indicated by UL/DL configuration of the serving cell can be used to derive the interference measurement for the serving cell.

For a LAA Scell,

- for channel measurements, if the UE averages CRS/CSI-RS measurements from multiple subframes
  - the UE should not average CSI-RS measurement in subframe n1 with CSI-RS measurement in subframe n2, if any OFDM symbol of subframe n1 or any subframe between subframe n1 and subframe n2, is not occupied.
  - the UE should not average CRS measurement in subframe n1 with CRS measurement in subframe n2, if any OFDM symbol of the second slot of subframe n1 or any subframe between subframe n1 and subframe n2, is not occupied.
- for interference measurements, the UE shall derive the interference measurements for computing the CQI value based on only measurements in subframes with occupied OFDM symbols.

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 or special 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 or valid special subframe,
    - where for aperiodic CSI reporting, if the UE is not configured with the higher layer parameter *csi-SubframePatternConfig-r12*,.
      - n_{CQI_ref} is such that the reference resource is in the same valid downlink or valid special subframe as the corresponding CSI request in an uplink DCI format.
      - n_{CQI_ref} is equal to 4 and subframe n-n_{CQI_ref} corresponds to a valid downlink or valid special subframe, where subframe n-n_{CQI_ref} is received after the subframe with the corresponding CSI request in a Random Access Response Grant.
    - where for aperiodic CSI reporting, and the UE configured with the higher layer parameter *csi-SubframePatternConfig-r12*,

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- for the UE configured in transmission mode 1-9,
  - n_{CQI_ref} is the smallest value greater than or equal to 4 and subframe n-n_{CQI_ref} corresponds to a valid downlink or valid special subframe, where subframe n-n_{CQI_ref} is received on or after the subframe with the corresponding CSI request in an uplink DCI format;
  - n_{CQI_ref} is the smallest value greater than or equal to 4, and subframe n-n_{CQI_ref} corresponds to a valid downlink or valid special subframe, where subframe n-n_{CQI_ref} is received after the subframe with the corresponding CSI request in an Random Access Response Grant;
  - if there is no valid value for n_{CQI_ref} based on the above conditions, then n_{CQI_ref} is the smallest value such that the reference resource is in a valid downlink or valid special subframe n-n_{CQI_ref} prior to the subframe with the corresponding CSI request, where subframe n-n_{CQI_ref} is the lowest indexed valid downlink or valid special subframe within a radio frame;
- for the UE configured in transmission mode 10,
  - n_{CQI_ref} is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink or valid special subframe, and the corresponding CSI request is in an uplink DCI format;
  - n_{CQI_ref} is the smallest value greater than or equal to 4, and subframe n-n_{CQI_ref} corresponds to a valid downlink or valid special subframe, where 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 or special subframe n-n_{CQI_ref},
  - where for FDD serving cell 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 or valid special subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for FDD serving cell and aperiodic CSI reporting n_{CQI_ref} is equal to 5 and subframe n-n_{CQI_ref} corresponds to a valid downlink or valid special subframe, where subframe n-n_{CQI_ref} is received after the subframe with the corresponding CSI request in a Random Access Response Grant.
  - where for TDD serving cell, 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 or valid special subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for TDD serving cell, and 2 or 3 configured CSI processes, and aperiodic CSI reporting, n_{CQI_ref} is equal to 4 and subframe n-n_{CQI_ref} corresponds to a valid downlink or valid special subframe, where subframe n-n_{CQI_ref} is received after the subframe with the corresponding CSI request in a Random Access Response Grant;
  - where for TDD serving cell, 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 or valid special subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for TDD serving cell, and 4 configured CSI processes, and aperiodic CSI reporting, n_{CQI_ref} is equal to 5 and subframe n-n_{CQI_ref} corresponds to a valid downlink or valid special subframe, where subframe n-n_{CQI_ref} is received after the subframe with the corresponding CSI request in a Random Access Response Grant.

A subframe in a serving cell shall be considered to be a valid downlink or a valid special subframe if:

- it is configured as a downlink subframe or a special 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

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- 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 or special subframe with the corresponding CSI request in an uplink DCI format, when that UE is configured with CSI subframe sets for the CSI process and UE is not configured with the higher layer parameter *csi-SubframePatternConfig-r12*, and
- for a UE configured in transmission mode 1-9, and aperiodic CSI reporting, it is an element of the CSI subframe set associated with the corresponding CSI request in an uplink DCI format, when that UE is configured with CSI subframe sets by the higher layer parameter *csi-SubframePatternConfig-r12*, and
- for a UE configured in transmission mode 10, and aperiodic CSI reporting for a CSI process, it is an element of the CSI subframe set associated with the corresponding CSI request in an uplink DCI format, when that UE is configured with CSI subframe sets by the higher layer parameter *csi-SubframePatternConfig-r12* for the CSI process.
- except if the serving cell is a LAA Scell, and at least one OFDM symbol in the subframe is not occupied.
- except if the serving cell is a LAA Scell, and $n_s' \neq n_s$ as described in sub clause 6.10.1.1 in [3].

If there is no valid downlink or no valid special 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 or without PMI 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 υ 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 $x(i) = \begin{bmatrix} x^{(0)}(i) & \ldots & x^{(\upsilon-1)}(i) \end{bmatrix}^T$ is a vector of symbols from the layer mapping in subclause 6.3.3.2 of [3], $P \in \{1,2,4,8,12,16\}$ is the number of CSI-RS ports configured, and if only one CSI-RS port is configured, $W(i)$ is 1, otherwise for UE configured for PMI/RI reporting $W(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$ and for UE configured without PMI reporting $W(i)$ is the selected precoding matrix corresponding to the reported CQI applicable to $x(i)$. The corresponding PDSCH signals

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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 or without PMI 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 υ 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], $P \in \{1,2,4,8,12,16\}$ is the number of antenna ports of the associated CSI-RS resource, and if P=1, $W(i)$ is 1, otherwise for UE configured for PMI/RI reporting $W(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$ and for UE configured without PMI reporting $W(i)$ is the selected precoding matrix corresponding to the reported CQI 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
- 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).

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- 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 ρ_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 Δ_{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 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 If the UE is configured with PMI/RI reporting or without PMI 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 If a CSI process of the UE is configured with PMI/RI reporting or without PMI 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)

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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

Table 7.2.3-2: 4-bit CQI Table 2

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	193	0.3770
3	QPSK	449	0.8770
4	16QAM	378	1.4766
5	16QAM	490	1.9141
6	16QAM	616	2.4063
7	64QAM	466	2.7305
8	64QAM	567	3.3223
9	64QAM	666	3.9023
10	64QAM	772	4.5234
11	64QAM	873	5.1152
12	256QAM	711	5.5547
13	256QAM	797	6.2266
14	256QAM	885	6.9141
15	256QAM	948	7.4063

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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 antenna ports, except with UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1', each PMI value corresponds to a codebook index given in Table 6.3.4.2.3-1 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 $\{15,16,17,18\}$, except with UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1', each PMI value corresponds to a codebook index given in Table 6.3.4.2.3-2 of [3] or a pair of codebook indices given in Table 7.2.4-0A, 7.2.4-0B, 7.2.4-0C, or 7.2.4-0D as follows:

- 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 υ equal to the associated RI value except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* configured.
- If *alternativeCodeBookEnabledFor4TX-r12=TRUE* is configured, each PMI value corresponds to a pair of codebook indices given in Table 7.2.4-0A, 7.2.4-0B, 7.2.4-0C, or 7.2.4-0D, where the quantities φ_n, φ'_n and v'_m in Table 7.2.4-0A and Table 7.2.4-0B are given by

$$\varphi_n = e^{j\pi n/2}$$

$$\varphi'_n = e^{j2\pi n/32}$$

$$v'_m = \begin{bmatrix} 1 & e^{j2\pi m/32} \end{bmatrix}^T$$

  - A first PMI value of $i_1 \in \{0,1,\cdots,f(\upsilon)-1\}$ and a second PMI value of $i_2 \in \{0,1,\cdots,g(\upsilon)-1\}$ correspond to the codebook indices i_1 and i_2 respectively given in Table 7.2.4-0*j* with υ equal to the associated RI value and where *j* ={A,B,C,D} respectively when $\upsilon = \{1,2,3,4\}$, $f(\upsilon) = \{16,16,1,1\}$ and $g(\upsilon) = \{16,16,16,16\}$.
  - The quantity $W_n^{\{s\}}$ in Table 7.2.4-0C and Table 7.2.4-0D 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 4×4 identity matrix and the vector u_n is given by Table 6.3.4.2.3-2 in [3] and $n = i_2$.
  - In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1G for first and second precoding matrix indicators 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 7.2.2-1H. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1I for PUCCH Reporting Type 1a.

Table 7.2.4-0A: Codebook for 1-layer CSI reporting using antenna ports 0 to 3 or 15 to 18

i_1	i_2							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0 – 15	$W_{i_1,0}^{(1)}$	$W_{i_1,8}^{(1)}$	$W_{i_1,16}^{(1)}$	$W_{i_1,24}^{(1)}$	$W_{i_1+8,2}^{(1)}$	$W_{i_1+8,10}^{(1)}$	$W_{i_1+8,18}^{(1)}$	$W_{i_1+8,26}^{(1)}$
i_1	i_2							
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**

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0 - 15	$W_{i_1+16,4}^{(1)}$	$W_{i_1+16,12}^{(1)}$	$W_{i_1+16,20}^{(1)}$	$W_{i_1+16,28}^{(1)}$	$W_{i_1+24,6}^{(1)}$	$W_{i_1+24,14}^{(1)}$	$W_{i_1+24,22}^{(1)}$	$W_{i_1+24,30}^{(1)}$
where $W_{m,n}^{(1)} = \frac{1}{2}\begin{bmatrix} v'_m & \\ & \varphi'_n v'_m \end{bmatrix}$								

Table 7.2.4-0B: Codebook for 2-layer CSI reporting using antenna ports 0 to 3 or 15 to 18

i_1	i_2			
	0	**1**	**2**	**3**
0 – 15	$W_{i_1,i_1,0}^{(2)}$	$W_{i_1,i_1,1}^{(2)}$	$W_{i_1+8,i_1+8,0}^{(2)}$	$W_{i_1+8,i_1+8,1}^{(2)}$
i_1	i_2			
	4	**5**	**6**	**7**
0 – 15	$W_{i_1+16,i_1+16,0}^{(2)}$	$W_{i_1+16,i_1+16,1}^{(2)}$	$W_{i_1+24,i_1+24,0}^{(2)}$	$W_{i_1+24,i_1+24,1}^{(2)}$
i_1	i_2			
	8	**9**	**10**	**11**
0 – 15	$W_{i_1,i_1+8,0}^{(2)}$	$W_{i_1,i_1+8,1}^{(2)}$	$W_{i_1+8,i_1+16,0}^{(2)}$	$W_{i_1+8,i_1+16,1}^{(2)}$
i_1	i_2			
	12	**13**	**14**	**15**
0 – 15	$W_{i_1,i_1+24,0}^{(2)}$	$W_{i_1,i_1+24,1}^{(2)}$	$W_{i_1+8,i_1+24,0}^{(2)}$	$W_{i_1+8,i_1+24,1}^{(2)}$
where $W_{m,m',n}^{(2)} = \frac{1}{\sqrt{8}}\begin{bmatrix} v'_m & v'_{m'} \\ \varphi_n v'_m & -\varphi_n v'_{m'} \end{bmatrix}$				

Table 7.2.4-0C: Codebook for 3-layer CSI reporting using antenna ports 15 to 18

i_1	i_2							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	$W_0^{\{124\}}/\sqrt{3}$	$W_1^{\{123\}}/\sqrt{3}$	$W_2^{\{123\}}/\sqrt{3}$	$W_3^{\{123\}}/\sqrt{3}$	$W_4^{\{124\}}/\sqrt{3}$	$W_5^{\{124\}}/\sqrt{3}$	$W_6^{\{134\}}/\sqrt{3}$	$W_7^{\{134\}}/\sqrt{3}$
i_1	i_2							
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0	$W_8^{\{124\}}/\sqrt{3}$	$W_9^{\{134\}}/\sqrt{3}$	$W_{10}^{\{123\}}/\sqrt{3}$	$W_{11}^{\{134\}}/\sqrt{3}$	$W_{12}^{\{123\}}/\sqrt{3}$	$W_{13}^{\{123\}}/\sqrt{3}$	$W_{14}^{\{123\}}/\sqrt{3}$	$W_{15}^{\{123\}}/\sqrt{3}$

Table 7.2.4-0D: Codebook for 4-layer CSI reporting using antenna ports 15 to 18

i_1	i_2							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	$W_0^{\{1234\}}/2$	$W_1^{\{1234\}}/2$	$W_2^{\{3214\}}/2$	$W_3^{\{3214\}}/2$	$W_4^{\{1234\}}/2$	$W_5^{\{1234\}}/2$	$W_6^{\{1324\}}/2$	$W_7^{\{1324\}}/2$
i_1	i_2							
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0	$W_8^{\{1234\}}/2$	$W_9^{\{1234\}}/2$	$W_{10}^{\{1324\}}/2$	$W_{11}^{\{1324\}}/2$	$W_{12}^{\{1234\}}/2$	$W_{13}^{\{1324\}}/2$	$W_{14}^{\{3214\}}/2$	$W_{15}^{\{1234\}}/2$

The UE is not expected to receive the configuration of *alternativeCodeBookEnabledFor4TX-r12* except for transmission mode 8 configured with 4 CRS ports, and transmission modes 9 and 10 configured with 4 CSI-RS ports. For a UE configured in transmission mode 10, the parameter *alternativeCodeBookEnabledFor4TX-r12* may be configured for each CSI process.

For 8 antenna ports, except with,

- UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting Type* is set to 'CLASS A', or

- UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1',

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 φ_n and v_m are given by

$$\varphi_n = e^{j\pi n/2}$$
$$v_m = \begin{bmatrix} 1 & e^{j2\pi m/32} & e^{j4\pi m/32} & e^{j6\pi m/32} \end{bmatrix}^T$$

- 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 υ 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	$W^{(5)}_{i_1} = \frac{1}{\sqrt{40}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} \end{bmatrix}$

Table 7.2.4-6: Codebook for 6-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0 - 3	$W^{(6)}_{i_1} = \frac{1}{\sqrt{48}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} \end{bmatrix}$

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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	$W_{i_1}^{(8)} = \frac{1}{8}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} & v_{2i_1+24} & v_{2i_1+24} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} & v_{2i_1+24} & -v_{2i_1+24} \end{bmatrix}$

For 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, 12 antenna ports $\{15,16,17,18,19,20,21,22,23,24,25,26\}$, 16 antenna ports $\{15,16,17,18,19,20,21,22,23,24,25,26,26,28,29,30\}$, and UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting Type* is set to 'CLASS A', each PMI value corresponds to three codebook indices given in Table 7.2.4-10, 7.2.4-11, 7.2.4-12, 7.2.4-13, 7.2.4-14, 7.2.4-15, 7.2.4-16, or 7.2.4-17, where the quantities φ_n, u_m and $v_{l,m}$ are given by

$$\varphi_n = e^{j\pi n/2}$$

$$u_m = \begin{bmatrix} 1 & e^{j\frac{2\pi m}{O_2 N_2}} & \cdots & e^{j\frac{2\pi m(N_2-1)}{O_2 N_2}} \end{bmatrix}$$

$$v_{l,m} = \begin{bmatrix} u_m & e^{j\frac{2\pi l}{O_1 N_1}} u_m & \cdots & e^{j\frac{2\pi l(N_1-1)}{O_1 N_1}} u_m \end{bmatrix}^T$$

- The values of N_1, N_2, O_1, and O_2 are configured with the higher-layer parameters *codebook-Config-N1*, *codebook-Config-N2*, *codebook-Over-Sampling-RateConfig-O1*, and *codebook-Over-Sampling-RateConfig-O2*, respectively. The supported configurations of (O_1, O_2) and (N_1, N_2) for a given number of CSI-RS ports are given in Table 7.2.4-17. The number of CSI-RS ports, P, is $2N_1N_2$.
- UE is not expected to be configured with value of CodebookConfig set to 2 or 3, if the value of codebookConfigN2 is set to 1.
- UE shall only use $i_{1,2} = 0$ and shall not report $i_{1,2}$ if the value of codebookConfigN2 is set to 1.
- A first PMI value i_1 corresponds to the codebook indices pair $\{i_{1,1}, i_{1,2}\}$, and a second PMI value i_2 corresponds to the codebook index i_2 given in Table 7.2.4-j with υ equal to the associated RI value and where $j = \upsilon + 9$.
- In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 2-1 for value of parameter *Codebook-Config* set to 2, 3, or 4 is defined in Table 7.2.2-1F for PUCCH Reporting Type 1a.

Table 7.2.4-9: Supported configurations of (O_1, O_2) and (N_1, N_2)

Number of CSI-RS antenna ports, P	(N_1, N_2)	(O_1, O_2)

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8	(2,2)	(4,4), (8,8)
12	(2,3)	(8,4), (8,8)
	(3,2)	(8,4), (4,4)
16	(2,4)	(8,4), (8,8)
	(4,2)	(8,4), (4,4)
	(8,1)	(4,-), (8,-)

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Table 7.2.4-10: Codebook for 1-layer CSI reporting using antenna ports 15 to 14+*P*

Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			0	1	2	3
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(1)}_{i_{1,1},i_{1,2},0}$	$W^{(1)}_{i_{1,1},i_{1,2},1}$	$W^{(1)}_{i_{1,1},i_{1,2},2}$	$W^{(1)}_{i_{1,1},i_{1,2},3}$
where $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \end{bmatrix}$						

Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			0	1	2	3
2	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1},2i_{1,2},0}$	$W^{(1)}_{2i_{1,1},2i_{1,2},1}$	$W^{(1)}_{2i_{1,1},2i_{1,2},2}$	$W^{(1)}_{2i_{1,1},2i_{1,2},3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			4	**5**	**6**	**7**
2	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},0}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},1}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},2}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			8	**9**	**10**	**11**
2	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,0}$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,1}$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,2}$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			12	**13**	**14**	**15**
2	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,0}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,1}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,2}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,3}$
where $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \end{bmatrix}$						

Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			0	1	2	3
3	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x,2y,0}$	$W^{(1)}_{2x,2y,1}$	$W^{(1)}_{2x,2y,2}$	$W^{(1)}_{2x,2y,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			4	**5**	**6**	**7**
3	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+2,2y,0}$	$W^{(1)}_{2x+2,2y,1}$	$W^{(1)}_{2x+2,2y,2}$	$W^{(1)}_{2x+2,2y,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			8	**9**	**10**	**11**
3	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+1,2y+1,0}$	$W^{(1)}_{2x+1,2y+1,1}$	$W^{(1)}_{2x+1,2y+1,2}$	$W^{(1)}_{2x+1,2y+1,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			12	**13**	**14**	**15**
3	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+3,2y+1,0}$	$W^{(1)}_{2x+3,2y+1,1}$	$W^{(1)}_{2x+3,2y+1,2}$	$W^{(1)}_{2x+3,2y+1,3}$
where $x=i_{1,1}$, $y=i_{1,2}$, $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \end{bmatrix}$, if $N_1 \geq N_2$ $x=i_{1,2}$, $y=i_{1,1}$, $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix} v_{m,l} \\ \varphi_n v_{m,l} \end{bmatrix}$, if $N_1 < N_2$						

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Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			0	**1**	**2**	**3**
4	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x,2y,0}$	$W^{(1)}_{2x,2y,1}$	$W^{(1)}_{2x,2y,2}$	$W^{(1)}_{2x,2y,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			4	**5**	**6**	**7**
4	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+1,2y,0}$	$W^{(1)}_{2x+1,2y,1}$	$W^{(1)}_{2x+1,2y,2}$	$W^{(1)}_{2x+1,2y,3}$
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	i_2			
			8	**9**	**10**	**11**
4	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+2,2y,0}$	$W^{(1)}_{2x+2,2y,1}$	$W^{(1)}_{2x+2,2y,2}$	$W^{(1)}_{2x+2,2y,3}$
Value of Codebook-Config	$i_{1,1}$	$i_{1,2}$	i_2			
			12	**13**	**14**	**15**
4	$0,1,\ldots,\frac{N_1O_1}{2}-1$	$0,1,\ldots,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2x+3,2y,0}$	$W^{(1)}_{2x+3,2y,1}$	$W^{(1)}_{2x+3,2y,2}$	$W^{(1)}_{2x+3,2y,3}$
where $x=i_{1,1}$, $y=i_{1,2}$, $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \end{bmatrix}$, if $N_1 \geq N_2$ $x=i_{1,2}$, $y=i_{1,1}$, $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P}}\begin{bmatrix} v_{m,l} \\ \varphi_n v_{m,l} \end{bmatrix}$, if $N_1 < N_2$						

Table 7.2.4-11: Codebook for 2-layer CSI reporting using antenna ports 15 to 14+*P*

2 Layers, Codebook-Config = 1				
$i_{1,2}=0,\cdots,N_2O_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1O-1$	$W^{(2)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2},0}$	$W^{(2)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2},1}$	$W^{(2)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2},2}$	$W^{(2)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2},3}$
where $W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$.				

2 Layers, Codebook-Config = 2				
If $N_1 > N_2, p=1$ otherwise $p=O_1$				
$i_{1,2}=0,\cdots,N_2O_2/2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2},0}$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2},1}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2},2i_{1,2},0}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2},2i_{1,2},1}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2i_{1,1},2i_{1,1}+p,2i_{1,2},2i_{1,2},0}$	$W^{(2)}_{2i_{1,1},2i_{1,1}+p,2i_{1,2},2i_{1,2},1}$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+1,1}$
$i_{1,1}$	i_2			
	8	**9**	**10**	**11**

$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2}+1,2i_{1,2}+1}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2}+1,2i_{1,2}+1,1}$	$W^{(2)}_{2i_{1,1},2i_{1,1}+p,2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(2)}_{2i_{1,1},2i_{1,1}+p,2i_{1,2}+1,2i_{1,2}+1,1}$
$i_{1,1}$	i_2			
	12	13	14	15
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+1,0}$	$W^{(2)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+1,1}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2},2i_{1,2}+1,0}$	$W^{(2)}_{2i_{1,1}+p,2i_{1,1}+p,2i_{1,2},2i_{1,2}+1,1}$
where $W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$.				

2 Layers, Codebook-Config = 3				
$i_{1,2}=0,\cdots,N_2O_2/2-1$				
$i_{1,1}$	i_2			
	0	1	2	3
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x,2y,2y,0}$	$W^{(2)}_{2x,2x,2y,2y,1}$	$W^{(2)}_{2x+1,2x+1,2y+1,2y+1,0}$	$W^{(2)}_{2x+1,2x+1,2y+1,2y+1,1}$
$i_{1,1}$	i_2			
	4	5	6	7
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x+2,2x+2,2y,2y,0}$	$W^{(2)}_{2x+2,2x+2,2y,2y,1}$	$W^{(2)}_{2x+3,2x+3,2y+1,2y+1,0}$	$W^{(2)}_{2x+3,2x+3,2y+1,2y+1,1}$
$i_{1,1}$	i_2			
	8	9	10	11
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x+1,2y,2y+1,0}$	$W^{(2)}_{2x,2x+1,2y,2y+1,1}$	$W^{(2)}_{2x+1,2x+2,2y+1,2y,0}$	$W^{(2)}_{2x+1,2x+2,2y+1,2y,1}$
$i_{1,1}$	i_2			
	12	13	14	15
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x+3,2y,2y+1,0}$	$W^{(2)}_{2x,2x+3,2y,2y+1,1}$	$W^{(2)}_{2x+1,2x+3,2y+1,2y+1,0}$	$W^{(2)}_{2x+1,2x+3,2y+1,2y+1,1}$
where $x=i_{1,1}$, $y=i_{1,2}$, $W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$ if $N_1 \geq N_2$ and $x=i_{1,2}$, $y=i_{1,1}$, $W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{m,l} & v_{m',l'} \\ \varphi_n v_{m,l} & -\varphi_n v_{m',l'} \end{bmatrix}$, if $N_1 < N_2$				

2 Layers, Codebook-Config = 4				
$i_{1,2}=0,\cdots,N_2O_2/2-1$				
$i_{1,1}$	i_2			
	0	1	2	3
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x,2y,2y,0}$	$W^{(2)}_{2x,2x,2y,2y,1}$	$W^{(2)}_{2x+1,2x+1,2y,2y,0}$	$W^{(2)}_{2x+1,2x+1,2y,2y,1}$
$i_{1,1}$	i_2			
	4	5	6	7

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$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x+2,2x+2,2y,2y,0}$	$W^{(2)}_{2x+2,2x+2,2y,2y,1}$	$W^{(2)}_{2x+3,2x+3,2y,2y,0}$	$W^{(2)}_{2x+3,2x+3,2y,2y,1}$
$i_{1,1}$	i_2			
	8	**9**	**10**	**11**
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x+1,2y,2y,0}$	$W^{(2)}_{2x,2x+1,2y,2y,1}$	$W^{(2)}_{2x+1,2x+2,2y,2y,0}$	$W^{(2)}_{2x+1,2x+2,2y,2y,1}$
$i_{1,1}$	i_2			
	12	**13**	**14**	**15**
$0,\cdots,\frac{N_1O_1}{2}-1$	$W^{(2)}_{2x,2x+3,2y,2y,0}$	$W^{(2)}_{2x,2x+3,2y,2y,1}$	$W^{(2)}_{2x+1,2x+3,2y,2y,0}$	$W^{(2)}_{2x+1,2x+3,2y,2y,1}$

where $x=i_{1,1}$, $y=i_{1,2}$, $W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$ if $N_1 \geq N_2$ and

$x=i_{1,2}$, $y=i_{1,1}$, $W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P}}\begin{bmatrix} v_{m,l} & v_{m',l'} \\ \varphi_n v_{m,l} & -\varphi_n v_{m',l'} \end{bmatrix}$, if $N_1 < N_2$

Table 7.2.4-12: Codebook for 3-layer CSI reporting using antenna ports 15 to 14+*P*

***3 Layers, Codebook-Config* = 1**, $N_1>1, N_2>1$		
$i_{1,2}=0,1,\cdots,N_2O_2-1$		
$i_{1,1}$	i_2	
	0	**1**
$0,\cdots,O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2}}$
$O_1N_1,\cdots,2O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2}+O_2}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2}+O_2}$

where $W^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} \\ v_{l,m} & -v_{l,m} & -v_{l',m} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l',m'} \\ v_{l,m} & v_{l',m} & -v_{l',m'} \end{bmatrix}$

***3 Layers, Codebook-Config* = 1**, $N_2=1$		
$i_{1,2}=0$		
$i_{1,1}$	i_2	
	0	**1**
$0,\cdots,O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1}+O_1,0,0}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1}+O_1,0,0}$
$O_1N_1,\cdots,2O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1}+2O_1,0,0}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1}+2O_1,0,0}$
$2O_1N_1,\cdots,3O_1N_1-1$	$W^{(3)}_{i_{1,1},i_{1,1}+3O_1,0,0}$	$\tilde{W}^{(3)}_{i_{1,1},i_{1,1}+3O_1,0,0}$

where $W^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} \\ v_{l,m} & -v_{l,m} & -v_{l',m'} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'}=\frac{1}{\sqrt{3P}}\begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l',m'} \\ v_{l,m} & v_{l',m} & -v_{l',m'} \end{bmatrix}$

***3 Layers, Codebook-Config* = 2**				
$i_{1,2}=0,1,\cdots,2N_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**

$i_{1,1}$	i_2			
	4	5	6	7
$0,\cdots,2N_1-1$	$W^{(3)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2},2i_{1,2}}$	$W^{(3)}_{2i_{1,1}+4,2i_{1,1},2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1}+4,2i_{1,1},2i_{1,2},2i_{1,2}}$
$2N_1,\cdots,4N_1-1$	$W^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+4}$	$W^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+4,2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2},2i_{1,2}+4}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+4,2i_{1,2}}$
$i_{1,1}$	i_2			
	8	9	10	11
$0,\cdots,2N_1-1$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2},2i_{1,2}}$	$W^{(3)}_{2i_{1,1}+5,2i_{1,1}+1,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+5,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1}+5,2i_{1,1}+1,2i_{1,2},2i_{1,2}}$
$2N_1,\cdots,4N_1-1$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2},2i_{1,2}+4}$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+4,2i_{1,2}}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2},2i_{1,2}+4}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+4,2i_{1,2}}$
$i_{1,1}$	i_2			
	12	13	14	15
$0,\cdots,2N_1-1$	$W^{(3)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1}$	$W^{(3)}_{2i_{1,1}+4,2i_{1,1},2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1}+4,2i_{1,1},2i_{1,2}+1,2i_{1,2}+1}$
$2N_1,\cdots,4N_1-1$	$W^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+5}$	$W^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+5,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+1,2i_{1,2}+5}$	$\tilde{W}^{(3)}_{2i_{1,1},2i_{1,1},2i_{1,2}+5,2i_{1,2}+1}$
$i_{1,1}$	i_2			
	0	1	2	3
$0,\cdots,2N_1-1$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+1}$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$
$2N_1,\cdots,4N_1-1$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5}$	$W^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5}$	$\tilde{W}^{(3)}_{2i_{1,1}+1,2i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$

where $W^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$

3 Layers, Codebook-Config =3				
$i_{1,2} = 0,1,\cdots,2N_2-1$				
$i_{1,1}$	i_2			
	0	1	2	3
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2}}$	$W^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,2i_{1,2},2i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2}+4,2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2}+4,2i_{1,2}}$
$i_{1,1}$	i_2			
	4	5	6	7
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2}}$	$W^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,2i_{1,2},2i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2}+4,2i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2}+4,2i_{1,2}}$
$i_{1,1}$	i_2			
	8	9	10	11
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1}$	$W^{(3)}_{4i_{1,1}+4,4i_{1,1},2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1}+4,4i_{1,1},2i_{1,2}+1,2i_{1,2}+1}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1},2i_{1,2}+1,2i_{1,2}+5}$	$W^{(3)}_{4i_{1,1},4i_{1,1},2i_{1,2}+5,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1},2i_{1,2}+1,2i_{1,2}+5}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1},2i_{1,2}+5,2i_{1,2}+1}$
$i_{1,1}$	i_2			
	12	13	14	15

$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1}$	$W^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+1}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5}$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+5,2i_{1,2}+1}$

where $W^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$

3 Layers, Codebook-Config =4, $N_1>1, N_2>1$

$i_{1,2}=0,1,\cdots,4N_2-1$

$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+4,i_{1,2},i_{1,2}}$	$W^{(3)}_{4i_{1,1}+4,4i_{1,1},i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+4,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+4,4i_{1,1},i_{1,2},i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1},i_{1,2},i_{1,2}+4}$	$W^{(3)}_{4i_{1,1},4i_{1,1},i_{1,2}+4,i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1},i_{1,2},i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1},i_{1,2}+4,i_{1,2}}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,i_{1,2},i_{1,2}}$	$W^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,i_{1,2},i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2},i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2}+4,i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2},i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2}+4,i_{1,2}}$
$i_{1,1}$	i_2			
	8	**9**	**10**	**11**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,i_{1,2},i_{1,2}}$	$W^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,i_{1,2},i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,i_{1,2},i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,i_{1,2}+4,i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,i_{1,2},i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+2,i_{1,2}+4,i_{1,2}}$
$i_{1,1}$	i_2			
	12	**13**	**14**	**15**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,i_{1,2},i_{1,2}}$	$W^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,i_{1,2},i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,i_{1,2},i_{1,2}}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,i_{1,2},i_{1,2}+4}$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,i_{1,2}+4,i_{1,2}}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,i_{1,2},i_{1,2}+4}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+3,i_{1,2}+4,i_{1,2}}$

where $W^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$

3 Layers, Codebook-Config =4, $N_2=1$

$i_{1,2}=0,1,\cdots,4N_2-1$

$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+4,0,0}$	$W^{(3)}_{4i_{1,1}+4,4i_{1,1},0,0}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+4,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+4,4i_{1,1},0,0}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+8,0,0}$	$W^{(3)}_{4i_{1,1}+8,4i_{1,1},0,0}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+8,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+8,4i_{1,1},0,0}$
$2N_1,\cdots,3N_1-1$	$W^{(3)}_{4i_{1,1},4i_{1,1}+12,0,0}$	$W^{(3)}_{4i_{1,1}+12,4i_{1,1},0,0}$	$\tilde{W}^{(3)}_{4i_{1,1},4i_{1,1}+12,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+12,4i_{1,1},0,0}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**

$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,0,0}$	$W^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+5,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+5,4i_{1,1}+1,0,0}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+9,0,0}$	$W^{(3)}_{4i_{1,1}+9,4i_{1,1}+1,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+9,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+9,4i_{1,1}+1,0,0}$
$2N_1,\cdots,3N_1-1$	$W^{(3)}_{4i_{1,1}+1,4i_{1,1}+13,0,0}$	$W^{(3)}_{4i_{1,1}+13,4i_{1,1}+1,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+1,4i_{1,1}+13,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+13,4i_{1,1}+1,0,0}$
$i_{1,1}$	i_2			
	8	**9**	**10**	**11**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,0,0}$	$W^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+6,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+6,4i_{1,1}+2,0,0}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+10,0,0}$	$W^{(3)}_{4i_{1,1}+10,4i_{1,1}+2,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+10,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+10,4i_{1,1}+2,0,0}$
$2N_1,\cdots,3N_1-1$	$W^{(3)}_{4i_{1,1}+2,4i_{1,1}+14,0,0}$	$W^{(3)}_{4i_{1,1}+6,4i_{1,1}+14,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+2,4i_{1,1}+14,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+14,4i_{1,1}+2,0,0}$
$i_{1,1}$	i_2			
	12	**13**	**14**	**15**
$0,\cdots,N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,0,0}$	$W^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+7,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+7,4i_{1,1}+3,0,0}$
$N_1,\cdots,2N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+11,0,0}$	$W^{(3)}_{4i_{1,1}+11,4i_{1,1}+3,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+11,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+11,4i_{1,1}+3,0,0}$
$2N_1,\cdots,3N_1-1$	$W^{(3)}_{4i_{1,1}+3,4i_{1,1}+15,0,0}$	$W^{(3)}_{4i_{1,1}+15,4i_{1,1}+3,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+3,4i_{1,1}+15,0,0}$	$\tilde{W}^{(3)}_{4i_{1,1}+15,4i_{1,1}+3,0,0}$

where $W^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$, $\tilde{W}^{(3)}_{l,l',m,m'} = \frac{1}{\sqrt{3P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} \end{bmatrix}$

Table 7.2.4-13: Codebook for 4-layer CSI reporting using antenna ports 15 to 14+*P*

***4 Layers, Codebook-Config* = 1,** $N_1 > 1, N_2 > 1$		
$i_{1,2} = 0,1,\cdots,N_2O_2-1$		
$i_{1,1}$	i_2	
	0	**1**
$0,\cdots,N_1O_1-1$	$W^{(4)}_{i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},0}$	$W^{(4)}_{i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},1}$
$O_1N_1,\cdots,2O_1N_1-1$	$W^{(4)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2}+O_2,0}$	$W^{(4)}_{i_{1,1},i_{1,1},i_{1,2},i_{1,2}+O_2,1}$

where $W^{(4)}_{i,l',m,m'} = \frac{1}{\sqrt{4P}}\begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$

4 Layers, , Codebook-Config = 1, $N_2 = 1$		
$i_{1,2} = 0$		
$i_{1,1}$	i_2	
	0	1
$0, \cdots, O_1 N_1 - 1$	$W^{(4)}_{i_{1,1}, i_{1,1}+O_1, 0, 0, 0}$	$W^{(4)}_{i_{1,1}, i_{1,1}+O_1, 0, 0, 1}$
$O_1 N_1, \cdots, 2O_1 N_1 - 1$	$W^{(4)}_{i_{1,1}, i_{1,1}+2O_1, 0, 0, 0}$	$W^{(4)}_{i_{1,1}, i_{1,1}+2O_1, 0, 0, 1}$
$2O_1 N_1, \cdots, 3O_1 N_1 - 1$	$W^{(4)}_{i_{1,1}, i_{1,1}+3O_1, 0, 0, 0}$	$W^{(4)}_{i_{1,1}, i_{1,1}+3O_1, 0, 0, 1}$
$W^{(4)}_{l,l',m,m'} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$		

4 Layers, Codebook-Config = 2				
$i_{1,2} = 0, 1, \cdots, 2N_2 - 1$				
$i_{1,1}$	i_2			
	0	1	2	3
$0, \cdots, 2N_1 - 1$	$W^{(4)}_{2i_{1,1}, 2i_{1,1}+4, 2i_{1,2}, 2i_{1,2}, 0}$	$W^{(4)}_{2i_{1,1}, 2i_{1,1}+4, 2i_{1,2}, 2i_{1,2}, 1}$	$W^{(4)}_{2i_{1,1}+1, 2i_{1,1}+5, 2i_{1,2}, 2i_{1,2}, 0}$	$W^{(4)}_{2i_{1,1}+1, 2i_{1,1}+5, 2i_{1,2}, 2i_{1,2}, 1}$
$2N_1, \cdots, 4N_1 - 1$	$W^{(4)}_{2i_{1,1}, 2i_{1,1}, 2i_{1,2}, 2i_{1,2}+4, 0}$	$W^{(4)}_{2i_{1,1}, 2i_{1,1}, 2i_{1,2}, 2i_{1,2}+4, 1}$	$W^{(4)}_{2i_{1,1}+1, 2i_{1,1}+1, 2i_{1,2}, 2i_{1,2}+4, 0}$	$W^{(4)}_{2i_{1,1}+1, 2i_{1,1}+1, 2i_{1,2}, 2i_{1,2}+4, 1}$
$i_{1,1}$	i_2			
	4	5	6	7
$0, \cdots, 2N_1 - 1$	$W^{(4)}_{2i_{1,1}, 2i_{1,1}+4, 2i_{1,2}+1, 2i_{1,2}+1, 0}$	$W^{(4)}_{2i_{1,1}, 2i_{1,1}+4, 2i_{1,2}+1, 2i_{1,2}+1, 1}$	$W^{(4)}_{2i_{1,1}+1, 2i_{1,1}+5, 2i_{1,2}+1, 2i_{1,2}+1, 0}$	$W^{(4)}_{2i_{1,1}+1, 2i_{1,1}+5, 2i_{1,2}+1, 2i_{1,2}+1, 1}$
$2N_1, \cdots, 4N_1 - 1$	$W^{(4)}_{2i_{1,1}, 2i_{1,1}, 2i_{1,2}+1, 2i_{1,2}+5, 0}$	$W^{(4)}_{2i_{1,1}, 2i_{1,1}, 2i_{1,2}+1, 2i_{1,2}+5, 1}$	$W^{(4)}_{2i_{1,1}+1, 2i_{1,1}+1, 2i_{1,2}+1, 2i_{1,2}+5, 0}$	$W^{(4)}_{2i_{1,1}+1, 2i_{1,1}+1, 2i_{1,2}+1, 2i_{1,2}+5, 1}$
$W^{(4)}_{i,i',m,m'} = \frac{1}{\sqrt{4P}} \begin{bmatrix} v_{\frac{O_1}{4}i, \frac{O_2}{4}m} & v_{\frac{O_1}{4}i', \frac{O_2}{4}m'} & v_{\frac{O_1}{4}i, \frac{O_2}{4}m} & v_{\frac{O_1}{4}i', \frac{O_2}{4}m'} \\ \varphi_n v_{\frac{O_1}{4}i, \frac{O_2}{4}m} & \varphi_n v_{\frac{O_1}{4}i', \frac{O_2}{4}m} & -\varphi_n v_{\frac{O_1}{4}i, \frac{O_2}{4}m} & -\varphi_n v_{\frac{O_1}{4}i', \frac{O_2}{4}m'} \end{bmatrix}$				

4 Layers, Codebook-Config =3				
$i_{1,2} = 0, 1, \cdots, 2N_2 - 1$				
$i_{1,1}$	i_2			
	0	1	2	3
$0, \cdots, N_1 - 1$	$W^{(4)}_{4i_{1,1}+2, 4i_{1,1}+6, 2i_{1,2}, 2i_{1,2}, 0}$	$W^{(4)}_{4i_{1,1}+2, 4i_{1,1}+6, 2i_{1,2}, 2i_{1,2}, 1}$	$W^{(4)}_{4i_{1,1}+3, 4i_{1,1}+7, 2i_{1,2}, 2i_{1,2}, 0}$	$W^{(4)}_{4i_{1,1}+3, 4i_{1,1}+7, 2i_{1,2}, 2i_{1,2}, 1}$
$N_1, \cdots, 2N_1 - 1$	$W^{(4)}_{4i_{1,1}+2, 4i_{1,1}+2, 2i_{1,2}, 2i_{1,2}+4, 0}$	$W^{(4)}_{4i_{1,1}+2, 4i_{1,1}+2, 2i_{1,2}, 2i_{1,2}+4, 1}$	$W^{(4)}_{4i_{1,1}+3, 4i_{1,1}+3, 2i_{1,2}, 2i_{1,2}+4, 0}$	$W^{(4)}_{4i_{1,1}+3, 4i_{1,1}+3, 2i_{1,2}, 2i_{1,2}+4, 1}$
$i_{1,1}$	i_2			
	4	5	6	7

$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,2i_{1,2}+1,2i_{1,2}+1,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,2i_{1,2}+1,2i_{1,2}+1,1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1},2i_{1,2}+1,2i_{1,2}+5,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1},2i_{1,2}+1,2i_{1,2}+5,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+1,2i_{1,2}+1,2i_{1,2}+5,1}$

$$W^{(4)}_{l,l',m,m'}=\frac{1}{\sqrt{4P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} \\ \varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & \varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -\varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -\varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} \end{bmatrix}$$

4 Layers, Codebook-Config =4, $N_1>1, N_2>1$				
$i_{1,2}=0,1,\cdots,4N_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,i_{1,2},i_{1,2},0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,i_{1,2},i_{1,2},1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,i_{1,2},i_{1,2},0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,i_{1,2},i_{1,2},1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1},i_{1,2},i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1},i_{1,2},i_{1,2}+4,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2},i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+1,i_{1,2},i_{1,2}+4,1}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**
$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2},0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,2i_{1,2},2i_{1,2},1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2},0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,2i_{1,2},2i_{1,2},1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+2,2i_{1,2},2i_{1,2}+4,1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4,0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+3,2i_{1,2},2i_{1,2}+4,1}$

$$W^{(4)}_{l,l',m,m'}=\frac{1}{\sqrt{4P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} \\ \varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & \varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & -\varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -\varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} \end{bmatrix}$$

4 Layers, Codebook-Config =4, $N_2=1$				
$i_{1,2}=0,1,\cdots,4N_2-1$				
$i_{1,1}$	i_2			
	0	**1**	**2**	**3**
$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,0,0,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+4,0,0,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,0,0,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+5,0,0,1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+8,0,0,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+8,0,0,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+9,0,0,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+9,0,0,1}$
$2N_1,\cdots,3N_1-1$	$W^{(4)}_{4i_{1,1},4i_{1,1}+12,0,0,0}$	$W^{(4)}_{4i_{1,1},4i_{1,1}+12,0,0,1}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+13,0,0,0}$	$W^{(4)}_{4i_{1,1}+1,4i_{1,1}+13,0,0,1}$
$i_{1,1}$	i_2			
	4	**5**	**6**	**7**
$0,\cdots,N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,0,0,0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+6,0,0,1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,0,0,0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+7,0,0,1}$
$N_1,\cdots,2N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+10,0,0,0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+10,0,0,1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+11,0,0,0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+11,0,0,1}$
$2N_1,\cdots,3N_1-1$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+14,0,0,0}$	$W^{(4)}_{4i_{1,1}+2,4i_{1,1}+14,0,0,1}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+15,0,0,0}$	$W^{(4)}_{4i_{1,1}+3,4i_{1,1}+15,0,0,1}$

$$W^{(4)}_{l,l',m,m'}=\frac{1}{\sqrt{4P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} \\ \varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & \varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & -\varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -\varphi_n v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} \end{bmatrix}$$

Table 7.2.4-14: Codebook for 5-layer CSI reporting using antenna ports 15 to 14+*P*

5 Layers, $P=8$, $N_1>N_2$			
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2-4	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
$W^{(5)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} \end{bmatrix}$ for *Codebook-Config* = 2-4			
$W^{(5)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} \end{bmatrix}$ for *Codebook-Config* = 1			

5 Layers, $P=12$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1,\ N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8}$
where $W^{(5)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} \end{bmatrix}$ for *Codebook-Config* = 2-4 $W^{(5)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} \end{bmatrix}$ for *Codebook-Config* = 1				

5 Layers, $P=16$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1, N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2	$N_1>1, N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(5)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8}$

where

$$W^{(5)}_{l,l',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m''}{4}} \\ v_{\frac{O_1 l'}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} \end{bmatrix} \quad \text{for } \textit{Codebook-Config} = 2\text{-}4$$

$$W^{(5)}_{l,l',m,m',m''}=\frac{1}{\sqrt{5P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} & v_{l,m'} & v_{l,m''} \\ v_{l',m} & -v_{l',m} & v_{l',m'} & -v_{l',m'} & v_{l',m''} \end{bmatrix} \quad \text{for } \textit{Codebook-Config} = 1$$

Table 7.2.4-15: Codebook for 6-layer CSI reporting using antenna ports 15 to 14+*P*

6 Layers, $P=8$, $N_1=N_2$			
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2-4	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$

where

$$W^{(6)}_{l,l',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m''}{4}} \\ v_{\frac{O_1 l'}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} \end{bmatrix} \quad \text{for } \textit{Codebook-Config} = 2\text{-}4$$

$$W^{(6)}_{l,l',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} & v_{l,m'} & v_{l,m''} & v_{l,m''} \\ v_{l',m} & -v_{l',m} & v_{l',m'} & -v_{l',m'} & v_{l',m''} & -v_{l',m''} \end{bmatrix} \quad \text{for } \textit{Codebook-Config} = 1$$

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6 Layers, $P=12$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1,\ N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8}$

where

$$W^{(6)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} & -v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} \end{bmatrix} \quad \text{for } \textit{Codebook-Config} = 2\text{-}4$$

$$W^{(6)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix} \quad \text{for } \textit{Codebook-Config} = 1$$

6 Layers, $P=16$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1,\ N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2}$
2	$N_1>1,\ N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,2},i_{1,2},i_{1,2}}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(6)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8}$

where

$$W^{(6)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} & -v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} \end{bmatrix} \quad \text{for } \textit{Codebook-Config} = 2\text{-}4$$

$$W^{(6)}_{l,l',l'',m,m',m''}=\frac{1}{\sqrt{6P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix} \quad \text{and for } \textit{Codebook-Config} = 1$$

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Table 7.2.4-16: Codebook for 7-layer CSI reporting using antenna ports 15 to 14+*P*

7 Layers $P=8$, $N_1=N_2$			
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2-4	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
where			
$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l'''}{4},\frac{O_2 m'''}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} & -v_{\frac{O_1 l''}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l'''}{4},\frac{O_2 m'''}{4}} \end{bmatrix}$ for *Codebook-Config* = 2-4			
$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} \end{bmatrix}$ for *Codebook-Config* = 1			

7 Layers, $P=12$				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1, N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2	$N_1>1, N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+4}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1},i_{1,2},i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}}$
where				
$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} \end{bmatrix}$ for *Codebook-Config* = 2-4				
$W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} \end{bmatrix}$ for *Codebook-Config* = 1				

7 Layers, $P=16$				
Value of *Codebook-Config*	Configuration	$i_{1,1}$	$i_{1,2}$	
1	$N_1>1, N_2\geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2	$N_1>1, N_2>1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
3	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+12}$
4	$N_1\geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2},i_{1,2}}$
	$N_1<N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(7)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+12}$
where $W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'''}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'''}{4}} \end{bmatrix}$ for *Codebook-Config* = 2-4							
and for *Codebook-Config* = 1 $W^{(7)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{7P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} & v_{l,m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m''} \\ v_{l,m} & -v_{l,m} & v_{l,m'} & -v_{l,m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m''} \end{bmatrix}$							

Table 7.2.4-17: Codebook for 8-layer CSI reporting using antenna ports 15 to 14+*P*

8 Layers, $P=8$, $N_1=N_2$			
Value of *Codebook-Config*	$i_{1,1}$	$i_{1,2}$	
1	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2-4	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
where $W^{(8)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{8P}}\begin{bmatrix} v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'''}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'''}{4}} \\ v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m}{4}} & v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & -v_{\frac{O_1 l}{4},\frac{O_2 m'}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m''}{4}} & v_{\frac{O_1 l'}{4},\frac{O_2 m'''}{4}} & -v_{\frac{O_1 l'}{4},\frac{O_2 m'''}{4}} \end{bmatrix}$ for *Codebook-Config* = 2-4		
$W^{(8)}_{l,l',l'',l''',m,m',m'',m'''}=\frac{1}{\sqrt{8P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l,m'} & v_{l,m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m''} & v_{l''',m''} \\ v_{l,m} & -v_{l,m} & v_{l,m'} & -v_{l,m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m''} & -v_{l''',m''} \end{bmatrix}$ for *Codebook-Config* = 1			

8 Layers, P=12				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1 > 1, N_2 \geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2	$N_1 > 1, N_2 > 1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
3	$N_1 \geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+4,i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
	$N_1 < N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+4}$
4	$N_1 \geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1},i_{1,2},i_{1,2},i_{1,2},i_{1,2}+4}$
	$N_1 < N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}}$

where $W^{(8)}_{l,l',l'',m,m',m''} = \frac{1}{\sqrt{8P}}\begin{bmatrix} v_{O_1 l,O_2 m} & v_{O_1 l,O_2 m} & v_{O_1 l,O_2 m'} & v_{O_1 l,O_2 m'} & v_{O_1 l',O_2 m''} & v_{O_1 l',O_2 m''} & v_{O_1 l'',O_2 m'''} & v_{O_1 l'',O_2 m'''} \\ v_{O_1 l,O_2 m} & -v_{O_1 l,O_2 m} & v_{O_1 l,O_2 m} & -v_{O_1 l,O_2 m'} & v_{O_1 l',O_2 m''} & -v_{O_1 l',O_2 m''} & v_{O_1 l'',O_2 m'''} & -v_{O_1 l'',O_2 m'''} \end{bmatrix}$ for *Codebook-Config* = 2-4

$W^{(8)}_{l,l',l'',m,m',m'',m'''} = \frac{1}{\sqrt{8P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$ for *Codebook-Config* = 1

8 Layers, P=16				
Value of *Codebook-Config*	**Configuration**	$i_{1,1}$	$i_{1,2}$	
1	$N_1 > 1, N_2 \geq 1$	$0,1,\cdots,O_1N_1-1$	$0,1,\cdots,O_2N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2}$
2	$N_1 > 1, N_2 > 1$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,1},i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
3	$N_1 \geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2}+4,i_{1,2}+4}$
	$N_1 < N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1},i_{1,1}+4,i_{1,1}+4,i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+12}$
4	$N_1 \geq N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1}+4,i_{1,1}+8,i_{1,1}+12,i_{1,2},i_{1,2},i_{1,2},i_{1,2}}$
	$N_1 < N_2$	$0,1,\cdots,4N_1-1$	$0,1,\cdots,4N_2-1$	$W^{(8)}_{i_{1,1},i_{1,1},i_{1,1},i_{1,1},i_{1,2},i_{1,2}+4,i_{1,2}+8,i_{1,2}+12}$

where $W^{(8)}_{l,l',l'',m,m',m'',m'''} = \frac{1}{\sqrt{8P}}\begin{bmatrix} v_{O_1 l,O_2 m} & v_{O_1 l,O_2 m} & v_{O_1 l,O_2 m'} & v_{O_1 l,O_2 m'} & v_{O_1 l',O_2 m''} & v_{O_1 l',O_2 m''} & v_{O_1 l'',O_2 m'''} & v_{O_1 l'',O_2 m'''} \\ v_{O_1 l,O_2 m} & -v_{O_1 l,O_2 m} & v_{O_1 l,O_2 m'} & -v_{O_1 l,O_2 m'} & v_{O_1 l',O_2 m''} & -v_{O_1 l',O_2 m''} & v_{O_1 l'',O_2 m'''} & -v_{O_1 l'',O_2 m'''} \end{bmatrix}$ for *Codebook-Config* = 1

$W^{(8)}_{l,l',l'',m,m',m'',m'''} = \frac{1}{\sqrt{8P}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ v_{l,m} & -v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$ *Codebook-Config* = 2-4

For a UE configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting Type* is set to 'CLASS B', and one CSI-RS resource configured, and higher layer parameter *PMI-Config* is set to '1',

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- For 2 antenna ports $\{15,16\}$, a PMI value corresponds to the codebook index n given in Table 7.2.4-18 with υ equal to the associated RI value.
- For 4 antenna ports $\{15,16,17,18\}$, a PMI corresponds to the codebook index n given in Table 7.2.4-19 with υ equal to the associated RI value.
- For 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, a PMI value corresponds to the codebook index n given in Table 7.2.4-20 with υ equal to the associated RI value.

where $e_k^{(N)}$ is a length-N column-vector where its l-th element is 1 for $k=l$ ($k,l \in \{0,1,\cdots,N-1\}$), and 0 otherwise.

Table 7.2.4-18: Codebook for υ-layer CSI reporting using antenna ports $\{15,16\}$

Codebook index, n	Number of layers υ	
	1	2
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\j & -j\end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	-
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	-

Table 7.2.4-19: Codebook for υ-layer CSI reporting using antenna ports $\{15,16,17,18\}$

Codebook index, n	Number of layers υ			
	1	2	3	4
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}e_0^{(2)}\\e_0^{(2)}\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}e_0^{(2)} & e_0^{(2)}\\e_0^{(2)} & -e_0^{(2)}\end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix}e_0^{(2)} & e_0^{(2)} & e_1^{(2)}\\e_0^{(2)} & -e_0^{(2)} & -e_1^{(2)}\end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix}e_0^{(2)} & e_1^{(2)} & e_0^{(2)} & e_1^{(2)}\\e_0^{(2)} & e_1^{(2)} & -e_0^{(2)} & -e_1^{(2)}\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}e_0^{(2)}\\-e_0^{(2)}\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}e_0^{(2)} & e_0^{(2)}\\je_0^{(2)} & -je_0^{(2)}\end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix}e_1^{(2)} & e_0^{(2)} & e_1^{(2)}\\e_1^{(2)} & -e_0^{(2)} & -e_1^{(2)}\end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix}e_0^{(2)} & e_1^{(2)} & e_0^{(2)} & e_1^{(2)}\\je_0^{(2)} & je_1^{(2)} & -je_0^{(2)} & -je_1^{(2)}\end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}e_0^{(2)}\\j\cdot e_0^{(2)}\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}e_1^{(2)} & e_1^{(2)}\\e_1^{(2)} & -e_1^{(2)}\end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix}e_0^{(2)} & e_1^{(2)} & e_1^{(2)}\\e_0^{(2)} & e_1^{(2)} & -e_1^{(2)}\end{bmatrix}$	-
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}e_0^{(2)}\\-j\cdot e_0^{(2)}\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}e_1^{(2)} & e_1^{(2)}\\je_1^{(2)} & -je_1^{(2)}\end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix}e_1^{(2)} & e_0^{(2)} & e_0^{(2)}\\e_1^{(2)} & e_0^{(2)} & -e_0^{(2)}\end{bmatrix}$	-
4	$\frac{1}{\sqrt{2}}\begin{bmatrix}e_1^{(2)}\\e_1^{(2)}\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}e_0^{(2)} & e_1^{(2)}\\e_0^{(2)} & -e_1^{(2)}\end{bmatrix}$	-	-
5	$\frac{1}{\sqrt{2}}\begin{bmatrix}e_1^{(2)}\\-e_1^{(2)}\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}e_0^{(2)} & e_1^{(2)}\\je_0^{(2)} & -je_1^{(2)}\end{bmatrix}$	-	-
6	$\frac{1}{\sqrt{2}}\begin{bmatrix}e_1^{(2)}\\j\cdot e_1^{(2)}\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}e_1^{(2)} & e_0^{(2)}\\e_1^{(2)} & -e_0^{(2)}\end{bmatrix}$	-	-
7	$\frac{1}{\sqrt{2}}\begin{bmatrix}e_1^{(2)}\\-j\cdot e_1^{(2)}\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}e_1^{(2)} & e_0^{(2)}\\je_1^{(2)} & -je_0^{(2)}\end{bmatrix}$	-	-

Table 7.2.4-20: Codebook for υ-layer CSI reporting using antenna ports $\{15,16,17,18,19,20,21,22\}$

Codebook index, n	Number of layers υ			
	1	2	3	4
0	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(4)} \\ e_0^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} \\ e_0^{(4)} & -e_0^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} & e_0^{(4)} & e_1^{(4)} \\ e_0^{(4)} & e_1^{(4)} & -e_0^{(4)} & -e_1^{(4)} \end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(4)} \\ -e_0^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} \\ je_0^{(4)} & -je_0^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(4)} & e_0^{(4)} & e_1^{(4)} \\ e_1^{(4)} & -e_0^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} & e_0^{(4)} & e_1^{(4)} \\ je_0^{(4)} & je_1^{(4)} & -je_0^{(4)} & -je_1^{(4)} \end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(4)} \\ j\cdot e_0^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_1^{(4)} \\ e_1^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} & e_1^{(4)} \\ e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} & e_1^{(4)} & e_2^{(4)} \\ e_1^{(4)} & e_2^{(4)} & -e_1^{(4)} & -e_2^{(4)} \end{bmatrix}$
3	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_0^{(4)} \\ -j\cdot e_0^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_1^{(4)} \\ je_1^{(4)} & -je_1^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(4)} & e_0^{(4)} & e_0^{(4)} \\ e_1^{(4)} & e_0^{(4)} & -e_0^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} & e_1^{(4)} & e_2^{(4)} \\ je_1^{(4)} & je_2^{(4)} & -je_1^{(4)} & -je_2^{(4)} \end{bmatrix}$
4	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(4)} \\ e_1^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_2^{(4)} & e_2^{(4)} \\ e_2^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(4)} & e_1^{(4)} & e_2^{(4)} \\ e_1^{(4)} & -e_1^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_2^{(4)} & e_3^{(4)} & e_2^{(4)} & e_3^{(4)} \\ e_2^{(4)} & e_3^{(4)} & -e_2^{(4)} & -e_3^{(4)} \end{bmatrix}$
5	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(4)} \\ -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_2^{(4)} & e_2^{(4)} \\ je_2^{(4)} & -je_2^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_2^{(4)} & e_1^{(4)} & e_2^{(4)} \\ e_2^{(4)} & -e_1^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_2^{(4)} & e_3^{(4)} & e_2^{(4)} & e_3^{(4)} \\ je_2^{(4)} & je_3^{(4)} & -je_2^{(4)} & -je_3^{(4)} \end{bmatrix}$
6	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(4)} \\ j\cdot e_1^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_3^{(4)} & e_3^{(4)} \\ e_3^{(4)} & -e_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} & e_2^{(4)} \\ e_1^{(4)} & e_2^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_3^{(4)} & e_0^{(4)} & e_3^{(4)} & e_0^{(4)} \\ e_3^{(4)} & e_0^{(4)} & -e_0^{(4)} & -e_0^{(4)} \end{bmatrix}$
7	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_1^{(4)} \\ -j\cdot e_1^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_3^{(4)} & e_3^{(4)} \\ je_3^{(4)} & -je_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_2^{(4)} & e_1^{(4)} & e_1^{(4)} \\ e_2^{(4)} & e_1^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{2}}\begin{bmatrix} e_3^{(4)} & e_0^{(4)} & e_3^{(4)} & e_0^{(4)} \\ je_3^{(4)} & je_0^{(4)} & -je_0^{(4)} & -je_0^{(4)} \end{bmatrix}$
8	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_2^{(4)} \\ e_2^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} \\ e_0^{(4)} & -e_1^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_2^{(4)} & e_2^{(4)} & e_3^{(4)} \\ e_2^{(4)} & -e_2^{(4)} & -e_3^{(4)} \end{bmatrix}$	-
9	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_2^{(4)} \\ -e_2^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_1^{(4)} \\ je_0^{(4)} & -je_1^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_3^{(4)} & e_2^{(4)} & e_3^{(4)} \\ e_3^{(4)} & -e_2^{(4)} & -e_3^{(4)} \end{bmatrix}$	-
10	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_2^{(4)} \\ j\cdot e_0^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} \\ e_1^{(4)} & -e_2^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_2^{(4)} & e_3^{(4)} & e_3^{(4)} \\ e_2^{(4)} & e_3^{(4)} & -e_3^{(4)} \end{bmatrix}$	-
11	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_2^{(4)} \\ -j\cdot e_2^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_2^{(4)} \\ je_1^{(4)} & -je_2^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_3^{(4)} & e_2^{(4)} & e_2^{(4)} \\ e_3^{(4)} & e_2^{(4)} & -e_2^{(4)} \end{bmatrix}$	-
12	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_3^{(4)} \\ e_3^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_3^{(4)} \\ e_0^{(4)} & -e_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_3^{(4)} & e_3^{(4)} & e_0^{(4)} \\ e_3^{(4)} & -e_3^{(4)} & -e_0^{(4)} \end{bmatrix}$	-
13	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_3^{(4)} \\ -e_3^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_0^{(4)} & e_3^{(4)} \\ je_0^{(4)} & -je_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(4)} & e_3^{(4)} & e_0^{(4)} \\ e_0^{(4)} & -e_3^{(4)} & -e_0^{(4)} \end{bmatrix}$	-
14	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_3^{(4)} \\ j\cdot e_3^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_3^{(4)} \\ e_1^{(4)} & -e_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_3^{(4)} & e_0^{(4)} & e_0^{(4)} \\ e_3^{(4)} & e_0^{(4)} & -e_0^{(4)} \end{bmatrix}$	-
15	$\frac{1}{\sqrt{2}}\begin{bmatrix} e_3^{(4)} \\ -j\cdot e_3^{(4)} \end{bmatrix}$	$\frac{1}{2}\begin{bmatrix} e_1^{(4)} & e_3^{(4)} \\ je_1^{(4)} & -je_3^{(4)} \end{bmatrix}$	$\frac{1}{\sqrt{6}}\begin{bmatrix} e_0^{(4)} & e_3^{(4)} & e_3^{(4)} \\ e_0^{(4)} & e_3^{(4)} & -e_3^{(4)} \end{bmatrix}$	-

Codebook index, n	Number of layers υ	
	5	6
0	$\frac{1}{\sqrt{10}}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} & e_1^{(4)} & e_2^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} & e_2^{(4)} \end{bmatrix}$	$\frac{1}{2\sqrt{3}}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} & e_1^{(4)} & e_2^{(4)} & e_2^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} & e_2^{(4)} & -e_2^{(4)} \end{bmatrix}$
1-15	-	-

Codebook index, n	Number of layers υ	
	7	8
0	$\frac{1}{\sqrt{14}}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} & e_1^{(4)} & e_2^{(4)} & e_2^{(4)} & e_3^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} & e_2^{(4)} & -e_2^{(4)} & e_3^{(4)} \end{bmatrix}$	$\frac{1}{4}\begin{bmatrix} e_0^{(4)} & e_0^{(4)} & e_1^{(4)} & e_1^{(4)} & e_2^{(4)} & e_2^{(4)} & e_3^{(4)} & e_3^{(4)} \\ e_0^{(4)} & -e_0^{(4)} & e_1^{(4)} & -e_1^{(4)} & e_2^{(4)} & -e_2^{(4)} & e_3^{(4)} & -e_3^{(4)} \end{bmatrix}$
1-15	-	-

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_{ID}. The allowable values are given in [11].
- CDM type parameter, if the UE is configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS A' for a CSI process. The allowable values are given in subclause 6.10.5.3 of [3].
- 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 ρ_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 serving cell 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.

A UE configured in transmission mode 10, and configured with higher layer parameter *CSI-Reporting-Type*, and *CSI-Reporting-Type* is set to 'CLASS B', and the number of configured CSI-RS resources is more than one for a CSI process, and with quasi co-location type B, is not expected to receive CSI-RS resource configurations for the CSI process that have different values of the higher layer parameter *qcl-CRS-Info-r11*.

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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].

For a serving cell, if a UE is not configured with the higher layer parameter *csi-SubframePatternConfig-r12*, the 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.

For a serving cell, if a UE is not configured with CSI subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ for any CSI process, and the UE is configured with four CSI-IM resources, then the UE is not expected to be configured with CSI processes that are associated with all of the four CSI-IM resources.

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 and UE not configured with *csi-SubframePatternConfig-r12* for the serving cell, the UE can be configured with one zero-power CSI-RS resource configuration. For a serving cell and UE configured in transmission mode 1-9 and UE configured with *csi-SubframePatternConfig-r12* for the serving cell, the UE can be configured with up to two zero-power CSI-RS resource configurations. 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).

For a serving cell, the UE can be configured with up to 5 additional zero-power CSI-RS resource configurations according to the higher layer parameter *ds-ZeroTxPowerCSI-RS-r12*.

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 serving cell, 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 serving cell 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

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group unless stated otherwise

- When the procedures are applied for the primary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', and 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell or serving cells belonging to the primary PUCCH group respectively unless stated otherwise.

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- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell' and 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PUCCH-SCell), serving cell, serving cells belonging to the secondary PUCCH group respectively unless stated otherwise. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group.

If each of the serving cell(s) configured for the UE has frame structure type 1, the UE procedure for HARQ-ACK reporting for frame structure type 1 is given in subclause 7.3.1.

If each of the serving cell(s) configured for the UE has frame structure type 2, the UE procedure for HARQ-ACK reporting for frame structure type 2 is given in subclause 7.3.2.

If the UE is configured with more than one serving cell, and if the frame structure type of any two configured serving cells is different, and if the primary cell is frame structure type 1, UE procedure for HARQ-ACK reporting is given in subclause 7.3.3.

If the UE is configured for more than one serving cell, and if the frame structure type of any two configured serving cells is different, and if the primary cell is frame structure type 2, UE procedure for HARQ-ACK reporting is given in subclause 7.3.4.

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 3/4/5 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].

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13* = *0*, for FDD and a subframe n, the value of the counter Downlink Assignment Indicator (DAI) in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of serving cell(s) with PDSCH transmission(s) associated with PDCCH/EPDCCH and serving cell with PDCCH/EPDCCH indicating downlink SPS release, up to the present serving cell in increasing order of serving cell index; the value of the total DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the total number of serving cell(s) with PDSCH transmission(s) associated with PDCCH/EPDCCH(s) and serving cell with PDCCH/EPDCCH indicating downlink SPS release. Denote $V_{C-DAI,c}^{DL}$ as the value of the counter DAI in DCI format

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1/1A/1B/1D/2/2A/2B/2C/2D scheduling PDSCH transmission or indicating downlink SPS release for serving cell c, according to table 7.3.1-1. Denote V_{T-DAI}^{DL} as the value of the total DAI, according to Table 7.3.1-1. The UE shall assume a same value of total DAI in all PDCCH/EPDCCH scheduling PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release in a subframe.

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = 0* and if the UE transmits HARQ-ACK using PUCCH format 3 or PUCCH format 4 or PUCCH format 5 in subframe n, the UE shall determine the $o_0^{ACK}, o_1^{ACK}, \ldots, o_{O^{ACK}-1}^{ACK}$ according to the following pseudo-code:

Set $c = 0$ -- cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$

Set $V_{temp} = 0$

Set $V_s = \varnothing$

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c < N_{cells}^{DL}$

if there is a PDSCH on serving cell c associated with PDCCH/EPDCCH or there is a PDCCH/EPDCCH indicating downlink SPS release on serving cell c,

if $V_{C-DAI,c}^{DL} \le V_{temp}$

$j = j+1$

end if

$V_{temp} = V_{C-DAI,c}^{DL}$

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$o_{8j+2\left(V_{C-DAI,c}^{DL}-1\right)}^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$o_{8j+2\left(V_{C-DAI,c}^{DL}-1\right)+1}^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$$V_s = V_s \cup \left\{8j+2\left(V_{C-DAI,c}^{DL}-1\right), 8j+2\left(V_{C-DAI,c}^{DL}-1\right)+1\right\}$$

elseif the higher layer parameter *spatialBundlingPUCCH* is set *TRUE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$o_{4j+V_{C-DAI,c}^{DL}-1}^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$$V_s = V_s \cup \left\{4j+V_{C-DAI,c}^{DL}-1\right\}$$

else

$o_{4j+V_{C-DAI,c}^{DL}-1}^{ACK}$ = HARQ-ACK bit of this cell

$$V_s = V_s \cup \left\{4j+V_{C-DAI,c}^{DL}-1\right\}$$

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end if

end if

$c = c + 1$

end while

if $V_{T-DAI}^{DL} < V_{temp}$

$j = j+1$

end if

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE* and the UE is configured with a transmission mode supporting two transport blocks in at least one configured serving cell,

$$O^{ACK} = 2 \cdot \left(4 \cdot j + V_{T-DAI}^{DL}\right)$$

else

$$O^{ACK} = 4 \cdot j + V_{T-DAI}^{DL}$$

end if

$$o_i^{ACK} = NACK \quad \text{for any} \quad i \in \left\{0,1,\ldots,O^{ACK}-1\right\} \setminus V_s$$

For a UE configured with higher layer parameter *codebooksizeDetermination-r13 = 0*, if the UE transmits HARQ-ACK on PUSCH in a subframe, the UE shall determine the $o_0^{ACK}, o_1^{ACK}, \ldots, o_{O^{ACK}-1}^{ACK}$ according to the above procedure as if the UE transmits HARQ-ACK using PUCCH format 3 or PUCCH format 4 or PUCCCH format 5, except that the higher layer parameter *spatialBundlingPUCCH* is replaced by *spatialBundlingPUSCH*.

Table 7.3.1-1: Value of counter DAI and total DAI

DAI MSB, LSB	$V_{C-DAI,c}^{DL}$ or V_{T-DAI}^{DL}	Number of serving cells with PDSCH transmission associated with PDCCH/EPDCCH and serving cell with PDCCH/EPDCCH indicating DL SPS release
0,0	1	1 or 5 or 9 or 13 or 17 or 21 or 25 or 29
0,1	2	2 or 6 or 10 or 14 or 18 or 22 or 26 or 30
1,0	3	3 or 7 or 11 or 15 or 19 or 23 or 27 or 31
1,1	4	0 or 4 or 8 or 12 or 16 or 20 or 24 or 28 or 32

If a UE is configured with higher layer parameter *codebooksizeDetermination-r13 = 1* and if the UE transmits HARQ-ACK using PUCCH format 4 or PUCCH format 5 in subframe n, the UE shall determine the $o_0^{ACK}, o_1^{ACK}, \ldots, o_{O^{ACK}-1}^{ACK}$ according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$

Set $V_s = \varnothing$

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c < N_{cells}^{DL}$

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if there is a PDSCH on serving cell c associated with PDCCH/EPDCCH or there is a PDCCH/EPDCCH indicating downlink SPS release on serving cell c,

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE* and if serving cell c is configured with a transmission mode supporting two transport blocks,

o_j^{ACK} = HARQ-ACK bit corresponding to the first codeword of this cell

$V_s = V_s \cup \{j\}$

$j = j + 1$

o_j^{ACK} = HARQ-ACK bit corresponding to the second codeword of this cell

$V_s = V_s \cup \{j\}$

$j = j + 1$

elseif the higher layer parameter *spatialBundlingPUCCH* is set *TRUE* and if serving cell c is configured with a transmission mode supporting two transport blocks,

o_j^{ACK} = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$V_s = V_s \cup \{j\}$

$j = j + 1$

else

o_j^{ACK} = HARQ-ACK bit of this cell

$V_s = V_s \cup \{j\}$

$j = j + 1$

end if

end if

$c = c + 1$

end while

if the higher layer parameter *spatialBundlingPUCCH* is set *FALSE*,

$O^{ACK} = 2 \cdot N_{cells}^{DL,2} + N_{cells}^{DL,1}$ where $N_{cells}^{DL,2}$ is the number of configured with serving cells with transmission mode(s) supporting two transport blocks for the UE, and $N_{cells}^{DL,1}$ is the number of configured with serving cells with transmission mode(s) supporting two transport blocks for the UE,

else

$O^{ACK} = N_{cells}^{DL}$

end if

$o_i^{ACK} = \text{NACK}$ for any $i \in \{0,1,\ldots,O^{ACK}-1\} \setminus V_s$

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For a UE configured with higher layer parameter *codebooksizeDetermination-r13 = 1*, if the UE transmits HARQ-ACK on PUSCH in a subframe, the UE shall determine the $o_0^{ACK}, o_1^{ACK}, \ldots, o_{O^{ACK}-1}^{ACK}$ according to the above procedure as if the UE transmits HARQ-ACK using PUCCH format 4 or PUCCCH format 5, except that the higher layer parameter *spatialBundlingPUCCH* is replaced by *spatialBundlingPUSCH*.

7.3.2 TDD HARQ-ACK reporting procedure

For TDD and a UE not configured with the parameter *EIMTA-MainConfigServCell-r12* for any serving cell, 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, 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, or if the UE is configured with the parameter *EIMTA-MainConfigServCell-r12* for at least one serving cell, 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 3/4/5 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.

If a UE is not configured with higher layer parameter *codebooksizeDetermination-r13 = 0*, 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

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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 downlink and special 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_{bundled}.

- For TDD UL/DL configuration 0, N_{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_{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_{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 without PUCCH format 4 or PUCCH format 5 configured for transmission of HARQ-ACK, the HARQ-ACK feedback bits $o_{c,0}^{ACK}\, o_{c,1}^{ACK},\ldots,o_{c,O_c^{ACK}-1}^{ACK}$ 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 and special 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

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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 without PUCCH format 4/5 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 $k \in K$.

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