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Technical Specification

3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Physical Channels and Modulation (Release 8)



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

1 Scope

The present document describes the physical channels for evolved UTRA.

2 References

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

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

- [1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
- [2] 3GPP TS 36.201: "LTE Physical Layer – General Description".
- [3] 3GPP TS 36.212: "Multiplexing and channel coding".
- [4] 3GPP TS 36.213: "Physical layer procedures".
- [5] 3GPP TS 36.214: "Physical layer – Measurements".
- [6] 3GPP TS xx.xxx: <RAN4 specification listing supported transmission bandwidths>

3 Definitions, symbols and abbreviations

Delete from the above heading those words which are not applicable.

Subclause numbering depends on applicability and should be renumbered accordingly.

3.1 Definitions

For the purposes of the present document, the [following] terms and definitions [given in ... and the following] apply.

Definition format

<defined term>: <definition>.

example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

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

$N_{\text{BW}}^{\text{DL}}$	Downlink bandwidth configuration, expressed as a number of subcarriers
$N_{\text{BW}}^{\text{UL}}$	Uplink bandwidth configuration, expressed as a number of virtual subcarriers
$N_{\text{sybm}}^{\text{DL}}$	Number of OFDM symbols in a downlink slot
$N_{\text{sybm}}^{\text{UL}}$	Number of SC-FDMA symbols in an uplink slot
$N_{\text{BW}}^{\text{RB}}$	Resource block size in the frequency domain, expressed as a number of subcarriers
N_{OS}	Number of orthogonal two-dimensional reference signal sequences
N_{PRS}	Number of pseudo-random two-dimensional reference signal sequences
N_{TX}	Scheduled bandwidth for uplink transmission, expressed as a number of virtual subcarriers
k_0	Scheduled starting frequency for uplink transmission, expressed as a virtual subcarrier number
T_{f}	Radio frame duration
T_{slot}	Slot duration
T_{s}	Basic time unit
Δf	Subcarrier spacing
N_{TA}	Timing offset between uplink and downlink radio frames at the UE, expressed as a number of time units T_{s}
N_{d}	Length of SC-FDMA symbol excluding cyclic prefix, expressed as a number of time units T_{s}

3.3 Abbreviations

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

Abbreviation format

<ACRONYM> <Explanation>

4 Frame Structure

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

- generic frame structure, applicable to both FDD and TDD transmissions,
- alternative frame structure, applicable to TDD only.

4.1 Generic frame structure

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

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.

For TDD, a subframe is either allocated to downlink or uplink transmission. The first subframe in a radio frame is always allocated for downlink transmission.

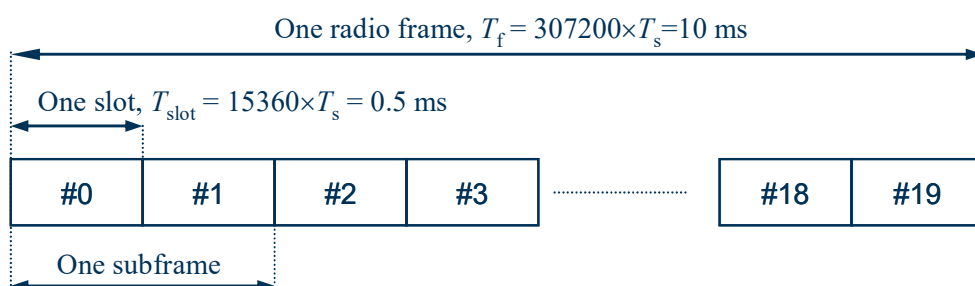


Figure 1: Generic frame structure.

4.2 Alternative frame structure

The alternative frame structure is only applicable to TDD. Each radio frame consists of two half-frames of length $T_f = 153600 \times T_s = 5$ ms each. The structure of each half-frame in a radio frame is identical. Each half-frame consists of seven slots, numbered from 0 to 6, and three special fields, DwPTS, GP, and UpPTS.

Slot #0 and DwPTS are always reserved for downlink transmission. UpPTS and slot #1 are always reserved for uplink transmission.

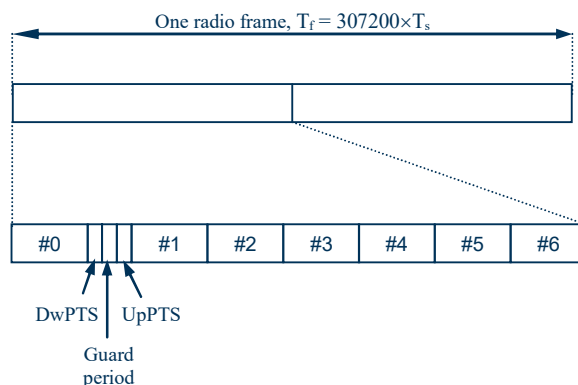


Figure 2: Alternative frame structure.

5 Downlink Physical Channels

5.1 Overview

The smallest time-frequency unit for downlink transmission is denoted a resource element and is defined in Section 5.2.

5.1.1 Physical Channels

A downlink physical channel corresponds to a set of resource elements carrying information originating from higher layers. The following downlink physical channels are defined:

- Physical Downlink Shared Channel, PDSCH
- Physical Downlink Control Channel, PDCCH
- Common Control Physical Channel, CCPCH

The following general steps can be identified for downlink transmission on a physical channel:

- scrambling
- modulation of scrambled bits to generate complex-valued modulation symbols
- mapping of complex-valued modulation symbols to resource elements
- generation of complex-valued time-domain OFDM signal for each layer



Figure 3: Overview of downlink signal generation.

5.1.2 Physical Signals

A downlink 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

5.2 Slot structure and physical resource elements

The transmitted signal in each slot is described by a resource grid of $N_{\text{BW}}^{\text{DL}}$ subcarriers and $N_{\text{symp}}^{\text{DL}}$ OFDM symbols. The resource grid and structure is illustrated in Figure 4.

In case of multi-layer transmission, there is one resource grid defined per layer. A layer is defined by a reference signal, unique within the cell.

Each element in the resource grid for layer p is called a resource element and is uniquely identified by the index triplet $\{p, k, l\}$ where p , k and l are the indices in the layer, frequency and time domains, respectively. One, two, or four layer transmission is supported, i.e., the index p shall fulfil $p = 0$, $p \in \{0, 1\}$, and $p \in \{0, 1, 2, 3\}$, respectively. Each resource element $\{p, k, l\}$ corresponds to one complex-valued modulation symbol $a_{k,l}^{(p)}$ where $k = 0, \dots, N_{\text{BW}}^{\text{DL}} - 1$ and

$l = 0, \dots, N_{\text{symb}}^{\text{DL}} - 1$. Modulation symbols $a_{k,l}^{(p)}$ corresponding to resource elements not used for transmission of a physical channel or a physical signal in a slot shall be set to zero.

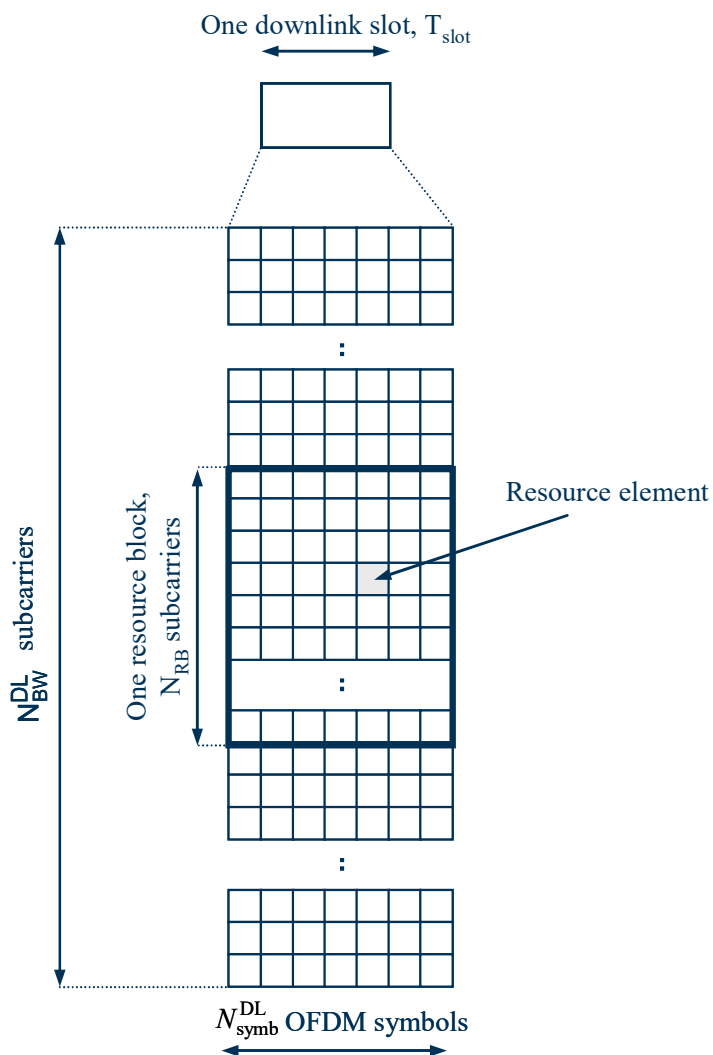


Figure 4: Downlink resource grid.

The value of $N_{\text{BW}}^{\text{DL}}$ depends on the transmission bandwidth configured in the cell and shall fulfil $[72] \leq N_{\text{BW}}^{\text{DL}} \leq 2048$. The set of allowed values for $N_{\text{BW}}^{\text{DL}}$ is given by [6]. Note that the value of $N_{\text{BW}}^{\text{DL}}$ does not include the DC subcarrier.

The number of OFDM symbols per slot, $N_{\text{symb}}^{\text{DL}}$, depends on the subcarrier spacing Δf and the cyclic prefix length configured by higher layers and is given by Table 1.

Table 1: Number of OFDM symbols per slot.

Configuration		N_{symb}	
		Generic frame structure	Alternative frame structure
Normal cyclic prefix	$\Delta f = 15 \text{ kHz}$	7	9
	$\Delta f = 15 \text{ kHz}$	6	8
Extended cyclic prefix	$\Delta f = 15 \text{ kHz}$	6	8
	$\Delta f = 7.5 \text{ kHz}$	3	4

A resource block is defined as $N_{\text{sybm}}^{\text{DL}}$ consecutive OFDM symbols in the time domain and $N_{\text{BW}}^{\text{RB}} = 12$ consecutive subcarriers in the frequency domain. A resource block thus consists of $N_{\text{sybm}}^{\text{DL}} \times N_{\text{BW}}^{\text{RB}}$ resource elements.

5.3 Physical Downlink Shared Channel

5.3.1 Scrambling

The block of bits $b(n)$, with the indexing starting at $n = 0$, to be transmitted on the physical downlink shared channel shall be scrambled prior to modulation, resulting in a block of scrambled bits $c(n)$.

5.3.2 Modulation

The block of scrambled bits $c(n)$ shall be modulated as described in Section 7, resulting in a block of complex-valued modulation symbols $d(n)$. Table 2 specifies the modulation mappings applicable for the physical downlink shared channel.

Table 2: PDSCH modulation schemes

Physical channel	Modulation schemes
PDSCH	QPSK, 16QAM, 64QAM

5.3.3 Physical resource mapping

The block of modulation symbols $d(n)$ shall be mapped to resource elements $\{k, l\}$ not used for other purposes in increasing order of first the index k and then the index l .

5.4 Physical Downlink Control Channel

Depending on future decisions, there may be multiple control channels, e.g., paging indicator, downlink scheduling control, uplink scheduling control, etc. In that case, a separate subsection per control channel will be needed.

5.4.1 Scrambling

The block of bits $b(n)$, with the indexing starting at $n = 0$, to be transmitted on the physical downlink control channel shall be scrambled prior to modulation, resulting in a block of scrambled bits $c(n)$.

5.4.2 Modulation

The block of scrambled bits $c(n)$ channel shall be modulated as described in Section 7, resulting in a block of complex-valued modulation symbols $d(n)$. Table 3 specifies the modulation mappings applicable for the physical downlink shared channel.

Table 3: PDCCH modulation schemes

Physical channel	Modulation schemes
PDCCH	

5.4.3 Physical resource mapping

The block of modulation symbols $d(n)$ shall be mapped to the first l OFDM symbols in a subframe, where $l \leq 3$.

5.5 Common Control Physical Channel

5.5.1 Scrambling

The block of bits $b(n)$, with the indexing starting at $n = 0$, to be transmitted on the common control physical channel shall be scrambled prior to modulation, resulting in a block of scrambled bits $c(n)$.

5.5.2 Modulation

The block of scrambled bits $c(n)$ shall be modulated as described in Section 7, resulting in a sequence block of complex-valued modulation symbols $d(n)$. Table 4 specifies the modulation mappings applicable for the common control physical channel.

Table 4: CCPCH modulation schemes

Physical channel	Modulation schemes
CCPCH	QPSK

5.5.3 Physical resource mapping

The CCPCH is transmitted on 72 active subcarriers, centred around the DC subcarrier. The block of complex-valued modulation symbols $d(n)$ shall be mapped to the resource elements $\{k, l\}$ not reserved for reference signal transmission. The mapping of $d(n)$ to resource elements shall be in increasing order of first the index k and then the index l .

5.6 Reference signal

There is one reference signal transmitted per layer. The number of layers equals 1, 2, or 4.

5.6.1 Sequence generation

The two-dimensional reference signal sequence $r_{m,n}$ is generated as the symbol-by-symbol product $r_{m,n} = r_{m,n}^{\text{OS}} \times r_{m,n}^{\text{PRS}}$ of a two-dimensional orthogonal sequence $r_{m,n}^{\text{OS}}$ and a two-dimensional pseudo-random sequence $r_{m,n}^{\text{PRS}}$.

There are $N_{\text{OS}} = 3$ different two-dimensional orthogonal sequences and $N_{\text{PRS}} = [170]$ different two-dimensional pseudo-random sequences. Each cell identity corresponds to a unique combination of one orthogonal sequence and one pseudo-random sequence, thus allowing for $N_{\text{OS}} \times N_{\text{PRS}} = [510]$ unique cell identities.

5.6.1.1 Orthogonal sequence generation

The two-dimensional orthogonal sequence shall be generated according to

$$r_{m,n}^{\text{OS}} = s_{m,n}, \quad n = 0,1 \quad \text{and} \quad m = 0,1,\dots,N_r - 1$$

where $N_r = \left\lceil \frac{N_{\text{BW}}^{\text{DL}}}{N_{\text{BW}}^{\text{RB}}/2} \right\rceil$ is the number of resource elements used for the reference signal in the OFDM symbol. The quantity $s_{m,n}$ is the entry at the m :th row and the n :th column of the matrix S_i , defined as

$$S_i^T = \underbrace{\begin{bmatrix} \bar{S}_i^T & \bar{S}_i^T & \dots & \bar{S}_i^T \end{bmatrix}}_{\left\lceil \frac{N_r}{3} \right\rceil \text{ repetitions}}, \quad i = 0,1,2$$

where

$$\bar{S}_0 = \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & 1 \end{bmatrix}, \quad \bar{S}_1 = \begin{bmatrix} 1 & e^{j4\pi/3} \\ e^{j2\pi/3} & 1 \\ e^{j4\pi/3} & e^{j2\pi/3} \end{bmatrix}, \quad \bar{S}_2 = \begin{bmatrix} 1 & e^{j2\pi/3} \\ e^{j4\pi/3} & 1 \\ e^{j2\pi/3} & e^{j4\pi/3} \end{bmatrix}$$

for orthogonal sequence 0, 1, and 2, respectively. Which orthogonal sequence to use is configured by higher layers.

5.6.1.2 Pseudo-random sequence generation

5.6.2 Physical resource mapping

The two-dimensional reference signal sequence $r_{m,n}$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ for each layer p according to

$$a_{k,l}^{(p)} = r_{m,n}$$

where

$$k = 6m + (q + x(i)) \bmod 6$$

$$l = \begin{cases} 0 & n = 0 \\ N_{\text{symb}} - 3 & n = 1 \end{cases}$$

and

$$m = 0, 1, \dots, \left\lfloor \frac{N_{\text{BW}}^{\text{DL}}}{N_{\text{BW}}^{\text{RB}}/2} \right\rfloor$$

$$n = \begin{cases} 0, \dots, 1 & \text{for } p = 0, 1 \\ 0 & \text{for } p = 2, 3 \end{cases}$$

The variable q defines a shift in the frequency domain for the different reference signals and is given by

$$q = \begin{cases} (0 + 3n) \bmod 6 & \text{for } p = 0 \\ (3 + 3n) \bmod 6 & \text{for } p = 1 \\ 1 & \text{for } p = 2 \\ 2 & \text{for } p = 3 \end{cases}$$

The variable $i \in \{0, 1\}$ represents the slot number within a radio frame.

Resource elements $\{k, l\}$ used for reference signal transmission on any of the layers shall not be used for any transmission on any other layer.

Figures 5, 6, and 7 illustrate the resource elements used for reference symbol transmission.

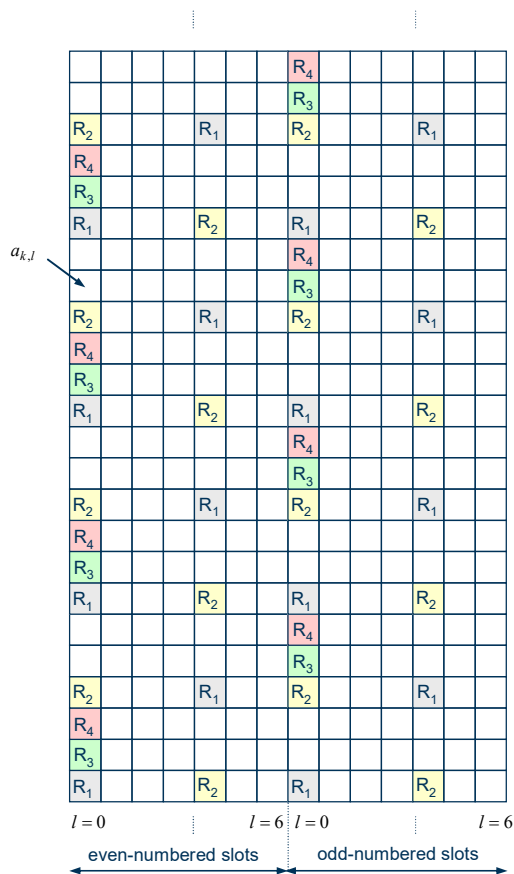


Figure 5. Mapping of downlink reference signals (generic frame structure, normal cyclic prefix).

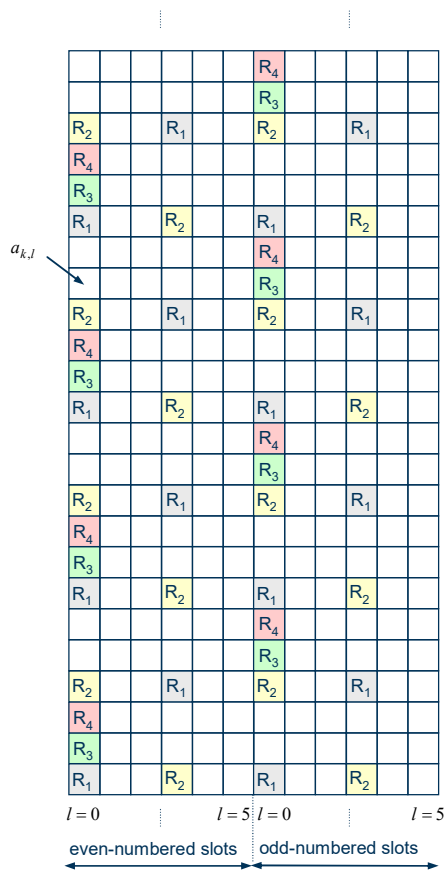


Figure 6. Mapping of downlink reference signals (generic frame structure, extended cyclic prefix).

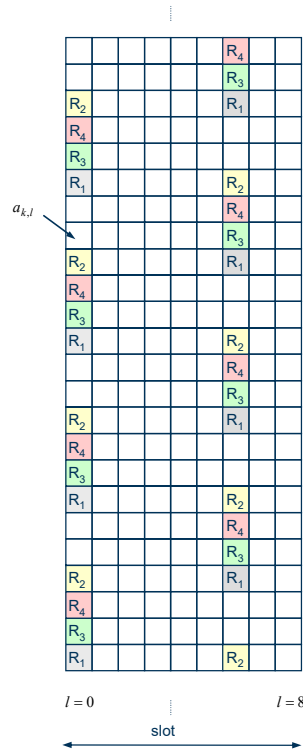


Figure 7. Mapping of downlink reference signals (alternative frame structure, normal cyclic prefix).

5.7 Synchronization signals

5.7.1 Primary synchronization signal

5.7.1.1 Sequence generation

5.7.1.2 Physical resource mapping

The primary synchronization signal is transmitted on 72 active subcarriers, centred around the DC subcarrier. The primary synchronization signal $d(n)$ shall be mapped to the resource elements according to

$$a_{k,l} = d(n), \quad k = n - 36 + \left\lfloor \frac{N_{\text{BW}}^{\text{DL}}}{2} \right\rfloor, \quad n = 0, \dots, 71$$

where $l = [\text{TBD}]$. The primary synchronization signal is only transmitted in slot [TBD].

5.7.2 Secondary synchronization signal

5.7.2.1 Sequence generation

5.7.2.2 Physical resource mapping

The secondary synchronization signal is transmitted on 72 active subcarriers, centred around the DC subcarrier. The secondary synchronization signal $d(m)$ shall be mapped to the resource elements according to

$$a_{k,l} = d(m), \quad k = m - 36 + \left\lfloor \frac{N_{\text{BW}}^{\text{DL}}}{2} \right\rfloor, \quad m = 0, \dots, 71$$

where $l = \lceil \text{TBD} \rceil$. The secondary synchronization signal is transmitted in and only in slots where the primary synchronization signal is transmitted.

5.8 OFDM signal generation

The OFDM symbols in a slot shall be transmitted in increasing order of l . The time-continuous signal $s_l^{(p)}(t)$ on layer p in OFDM symbol l in a downlink slot is defined by

$$s_l^{(p)}(t) = \sum_{k=-\lfloor N_{\text{BW}}^{\text{DL}}/2 \rfloor}^{-1} a_{k^{(-)},l}^{(p)} \cdot e^{j \frac{2\pi k}{N T_s} (t - N_{\text{CP},l} T_s)} + \sum_{k=1}^{\lfloor N_{\text{BW}}^{\text{DL}}/2 \rfloor} a_{k^{(+)},l}^{(p)} \cdot e^{j \frac{2\pi k}{N T_s} (t - N_{\text{CP},l} T_s)}$$

for $0 \leq t < (N_{\text{CP},l} + N) \times T_s$ where $k^{(-)} = k + \lfloor N_{\text{BW}}^{\text{DL}}/2 \rfloor$ and $k^{(+)} = k + \lfloor N_{\text{BW}}^{\text{DL}}/2 \rfloor - 1$.

Tables 5 and 6 list the value of $N_{\text{CP},l}$ that shall be used for the generic and alternative frame structure, respectively. Note that different OFDM symbols within a slot may have different cyclic prefix lengths.

Table 5: OFDM parameters for the generic frame structure.

Configuration		Cyclic prefix length $N_{\text{CP},l}$
Normal cyclic prefix	$\Delta f = 15 \text{ kHz}$	160 for $l = 0$
		144 for $l = 1, \dots, 6$
Extended cyclic prefix	$\Delta f = 15 \text{ kHz}$	512 for $l = 0, \dots, 5$
	$\Delta f = 7.5 \text{ kHz}$	1024 for $l = 0, \dots, 2$

Table 6: OFDM parameters for the alternative frame structure.

Configuration		Cyclic prefix length $N_{\text{CP},l}$
Normal cyclic prefix	$\Delta f = 15 \text{ kHz}$	224 for $l = 0, \dots, 8$
Extended cyclic prefix	$\Delta f = 15 \text{ kHz}$	512 for $l = 0, \dots, 7$
	$\Delta f = 7.5 \text{ kHz}$	1024 for $l = 0, \dots, 3$

5.9 Modulation and upconversion

Modulation and upconversion to the carrier frequency of the complex-valued OFDM signal for each layer is shown in Figure 8. The filtering required prior to transmission is defined by the requirements in [6].

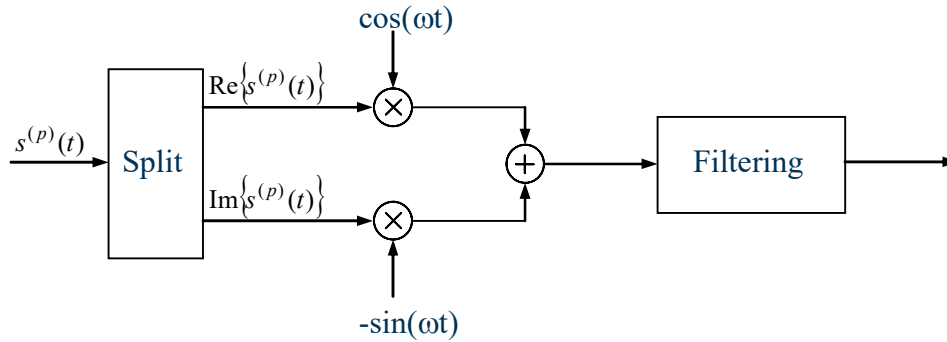


Figure 8: Downlink modulation.

6 Uplink Physical Channels

6.1 Overview

The smallest resource unit for uplink transmissions is denoted a resource element, defined in section 6.2.

6.1.1 Physical Channels

An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers. The following uplink physical channels are defined:

- Physical Uplink Shared Channel, PUSCH
- Physical Uplink Control Channel, PUCCH

The following general steps can be identified for uplink transmission on a physical channel:

- scrambling
- modulation of scrambled bits to generate complex-valued modulation symbols
- mapping of complex-valued modulation symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each layer



Figure 9: Overview of uplink signal generation.

6.1.2 Physical Signals

An uplink 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
- random access preamble

6.2 Slot structure and physical resources

The transmitted signal in each slot is described by the contents of $N_{\text{ymb}}^{\text{UL}}$ SC-FDMA symbols, numbered from 0 to $N_{\text{ymb}}^{\text{UL}} - 1$. Each SC-FDMA symbol carries multiple complex-valued modulation symbols $a_{u,l}$ where u is the time index within SC-FDMA symbol l . SC-FDMA symbol 1 and $N_{\text{ymb}}^{\text{UL}} - 2$ are denoted short SC-FDMA symbols, used to carry the uplink demodulation reference signal, while the remaining SC-FDMA symbols are denoted long SC-FDMA symbols. The uplink slot structure is illustrated in Figure 10.

The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by higher layers and is given in Table 7.

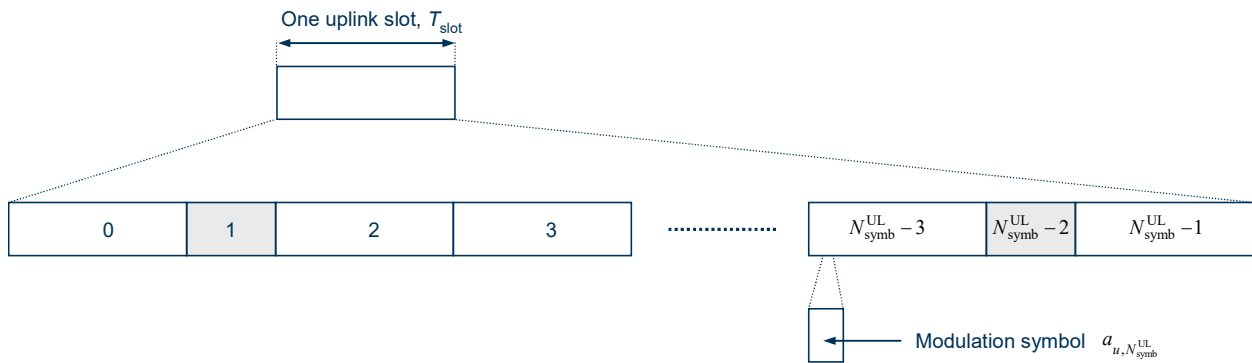


Figure 10: Uplink slot format.

Table 7: Number of SC-FDMA symbols per slot.

Configuration	$N_{\text{ymb}}^{\text{UL}}$	
	Generic frame structure	Alternative frame structure
Normal cyclic prefix	8	10
Extended cyclic prefix	7	9

6.3 Physical Uplink Shared Channel

The physical uplink shared channel is defined by one subframe and the parameters N_{TX} and k_0 , used in the generation of the SC-FDMA signal. The variables N_{TX} and k_0 , determining the transmission bandwidth and the frequency hopping pattern, respectively, are under control of the uplink scheduler, and may vary on a per-subframe basis.

6.3.1 Scrambling

The block of bits $b(n)$, with the indexing starting at $n = 0$, to be transmitted on the physical uplink shared channel shall be scrambled with a UE-specific scrambling sequence prior to modulation, resulting in a block of scrambled bits $c(n)$.

6.3.2 Modulation

The block of scrambled bits $c(n)$ shall be modulated as described in Section 7, resulting in a block of complex-valued modulation symbols $d(n)$. Table 8 specifies the modulation mappings applicable for the physical uplink shared channel.

Table 8: Uplink modulation schemes

Physical channel	Modulation schemes
PUSCH	QPSK, 16QAM

6.3.3 Mapping to physical resources

Each long SC-FDMA symbol l in a slot consists of N_{TX} complex-valued symbols $a_{u,l}$ where $u = 0, \dots, N_{\text{TX}} - 1$ and $l \in \{0, 2, \dots, N_{\text{symb}}^{\text{UL}} - 3, N_{\text{symb}}^{\text{UL}} - 1\}$. The block of modulation symbols $d(n)$ shall be mapped to the complex-valued symbols $a_{u,l}$ in SC-FDMA symbol l according to

$$a_{u,l} = \begin{cases} d(l' \times N_{\text{TX}} + u) & \text{for the first slot in a subframe} \\ d(\lceil l' + N_{\text{symb}}^{\text{UL}} - 2 \rceil \times N_{\text{TX}} + u) & \text{for the second slot in a subframe} \end{cases}$$

where

$$l' = \begin{cases} l & \text{if } l = 0 \\ l - 1 & \text{if } 2 \leq l < N_{\text{symb}}^{\text{UL}} - 2 \\ l - 2 & \text{if } l = N_{\text{symb}}^{\text{UL}} - 1 \end{cases}$$

6.4 Reference signal

Two types of uplink reference signals are supported:

- demodulation reference signal, associated with transmission of uplink data and/or control signalling
- sounding reference signal, not associated with uplink data transmission

6.4.1 Demodulation reference signal

6.4.1.1 Sequence generation

6.4.1.2 Mapping to physical resources

The demodulation reference signal is mapped to short SC-FDMA symbols. The same value of k_0 as for the PUSCH transmitted in the long SC-FDMA symbols in the subframe shall be used.

6.4.2 Sounding reference signal

6.4.2.1 Sequence generation

6.4.2.2 Mapping to physical resources

The sounding reference signal is mapped to a long SC-FDMA symbol. The bandwidth and location in frequency of the sounding reference signal is provided by higher layers.

6.5 Physical Uplink Control Channel

The physical uplink control channel, PUCCH, carries uplink control information. The PUCCH is never transmitted simultaneously with the PUSCH.

6.5.1 Scrambling

The block of bits $b(n)$, with the indexing starting at $n = 0$, to be transmitted on the physical uplink control channel shall be scrambled with a UE-specific scrambling sequence prior to modulation, resulting in a block of scrambled bits $c(n)$.

6.5.2 Modulation

The block of scrambled bits $c(n)$ shall be modulated as described in Section 7, resulting in a block of complex-valued modulation symbols $d(n)$.

6.5.3 Mapping to physical resources

The PUCCH shall be transmitted on a reserved frequency region in the uplink. Mapping of modulation symbols for the physical uplink control channel is illustrated in Figure 11.

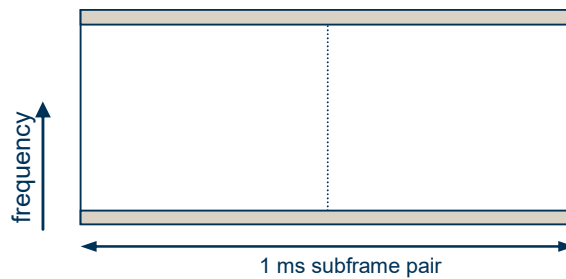


Figure 11: Physical uplink control channel

6.6 <Control channel 2>

6.7 SC-FDMA signal generation

This section does not apply to random access preamble transmission.

The SC-FDMA symbols in a slot shall be transmitted in increasing order of l . The time-continuous signal $s_l(t)$ in SC-FDMA symbol l in an uplink slot is defined by

$$s_l(t) = \sum_{k=0}^{N_{TX}-1} \sum_{u=0}^{N_{TX}-1} a_{u,l} \cdot e^{-j \frac{2\pi u k}{N_{TX}}} \cdot e^{j \frac{2\pi (k + f(k_0))}{N_d T_s} (t - N_{CP,l} T_s)}$$

for $0 \leq t < (N_{CP,l} + N_d) \times T_s$.

The frequency hopping pattern used for uplink transmission is determined by the function $f(k_0)$, where k_0 is given by the scheduling decision.

Tables 9 and 10 list the values of $N_{CP,l}$ and N_d that shall be used for the generic and alternative frame structure, respectively. Note that different blocks within a slot may have different cyclic prefix lengths.

For the alternative frame structure, note that the last part of each slot is not transmitted.

Table 9: SC-FDMA parameters for the generic frame structure

l	Normal cyclic prefix						Extended cyclic prefix	
	$N_{\text{BW}}^{\text{UL}} \leq 72$		$72 < N_{\text{BW}}^{\text{UL}} \leq 144$		$144 < N_{\text{BW}}^{\text{UL}}$		$N_{\text{CP},l}$	N_{d}
	$N_{\text{CP},l}$	N_{d}	$N_{\text{CP},l}$	N_{d}	$N_{\text{CP},l}$	N_{d}		
0	240	2048	184	2048	156	2048	432	2048
1	112	1024	120	1024	124	1024	440	1024
2		2048		2048		2048		2048
3								
4								
5								
6								
7		1024		1024		1024		
	2048	2048	2048					

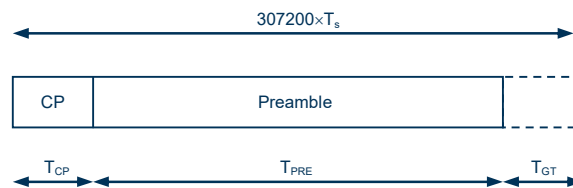
Table 10: SC-FDMA parameters for the alternative frame structure

l	Normal cyclic prefix				Extended cyclic prefix			
	$N_{\text{BW}}^{\text{UL}} \leq 300$		$300 < N_{\text{BW}}^{\text{UL}}$		$N_{\text{BW}}^{\text{UL}} \leq 300$		$300 < N_{\text{BW}}^{\text{UL}}$	
	$N_{\text{CP},l}$	N_{d}	$N_{\text{CP},l}$	N_{d}	$N_{\text{CP},l}$	N_{d}	$N_{\text{CP},l}$	N_{d}
0	320	2048	224	2048	560	2048	472	2048
1	192	1024	204	1024	423	1024	456	1024
2		2048		2048		2048		2048
3								
4								
5								
6								
7						1024		1024
8		1024		1024		2048		2048
9		2048		2048				

6.8 Physical layer random access

6.8.1 Overview

The physical layer random access preamble structure for the generic frame structure is illustrated in Figure 12. The preamble sequence occupies $T_{\text{PRE}} = 0.8 \text{ ms}$ and the cyclic prefix occupies $T_{\text{CP}} = 0.1 \text{ ms}$, resulting in a guard period of $T_{\text{GT}} = 0.1 \text{ ms}$ in case one subframe is reserved for random access. The bandwidth of the random access preamble is 1.08 MHz. Higher layer signalling controls in which subframes random access preamble transmission is allowed.

**Figure 12: Random access preamble format (generic frame structure).**

6.8.2 Sequence generation

The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, ZC-ZCZ, generated from one or several root Zadoff-Chu sequences. There are 64 different random access preambles in a cell.

The u :th root Zadoff-Chu sequence is defined by $x_u(n) = \exp(-j\pi un[n+1]/K)$. From the u :th root Zadoff-Chu sequence, $m-1$ additional random access preambles with zero correlation zone are obtained by cyclic shifts of multiples of $\lfloor K/m \rfloor$.

6.8.3 Mapping to physical resources

6.9 Modulation and upconversion

Modulation and upconversion to the carrier frequency of the complex-valued SC-FDMA signal for each layer is shown in Figure 13. The filtering required prior to transmission is defined by the requirements in [6].

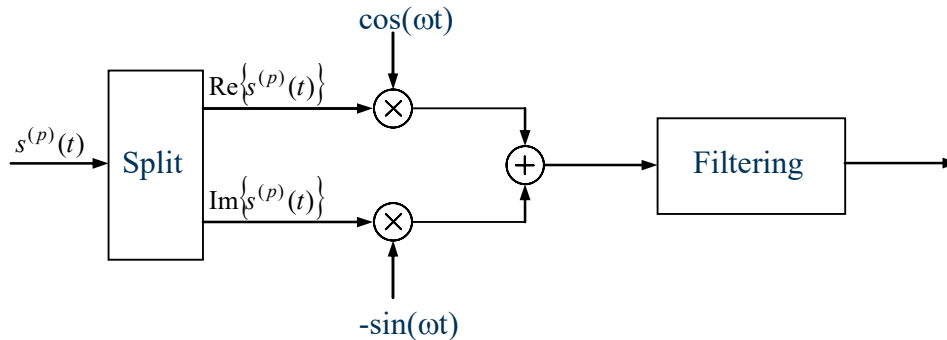


Figure 13: Uplink modulation.

7 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 QPSK

In case of QPSK modulation, pairs of bits, $b(n), b(n+1)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 11.

Table 11: QPSK modulation mapping

$b(n), b(n+1)$	I	Q
00	$1/\sqrt{2}$	$1/\sqrt{2}$
01	$1/\sqrt{2}$	$-1/\sqrt{2}$
10	$-1/\sqrt{2}$	$1/\sqrt{2}$
11	$-1/\sqrt{2}$	$-1/\sqrt{2}$

7.2 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(n), b(n+1), b(n+2), b(n+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 12.

Table 12: 16QAM modulation mapping

$b(n), b(n+1), b(n+2), b(n+3)$	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	$-3/\sqrt{10}$	$-3/\sqrt{10}$

7.3 64QAM

In case of 64QAM modulation, hexuplets of bits, $b(n), b(n+1), b(n+2), b(n+3), b(n+4), b(n+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 13.

Table 13: 64QAM modulation mapping

$b(n), b(n+1), b(n+2), b(n+3), b(n+4), b(n+5)$	I	Q	$b(n), b(n+1), b(n+2), b(n+3), b(n+4), b(n+5)$	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	$-7/\sqrt{42}$	$-7/\sqrt{42}$

8 Timing

Transmission of the uplink radio frame number i from the UE shall start $N_{TA} \times T_s$ time units before the start of the corresponding downlink radio frame at the UE. 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.

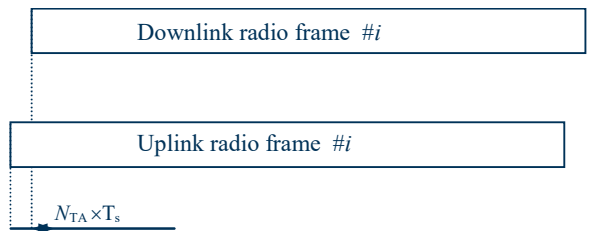


Figure 14: Uplink-downlink timing relation

Annex A (informative): Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
24/9/06	-	-	-		Draft version created	-	0.0.0
9/10/06	-	-	-		Updated skeleton	0.0.0	0.0.1
13/10/06	-	-	-		Endorsed by RAN1	0.0.1	0.1.0
23/10/06	-	-	-		Inclusion of decision from RAN1#46bis	0.1.0	0.1.1
6/11/06	-	-	-		Updated editor's version	0.1.1	0.1.2
9/11/06	-	-	-		Updated editor's version	0.1.2	0.1.3
10/11/06	-	-	-		Endorsed by RAN1#47	0.1.3	0.2.0
27/11/06	-	-	-		Editor's version, including decisions from RAN1#47	0.2.0	0.2.1