

ETSI TS 136 211 V17.3.0 (2023-04)



**LTE;
Evolved Universal Terrestrial Radio Access (E-UTRA);
Physical channels and modulation
(3GPP TS 36.211 version 17.3.0 Release 17)**

[ETSI TS 136 211 V17.3.0 \(2023-04\)](https://standards.iteh.ai/catalog/standards/sist/dde6e8c6-b99c-4258-bf99-4361dd7fbbb6/etsi-ts-136-211-v17-3-0-2023-04)

<https://standards.iteh.ai/catalog/standards/sist/dde6e8c6-b99c-4258-bf99-4361dd7fbbb6/etsi-ts-136-211-v17-3-0-2023-04>



ReferenceRTS/TSGR-0136211vh30

KeywordsLTE

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Important notice

The present document can be downloaded from:

<https://www.etsi.org/standards-search>

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the prevailing version of an ETSI deliverable is the one made publicly available in PDF format at www.etsi.org/deliver.

Users of the present document should be aware that the document may be subject to revision or change of status.

Information on the current status of this and other ETSI documents is available at

<https://portal.etsi.org/TB/ETSIDeliverableStatus.aspx>

If you find errors in the present document, please send your comment to one of the following services:

<https://standards-portal.etsi.org/People/CommitteeSupportStaff.aspx> 4258-bf99-

If you find a security vulnerability in the present document, please report it through our

Coordinated Vulnerability Disclosure Program:

<https://www.etsi.org/standards/coordinated-vulnerability-disclosure>

Notice of disclaimer & limitation of liability

The information provided in the present deliverable is directed solely to professionals who have the appropriate degree of experience to understand and interpret its content in accordance with generally accepted engineering or other professional standard and applicable regulations.

No recommendation as to products and services or vendors is made or should be implied.

No representation or warranty is made that this deliverable is technically accurate or sufficient or conforms to any law and/or governmental rule and/or regulation and further, no representation or warranty is made of merchantability or fitness for any particular purpose or against infringement of intellectual property rights.

In no event shall ETSI be held liable for loss of profits or any other incidental or consequential damages.

Any software contained in this deliverable is provided "AS IS" with no warranties, express or implied, including but not limited to, the warranties of merchantability, fitness for a particular purpose and non-infringement of intellectual property rights and ETSI shall not be held liable in any event for any damages whatsoever (including, without limitation, damages for loss of profits, business interruption, loss of information, or any other pecuniary loss) arising out of or related to the use of or inability to use the software.

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

© ETSI 2023.
All rights reserved.

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (<https://ipr.etsi.org/>).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM®** and the GSM logo are trademarks registered and owned by the GSM Association.

Legal Notice

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

The present document may refer to technical specifications or reports using their 3GPP identities. These shall be interpreted as being references to the corresponding ETSI deliverables.

The cross reference between 3GPP and ETSI identities can be found under <https://webapp.etsi.org/key/queryform.asp>.

Modal verbs terminology

In the present document **"shall"**, **"shall not"**, **"should"**, **"should not"**, **"may"**, **"need not"**, **"will"**, **"will not"**, **"can"** and **"cannot"** are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

"must" and **"must not"** are **NOT** allowed in ETSI deliverables except when used in direct citation.

Contents

Intellectual Property Rights	2
Legal Notice	2
Modal verbs terminology.....	2
Foreword.....	9
1 Scope	10
2 References	10
3 Symbols and abbreviations.....	11
3.1 Symbols.....	11
3.2 Abbreviations	15
4 Frame structure.....	15
4.1 Frame structure type 1	16
4.2 Frame structure type 2	17
4.3 Frame structure type 3	18
5 Uplink.....	20
5.1 Overview	20
5.1.1 Physical channels.....	20
5.1.2 Physical signals.....	20
5.2 Slot structure and physical resources.....	20
5.2.1 Resource grid.....	20
5.2.2 Resource elements	22
5.2.3 Resource blocks	22
5.2.4 Narrowbands and widebands	22
5.2.5 Guard period for narrowband and wideband retuning	23
5.3 Physical uplink shared channel	25
5.3.1 Scrambling	25
5.3.2 Modulation.....	26
5.3.2A Layer mapping.....	27
5.3.2A.1 Layer mapping for transmission on a single antenna port.....	27
5.3.2A.2 Layer mapping for spatial multiplexing	27
5.3.3 Transform precoding.....	28
5.3.3A Precoding	28
5.3.3A.1 Precoding for transmission on a single antenna port.....	28
5.3.3A.2 Precoding for spatial multiplexing	28
5.3.4 Mapping to physical resources.....	30
5.4 Physical uplink control channel.....	36
5.4.1 PUCCH formats 1, 1a and 1b	37
5.4.2 PUCCH formats 2, 2a and 2b	40
5.4.2A PUCCH format 3	41
5.4.2B PUCCH format 4	43
5.4.2C PUCCH format 5	43
5.4.3 Mapping to physical resources.....	44
5.4A Short Physical Uplink Control Channel	47
5.4A.1 General.....	47
5.4A.2 SPUCCH formats 1,1a,1b.....	47
5.4A.2.1 Slot-SPUCCH	47
5.4A.2.2 Subslot-SPUCCH.....	48
5.4A.3 SPUCCH format 3	49
5.4A.3.1 Slot-SPUCCH	49
5.4A.4 SPUCCH format 4	49
5.4A.4.1 Slot-SPUCCH	49
5.4A.4.2 Subslot-SPUCCH.....	50
5.4A.5 Mapping to physical resources.....	50
5.5 Reference signals.....	53

5.5.1	Generation of the reference signal sequence.....	53
5.5.1.1	Base sequences of length $3N_{sc}^{RB}$ or larger.....	54
5.5.1.2	Base sequences of length less than $3N_{sc}^{RB}$	55
5.5.1.3	Group hopping	58
5.5.1.4	Sequence hopping	59
5.5.1.5	Determining virtual cell identity for sequence generation	59
5.5.2	Demodulation reference signal	60
5.5.2.1	Demodulation reference signal for PUSCH	60
5.5.2.1.1	Reference signal sequence.....	60
5.5.2.1.2	Mapping to physical resources	64
5.5.2.1A	Demodulation reference signal for PUSCH with sub-PRB allocations.....	65
5.5.2.1A.1	Reference signal sequence using modulation schemes other than $\pi/2$ -BPSK	65
5.5.2.1A.2	Reference signal sequence using $\pi/2$ -BPSK modulation scheme.....	66
5.5.2.1A.3	Group hopping.....	67
5.5.2.1A.4	Mapping to physical resources	67
5.5.2.2	Demodulation reference signal for PUCCH.....	68
5.5.2.2.1	Reference signal sequence.....	68
5.5.2.2.2	Mapping to physical resources	70
5.5.2.3	Demodulation reference signal for SPUCCH.....	70
5.5.2.3.1	Reference signal sequence.....	70
5.5.2.3.2	Mapping to physical resources	71
5.5.3	Sounding reference signal.....	73
5.5.3.1	Sequence generation.....	73
5.5.3.1.1	Sequence generation for basic SRS	73
5.5.3.1.2	Sequence generation for additional SRS	73
5.5.3.2	Mapping to physical resources	74
5.5.3.2.1	Mapping to physical resources for basic SRS	74
5.5.3.2.2	Mapping to physical resources for additional SRS.....	76
5.5.3.3	Sounding reference signal subframe configuration	77
5.6	SC-FDMA baseband signal generation	79
5.6A	SC-FDMA baseband signal generation for PUSCH using sub-PRB allocations.....	80
5.6A.1	Modulation schemes other than $\pi/2$ -BPSK.....	80
5.6A.2	Modulation scheme $\pi/2$ -BPSK	80
5.7	Physical random access channel.....	81
5.7.1	Time and frequency structure	81
5.7.2	Preamble sequence generation	88
5.7.3	Baseband signal generation.....	92
5.8	Modulation and upconversion	94
6	Downlink.....	95
6.1	Overview	95
6.1.1	Physical channels.....	95
6.1.2	Physical signals.....	95
6.2	Slot structure and physical resource elements	96
6.2.1	Resource grid.....	96
6.2.2	Resource elements	97
6.2.3	Resource blocks	98
6.2.3.1	Virtual resource blocks of localized type	99
6.2.3.2	Virtual resource blocks of distributed type	99
6.2.4	Resource-element groups (REGs).....	100
6.2.4A	Enhanced Resource-Element Groups (EREGs).....	101
6.2.4B	Short Resource-Element Groups (SREGs)	101
6.2.5	Guard period for half-duplex FDD operation	101
6.2.6	Guard Period for TDD Operation	102
6.2.7	Narrowbands and widebands	102
6.2.8	Guard period for narrowband and wideband retuning	103
6.3	General structure for downlink physical channels.....	103
6.3.1	Scrambling.....	104
6.3.2	Modulation.....	105
6.3.3	Layer mapping.....	105
6.3.3.1	Layer mapping for transmission on a single antenna port.....	105
6.3.3.2	Layer mapping for spatial multiplexing	106

6.3.3.3	Layer mapping for transmit diversity	107
6.3.4	Precoding	107
6.3.4.1	Precoding for transmission on a single antenna port	107
6.3.4.2	Precoding for spatial multiplexing using antenna ports with cell-specific reference signals	108
6.3.4.2.1	Precoding without CDD	108
6.3.4.2.2	Precoding for large delay CDD	108
6.3.4.2.3	Codebook for precoding and CSI reporting	109
6.3.4.3	Precoding for transmit diversity	110
6.3.4.4	Precoding for spatial multiplexing using antenna ports with UE-specific reference signals	111
6.3.5	Mapping to resource elements	112
6.4	Physical downlink shared channel	113
6.4.1	Physical downlink shared channel for BL/CE UEs	115
6.4.2	Slot/subslot-based physical downlink shared channel	118
6.5	Physical multicast channel	120
6.6	Physical broadcast channel	120
6.6.1	Scrambling	120
6.6.2	Modulation	120
6.6.3	Layer mapping and precoding	121
6.6.4	Mapping to resource elements	121
6.6.4.1	PBCH repetition in the cell acquisition subframe	122
6.7	Physical control format indicator channel	123
6.7.1	Scrambling	123
6.7.2	Modulation	123
6.7.3	Layer mapping and precoding	124
6.7.4	Mapping to resource elements	124
6.8	Physical downlink control channel	124
6.8.1	PDCCH formats	124
6.8.2	PDCCH multiplexing and scrambling	124
6.8.3	Modulation	125
6.8.4	Layer mapping and precoding	125
6.8.5	Mapping to resource elements	125
6.8A	Enhanced physical downlink control channel	126
6.8A.1	EPDCCH formats	127
6.8A.2	Scrambling	128
6.8A.3	Modulation	128
6.8A.4	Layer mapping and precoding	128
6.8A.5	Mapping to resource elements	129
6.8B	MTC physical downlink control channel	130
6.8B.1	MPDCCH formats	130
6.8B.2	Scrambling	131
6.8B.3	Modulation	131
6.8B.4	Layer mapping and precoding	131
6.8B.5	Mapping to resource elements	131
6.8C	Short physical downlink control channel (SPDCCH)	135
6.8C.1	SPDCCH formats	135
6.8C.2	Scrambling	137
6.8C.3	Modulation	137
6.8C.4	Layer mapping and precoding	137
6.8C.5	Mapping to resource elements	137
6.9	Physical hybrid ARQ indicator channel	139
6.9.1	Modulation	140
6.9.2	Resource group alignment, layer mapping and precoding	140
6.9.3	Mapping to resource elements	142
6.10	Reference signals	144
6.10.1	Cell-specific Reference Signal (CRS)	144
6.10.1.1	Sequence generation	144
6.10.1.2	Mapping to resource elements	145
6.10.2	MBSFN reference signals	147
6.10.2.1	Sequence generation	147
6.10.2.1.1	Sequence generation for 15 kHz and 7.5 kHz subcarrier spacing	147
6.10.2.1.2	Sequence generation for 1.25 kHz subcarrier spacing	148
6.10.2.1.3	Sequence generation for 2.5 kHz subcarrier spacing	148

6.10.2.1.4	Sequence generation for 0.37 kHz subcarrier spacing.....	148
6.10.2.2	Mapping to resource elements.....	148
6.10.2.2.1	Mapping to resource elements for 15 kHz and 7.5 kHz subcarrier spacing	148
6.10.2.2.2	Mapping to resource elements for 1.25 kHz.....	150
6.10.2.2.3	Mapping to resource elements for 2.5 kHz subcarrier spacing.....	150
6.10.2.2.4	Mapping to resource elements for 0.37 kHz subcarrier spacing.....	151
6.10.3	UE-specific reference signals associated with PDSCH	151
6.10.3.1	Sequence generation.....	152
6.10.3.2	Mapping to resource elements.....	153
6.10.3A	Demodulation reference signals associated with EPDCCH, MPDCCH, or SPDCCH	160
6.10.3A.1	Sequence generation.....	161
6.10.3A.2	Mapping to resource elements.....	162
6.10.4	Positioning reference signals	164
6.10.4.1	Sequence generation.....	164
6.10.4.2	Mapping to resource elements.....	164
6.10.4.3	Positioning reference signal subframe configuration	167
6.10.5	CSI reference signals	167
6.10.5.1	Sequence generation.....	168
6.10.5.2	Mapping to resource elements.....	168
6.10.5.3	CSI reference signal subframe configuration.....	177
6.11	Synchronization signals.....	177
6.11.1	Primary synchronization signal (PSS)	177
6.11.1.1	Sequence generation.....	177
6.11.1.2	Mapping to resource elements.....	178
6.11.2	Secondary synchronization signal (SSS)	178
6.11.2.1	Sequence generation.....	178
6.11.2.2	Mapping to resource elements.....	180
6.11.3	Resynchronization signal (RSS)	181
6.11.3.1	Sequence generation.....	181
6.11.3.2	Mapping to resource elements.....	181
6.11A	Discovery signal	182
6.11B	MTC wake-up signal (MWUS)	183
6.11B.1	Sequence generation	183
6.11B.2	Mapping to resource elements	183
6.12	OFDM baseband signal generation	184
6.13	Modulation and upconversion	184
7	Generic functions	186
7.1	Modulation mapper	186
7.1.1	BPSK	186
7.1.2	QPSK	186
7.1.3	16QAM	186
7.1.4	64QAM	187
7.1.5	256QAM	189
7.1.6	1024QAM	190
7.2	Pseudo-random sequence generation.....	190
8	Timing	190
8.1	Uplink-downlink frame timing.....	191
9	Sidelink.....	193
9.1	Overview	193
9.1.1	Physical channels.....	193
9.1.2	Physical signals.....	193
9.1.3	Handling of simultaneous sidelink and uplink/downlink transmissions	193
9.2	Slot structure and physical resources.....	194
9.2.1	Resource grid	194
9.2.2	Resource elements	194
9.2.3	Resource blocks	195
9.2.4	Resource pool	195
9.2.5	Guard period	195
9.3	Physical Sidelink Shared Channel.....	195
9.3.1	Scrambling.....	195

9.3.2	Modulation.....	196
9.3.3	Layer mapping.....	196
9.3.4	Transform precoding.....	196
9.3.5	Precoding.....	196
9.3.6	Mapping to physical resources.....	196
9.4	Physical Sidelink Control Channel.....	197
9.4.1	Scrambling.....	197
9.4.2	Modulation.....	197
9.4.3	Layer mapping.....	197
9.4.4	Transform precoding.....	197
9.4.5	Precoding.....	197
9.4.6	Mapping to physical resources.....	197
9.5	Physical Sidelink Discovery Channel.....	198
9.5.1	Scrambling.....	198
9.5.2	Modulation.....	198
9.5.3	Layer mapping.....	198
9.5.4	Transform precoding.....	198
9.5.5	Precoding.....	198
9.5.6	Mapping to physical resources.....	198
9.6	Physical Sidelink Broadcast Channel.....	199
9.6.1	Scrambling.....	199
9.6.2	Modulation.....	199
9.6.3	Layer mapping.....	199
9.6.4	Transform precoding.....	199
9.6.5	Precoding.....	199
9.6.6	Mapping to physical resources.....	199
9.7	Sidelink Synchronization Signals.....	199
9.7.1	Primary sidelink synchronization signal.....	200
9.7.1.1	Sequence generation.....	200
9.7.1.2	Mapping to resource elements.....	200
9.7.2	Secondary sidelink synchronization signal.....	200
9.7.2.1	Sequence generation.....	200
9.7.2.2	Mapping to resource elements.....	200
9.8	Demodulation reference signals.....	200
9.9	SC-FDMA baseband signal generation.....	202
9.10	Timing.....	202
10	Narrowband IoT.....	203
10.0	General.....	203
10.0.1	Frame structure.....	203
10.0.1.1	Frame structure type 1.....	203
10.0.1.2	Frame structure type 2.....	203
10.1	Uplink.....	204
10.1.1	Overview.....	204
10.1.1.1	Physical channels.....	204
10.1.1.2	Physical signals.....	204
10.1.2	Slot structure and physical resources.....	204
10.1.2.1	Resource grid.....	204
10.1.2.2	Resource elements.....	205
10.1.2.3	Resource unit.....	205
10.1.3	Narrowband physical uplink shared channel.....	206
10.1.3.1	Scrambling.....	206
10.1.3.2	Modulation.....	206
10.1.3.3	Layer mapping.....	207
10.1.3.4	Transform precoding.....	207
10.1.3.5	Precoding.....	207
10.1.3.6	Mapping to physical resources.....	207
10.1.4	Demodulation reference signal.....	209
10.1.4.1	Reference signal sequence.....	209
10.1.4.1.1	Reference signal sequence for $N_{sc}^{RU} = 1$	209
10.1.4.1.2	Reference signal sequence for $N_{sc}^{RU} > 1$	210

10.1.4.1.3	Group hopping.....	211
10.1.4.2	Mapping to physical resources.....	212
10.1.5	SC-FDMA baseband signal generation.....	212
10.1.6	Narrowband physical random-access channel	213
10.1.6.1	Time and frequency structure.....	213
10.1.6.2	Baseband signal generation.....	216
10.1.7	Modulation and upconversion.....	217
10.2	Downlink.....	217
10.2.1	Overview	217
10.2.1.1	Physical channels	217
10.2.1.2	Physical signals	217
10.2.2	Slot structure and physical resource elements	217
10.2.2.1	Resource grid	217
10.2.2.2	Resource elements.....	218
10.2.2.3	Guard period for half-duplex FDD operation.....	218
10.2.2.4	Guard period for TDD operation.....	218
10.2.3	Narrowband physical downlink shared channel	218
10.2.3.1	Scrambling	218
10.2.3.2	Modulation.....	218
10.2.3.3	Layer mapping and precoding.....	218
10.2.3.4	Mapping to resource elements.....	219
10.2.4	Narrowband physical broadcast channel.....	220
10.2.4.1	Scrambling	220
10.2.4.2	Modulation.....	221
10.2.4.3	Layer mapping and precoding.....	221
10.2.4.4	Mapping to resource elements.....	221
10.2.5	Narrowband physical downlink control channel.....	221
10.2.5.1	NPDCCH formats	221
10.2.5.2	Scrambling	222
10.2.5.3	Modulation.....	222
10.2.5.4	Layer mapping and precoding.....	222
10.2.5.5	Mapping to resource elements.....	222
10.2.6	Narrowband reference signal (NRS).....	223
10.2.6.1	Sequence generation.....	226
10.2.6.2	Mapping to resource elements.....	226
10.2.6A	Narrowband positioning reference signal (NPRS).....	228
10.2.6A.1	Sequence generation.....	228
10.2.6A.2	Mapping to resource elements.....	229
10.2.6A.3	NPRS subframe configuration	230
10.2.6B	Narrowband wake up signal (NWUS).....	231
10.2.6B.1	Sequence generation.....	231
10.2.6B.2	Mapping to resource elements.....	231
10.2.7	Synchronization signals	232
10.2.7.1	Narrowband primary synchronization signal (NPSS)	232
10.2.7.1.1	Sequence generation	232
10.2.7.1.2	Mapping to resource elements	232
10.2.7.2	Narrowband secondary synchronization signal (NSSS).....	233
10.2.7.2.1	Sequence generation.....	233
10.2.7.2.2	Mapping to resource elements	233
10.2.8	OFDM baseband signal generation.....	234
10.2.9	Modulation and upconversion.....	235
Annex A (informative):	Change history	236
History		247

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.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ETSI TS 136 211 V17.3.0 (2023-04)

<https://standards.iteh.ai/catalog/standards/sist/dde6e8c6-b99c-4258-bf99-4361dd7fbbb6/etsi-ts-136-211-v17-3-0-2023-04>

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] TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description".
- [3] TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".
- [4] TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".
- [5] TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements".
- [6] TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".
- [7] TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".
- [8] TS 36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".
- [9] TS 36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) Protocol specification"
- [10] TS 36.304, "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode"
- [11] TS 37.213: "Physical layer procedures for shared spectrum channel access"
- [12] TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2"

3 Symbols and abbreviations

3.1 Symbols

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

(k, l)	Resource element with frequency-domain index k and time-domain index l
$a_{k,l}^{(p)}$	Value of resource element (k, l) [for antenna port p]
D	Matrix for supporting cyclic delay diversity
D_{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
$f_{\text{PRB,hop}}^{\text{PRACH}}$	PRACH frequency hopping offset, expressed as a number of resource blocks
$l_{\text{NPDCCHstart}}$	Start symbol in slot 0 for NPDCCH
$l_{\text{NPDSCHstart}}$	Start symbol in slot 0 for NPDSCH
$M_{\text{sc}}^{\text{PSBCH}}$	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
$M_{\text{rep}}^{\text{NPUSCH}}$	Scheduled number of repetitions of a NPUSCH transmission
$M_{\text{rep}}^{\text{NPDSCH}}$	Scheduled number of repetitions of a NPDSCH transmission
$M_{\text{sc}}^{\text{NPUSCH}}$	Scheduled bandwidth for uplink NPUSCH transmission, expressed as a number of subcarriers
$M_{\text{identical}}^{\text{NPUSCH}}$	Number of repetitions of identical slots for NPUSCH
$M_{\text{bit}}^{(q)}$	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
$M_{\text{sc}}^{\text{RU}}$	Number of consecutive subcarriers in an UL resource unit for PUSCH sub-PRB allocation
$M_{\text{slots}}^{\text{UL}}$	Number of slots in an UL resource unit for PUSCH sub-PRB allocation
$M_{\text{symb}}^{\text{UL}}$	Number of SC-FDMA symbols in an uplink slot for PUSCH sub-PRB allocation
$M_{\text{seq}}^{\text{RU}}$	Number of subcarriers in the frequency domain for PUSCH sub-PRB allocation
M_{RU}	Number of reference signal sequences available for the UL resource unit size for PUSCH sub-PRB allocation
N	Number of scheduled UL resource units for PUSCH sub-PRB allocation
$N_{\text{CP},l}$	A constant equal to 2048 for $\Delta f = 15$ kHz, 4096 for $\Delta f = 7.5$ kHz and 8192 for $\Delta f = 3.75$ kHz
N_{CS}	Downlink cyclic prefix length for OFDM symbol l in a slot
	Cyclic shift value used for random access preamble generation

$N_{cs}^{(1)}$	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
$N_{RB}^{(2)}$	Bandwidth available for use by PUCCH formats 2/2a/2b, expressed in multiples of N_{sc}^{RB}
N_{RB}^{HO}	The offset used for PUSCH frequency hopping, expressed in number of resource blocks (set by higher layers)
N_{ID}^{cell}	Physical layer cell identity
N_{ID}^{Ncell}	Narrowband physical layer cell identity
N_{ID}^{MBSFN}	MBSFN area identity
N_{ID}^{SL}	Physical layer sidelink synchronization identity
N_{ID}^{PRS}	Positioning reference signal identity
N_{RB}^{DL}	Downlink bandwidth configuration, expressed in multiples of N_{sc}^{RB}
$N_{RB}^{min,DL}$	Smallest downlink bandwidth configuration, expressed in multiples of N_{sc}^{RB}
$N_{RB}^{max,DL}$	Largest downlink bandwidth configuration, expressed in multiples of N_{sc}^{RB}
N_{RB}^{UL}	Uplink bandwidth configuration, expressed in multiples of N_{sc}^{RB}
$N_{RB}^{min,UL}$	Smallest uplink bandwidth configuration, expressed in multiples of N_{sc}^{RB}
$N_{RB}^{max,UL}$	Largest uplink bandwidth configuration, expressed in multiples of N_{sc}^{RB}
N_{RB}^{SL}	Sidelink bandwidth configuration, expressed in multiples of N_{sc}^{RB}
N_{RSS}	Duration of RSS measured in subframes
N_{SF}	Number of scheduled subframes for NPDSCH transmission
N_{symb}^{NPSS}	Number of symbols for NPSS in a subframe
N_{symb}^{NSSS}	Number of symbols for NSSS in a subframe
N_{sc}^{RU}	Number of consecutive subcarriers in an UL resource unit for NB-IoT
N_{seq}^{RU}	Number of reference signal sequences available for the UL resource unit size
N_{RU}	Number of scheduled UL resource units for NB-IoT
N_{NB}^{UL}	Total number of uplink narrowbands
N_{WB}^{UL}	Total number of uplink widebands
N_{sc}^{UL}	Number of subcarriers in the frequency domain for NB-IoT
N_{acc}	Number of consecutive absolute subframes over which the scrambling sequence stays the same
N_{abs}^{PUSCH}	Total number of absolute subframes a PUSCH with repetition spans expressed as a number of absolute subframes
N_{rep}^{PUSCH}	Number of repetitions of a PUSCH transmission
$N_{NB}^{ch,UL}$	Number of consecutive absolute subframes over which PUCCH or PUSCH stays at the same narrowband before hopping to another narrowband, expressed as a number of absolute subframes
$f_{NB,hop}^{PUSCH}$	Narrowband offset between one narrowband and the next narrowband a PUSCH hops to, expressed as a number of uplink narrowbands
N_{abs}^{PUCCH}	Total number of absolute subframes a PUCCH with repetition spans, expressed as a number of absolute subframes
N_{rep}^{PUCCH}	Number of repetitions of a PUCCH transmission
N_{rep}^{PRACH}	Number of PRACH repetitions per preamble transmission attempt
N_{sf}^{RA}	Number of subframes allowed for preamble transmission within a 1024-frame interval
N_{start}^{PRACH}	PRACH starting subframe periodicity
N_{rep}^{NPRACH}	Number of NPRACH repetitions per preamble transmission attempt

$N_{\text{period}}^{\text{NPRACH}}$	NPRACH resource periodicity
$N_{\text{scoffset}}^{\text{NPRACH}}$	Frequency location of the first sub-carrier allocated to NPRACH
$N_{\text{sc}}^{\text{NPRACH}}$	Number of sub-carriers allocated to NPRACH
$N_{\text{sc_cont}}^{\text{NPRACH}}$	Number of starting sub-carriers allocated for UE initiated random access
$N_{\text{start}}^{\text{NPRACH}}$	NPRACH starting subframe
$N_{\text{MSG3}}^{\text{NPRACH}}$	Fraction for starting subcarrier index for UE support for multi-tone msg3 transmission
$N_{\text{gap,period}}$	Periodicity for NPDSCH/NPDCCH gaps
$N_{\text{gap,duration}}$	Duration for NPDSCH/NPDCCH gaps
$N_{\text{gap,threshold}}$	Threshold for applying NPDSCH/NPDCCH gaps
$N_{\text{NB}}^{\text{DL}}$	Total number of downlink narrowbands
$N_{\text{WB}}^{\text{DL}}$	Total number of downlink widebands
$N_{\text{abs}}^{\text{PDSCH}}$	Total number of absolute subframes a PDSCH with repetition spans, expressed as a number of absolute subframes
$N_{\text{rep}}^{\text{PDSCH}}$	Number of repetitions of a PDSCH transmission
$N_{\text{NB}}^{\text{ch,DL}}$	Number of consecutive absolute subframes over which MPDCCH or PDSCH stays at the same narrowband before hopping to another narrowband, expressed as a number of absolute subframes
$N_{\text{hop}}^{\text{ch,DL}}$	Number of narrowbands over which MPDCCH or PDSCH frequency hops
$f_{\text{hop}}^{\text{DL}}$	Narrowband offset between one narrowband and the next narrowband an MPDCCH or PDSCH hops to, expressed as a number of downlink narrowbands
$N_{\text{PDSCH}}^{\text{SIB1-BR}}$	Number of times a PDSCH carrying SIB1-BR is transmitted over 8 radio frames
$N_{\text{abs}}^{\text{MPDCCH}}$	Total number of absolute subframes a MPDCCH with repetition spans, expressed as a number of absolute subframes
$N_{\text{rep}}^{\text{MPDCCH}}$	Number of repetitions of a MPDCCH transmission
$N_{\text{abs,ss}}^{\text{MPDCCH}}$	Total number of absolute subframes a MPDCCH search space with maximum repetition level spans, expressed as a number of absolute subframes
$N_{\text{rep,ss}}^{\text{MPDCCH}}$	Maximum repetition level of a MPDCCH search space
$N_{\text{ECCE}}^{\text{MPDCCH}}$	Number of ECCEs in a subframe for one MPDCCH
$N_{\text{symb}}^{\text{DL}}$	Number of OFDM symbols in a downlink slot
$N_{\text{symb}}^{\text{UL}}$	Number of SC-FDMA symbols in an uplink slot
$N_{\text{symb}}^{\text{retune}}$	Number of symbols in a guard period for narrowband or wideband retuning
$N_{\text{slots}}^{\text{UL}}$	Number of consecutive slots in an UL resource unit for NB-IoT
$N_{\text{symb}}^{\text{SL}}$	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
$N_{\text{RB}}^{\text{sb}}$	Size of each sub-band for PUSCH frequency-hopping with predefined hopping pattern, expressed as a number of resource blocks
$N_{\text{sc}}^{\text{RA}}$	Size of narrow-band random-access resource in number of subcarriers
N_{SP}	Number of downlink to uplink switch points within the radio frame
$N_{\text{RS}}^{\text{PUCCH}}$	Number of reference symbols per slot for PUCCH
$N_{\text{RS}}^{\text{SPUCCH}}$	Number of reference symbols per subslot or per slot for SPUCCH
N_{TA}	Timing offset between uplink and downlink radio frames at the UE, expressed in units of T_s
$N_{\text{TA offset}}$	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 format 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
$n_{PRBoffset}^{RA}$	First physical resource block available for PRACH
$n_{PRB,RSS}$	Lowest PRB number of RSS
n_{sc}^{RA}	Subcarrier occupied by NPRACH resource considered
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
n_{sf}^{abs}	Absolute subframe number
n_{sf}^{RA}	Index for subframes allowed for preamble transmission
O_{RSS}	Starting frame offset of RSS in each RSS period
P	Number of antenna ports used for transmission of a channel
p	Antenna port number
P_{RSS}	Period of RSS measured in frames
q	Codeword number
r_{RA}	Index for PRACH versions with same preamble format and PRACH density
Q_m	Modulation order: 1 for $\pi/2$ -BPSK, 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 SC-FDMA/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_{NPRACH}	Amplitude scaling for NPRACH
β_{PUCCH}	Amplitude scaling for PUCCH
β_{PUSCH}	Amplitude scaling for PUSCH
β_{NPUSCH}	Amplitude scaling for NPUSCH
β_{SPUCCH}	Amplitude scaling for SPUCCH
β_{SRS}	Amplitude scaling for sounding reference symbols
Δf	Subcarrier spacing
Δf_{RA}	Subcarrier spacing for the random access preamble
v	Number of transmission layers