ETSI TS 138 211 V16.10.0 (2022-07)

5G;
NR;
Physical channels and modulation
(3GPP TS 38.211 version 16.10.0 Release 16)

Reference
RTS/TSGR-0138211vga0

Keywords
5G

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

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 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 http://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

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 and signals for 5G-NR.

2 References

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

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

[2] 3GPP TS 38.201: "NR; Physical Layer – General Description"

[3] 3GPP TS 38.202: "NR; Services provided by the physical layer"

[4] 3GPP TS 38.212: "NR; Multiplexing and channel coding"

[5] 3GPP TS 38.213: "NR; Physical layer procedures for control "

[6] 3GPP TS 38.214: "NR; Physical layer procedures for data "

[7] 3GPP TS 38.215: "NR; Physical layer measurements"

[8] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception"

[9] void

[10] 3GPP TS 38.306: "NR; User Equipment (UE) radio access capabilities"

[11] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

[12] 3GPP TS 38.133: "NR; Requirements for support of radio resource management"

[13] 3GPP TS 38.304: "NR; User Equipment (UE) procedures in Idle mode and RRC Inactive state"

3 Definitions, symbols and abbreviations

3.1 Definitions

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

3.2 Symbols

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

$(k,l)_{p,\mu}$ Resource element with frequency-domain index k and time-domain index l for antenna port p and subcarrier spacing configuration μ; see clause 4.4.3

$a_{k,l}^{(p,\mu)}$ Value of resource element (k,l) for antenna port p and subcarrier spacing configuration μ; see clause 4.4.3

β Amplitude scaling for a physical channel/signal

$c(n)$ PN sequence; see clause 5.2.1

Δf Subcarrier spacing

Δf_{RA} Subcarrier spacing for random-access preambles

κ The ratio between T_s and T_c ; see clause 4.1

k	Subcarrier index relative to a reference
l	OFDM symbol index relative to a reference
μ	Subcarrier spacing configuration, $\Delta f = 2^{\mu} \cdot 15\ [kHz]$
$M_{\text{bit}}^{(q)}$	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
$M_{\text{sc}}^{\text{PUSCH}}$	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
$M_{\text{symb}}^{\text{ap}}$	Number of modulation symbols to transmit per antenna port for a physical channel
υ	Number of transmission layers
$N_{\text{BWP},i}^{\text{size}}$	Size of bandwidth part i; see clause 4.4.4.4
$N_{\text{BWP},i}^{\text{start}}$	Start of bandwidth part i; see clause 4.4.4.4
$N_{\text{CP},l}^{\mu}$	Cyclic prefix length; see clause 5.3.1
$N_{\text{grid},x}^{\text{size},\mu}$	The size of the resource grid; see clauses 4.4.2 and 5.3
$N_{\text{grid},x}^{\text{start},\mu}$	The start of the resource grid; see clause 4.4.2
$N_{\text{group}}^{\text{PT-RS}}$	The number of PT-RS groups; see clause 6.3.1.4
$N_{\text{ID}}^{\text{cell}}$	Physical layer cell identity; see clause 7.4.2.1
$N_{\text{ID}}^{\text{SL}}$	Physical-layer sidelink identity; see clause 8.4.2.1
$N_{\text{RB}}^{\text{CORESET}}$	Frequency-domain size of a control resource set; see clause 7.3.2.2
$N_{\text{REG}}^{\text{CORESET}}$	Number of resource-element groups in a CORESET; see clause 7.3.2.2
$N_{\text{samp}}^{\text{group}}$	Number of samples per PT-RS group; see clause 6.3.1.4
$N_{\text{sc}}^{\text{RB}}$	Number of subcarriers per resource block, see clause 4.4.4.1
$N_{\text{slot}}^{\text{subframe},\mu}$	Number of slots per subframe for subcarrier spacing configuration μ, see clause 4.3.2
$N_{\text{slot}}^{\text{frame},\mu}$	Number of slots per frame for subcarrier spacing configuration μ, see clause 4.3.2
$N_{\text{symb}}^{\text{CORESET}}$	Time duration of a control resource set; see clause 7.3.2.2
$N_{\text{symb}}^{\text{PUCCH}}$	Length of the PUCCH transmission in OFDM symbols; see clause 6.3.2.1
$N_{\text{symb}}^{\text{subframe},\mu}$	Number of OFDM symbols per subframe for subcarrier spacing configuration μ; see clause 4.3.1
$N_{\text{symb}}^{\text{slot}}$	Number of symbols per slot
N_{TA}	Timing advance between downlink and uplink; see clause 4.3.1
$N_{\text{TA,offset}}$	A fixed offset used to calculate the timing advance; see clause 4.3.1
$N_{\text{Rx-Tx}}$	Minimum time from reception to transmission for a half-duplex UE; see clause 4.3.2
n_{f}	System frame number (SFN)
n_{CRB}^{μ}	Common resource block number for subcarrier spacing configuration μ, see clause 4.4.4.3
n_{PRB}	Physical resource block number; see clause 4.4.4.4
n_{RNTI}	Radio network temporary identifier
n_{s}^{μ}	Slot number within a subframe for subcarrier spacing configuration μ; see clause 4.3.2
$n_{\text{s,f}}^{\mu}$	Slot number within a frame for subcarrier spacing configuration μ; see clause 4.3.2
p	Antenna port number
Q_m	Modulation order
ρ	Number of antenna ports
$\bar{r}_{u,v}(n)$	Low-PAPR base sequence; see clause 5.2.2
$r_{u,v}^{(\alpha,\delta)}(n)$	Low-PAPR sequence; see clause 5.2.2
$s_l^{(p,\mu)}(t)$	The time-continuous signal on antenna port p and subcarrier spacing configuration μ for OFDM symbol l in a subframe; see clause 5.3.1
T_{c}	Basic time unit for NR; see clause 4.1
T_{f}	Radio frame duration; see clause 4.3.1
T_{s}	Basic time unit for LTE
T_{sf}	Subframe duration; see clause 4.3.1
T_{slot}	Slot duration; see clause 4.3.2
T_{TA}	Timing advance between downlink and uplink; see clause 4.3.1
W	Precoding matrix for spatial multiplexing

3.3 Abbreviations

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

BWP	Bandwidth part
CCE	Control channel element
CORESET	Control resource set
CRB	Common resource block
CSI	Channel-state information
CSI-RS	CSI reference signal
DCI	Downlink Control Information
DM-RS	Demodulation reference signal
FR1	Frequency range 1 as defined in [8, TS 38.104]
FR2	Frequency range 2 as defined in [8, TS 38.104]
IAB	Integrated access and backhaul
IAB-MT	IAB mobile termination
IE	Information element
PBCH	Physical broadcast channel
PDCCH	Physical downlink control channel
PDSCH	Physical downlink shared channel
PRACH	Physical random-access channel
PRB	Physical resource block
PSS	Primary synchronization signal
PT-RS	Phase-tracking reference signal
PUCCH	Physical uplink control channel
PUSCH	Physical uplink shared channel
REG	Resource-element group
RIM	Remote interference management
RIM-RS	Remote interference management reference signal
SRS	Sounding reference signal
SSS	Secondary synchronization signal
VRB	Virtual resource block

4 Frame structure and physical resources

4.1 General

Throughout this specification, unless otherwise noted, the size of various fields in the time domain is expressed in time units $T_c = 1/(\Delta f_{max} \cdot N_f)$ where $\Delta f_{max} = 480 \cdot 10^3$ Hz and $N_f = 4096$. The constant $\kappa = T_s/T_c = 64$ where $T_s = 1/(\Delta f_{ref} \cdot N_{f,ref})$, $\Delta f_{ref} = 15 \cdot 10^3$ Hz and $N_{f,ref} = 2048$.

Throughout this specification, unless otherwise noted, statements using the term "UE" in clauses 4, 5, 6, or 7 are equally applicable to the IAB-MT part of an IAB-node.

4.2 Numerologies

Multiple OFDM numerologies are supported as given by Table 4.2-1 where μ and the cyclic prefix for a downlink or uplink bandwidth part are obtained from the higher-layer parameters *subcarrierSpacing* and *cyclicPrefix*, respectively.

Table 4.2-1: Supported transmission numerologies.

μ	$\Delta f = 2^{\mu} \cdot 15$[kHz]	Cyclic prefix
0	15	Normal
1	30	Normal
2	60	Normal, Extended
3	120	Normal
4	240	Normal

4.3 Frame structure

4.3.1 Frames and subframes

Downlink, uplink, and sidelink transmissions are organized into frames with $T_{\mathrm{f}} = (\Delta f_{\max} N_{\mathrm{f}} / 100) \cdot T_{\mathrm{c}} = 10\,\mathrm{ms}$ duration, each consisting of ten subframes of $T_{\mathrm{sf}} = (\Delta f_{\max} N_{\mathrm{f}} / 1000) \cdot T_{\mathrm{c}} = 1\,\mathrm{ms}$ duration. The number of consecutive OFDM symbols per subframe is $N_{\mathrm{symb}}^{\mathrm{subframe},\mu} = N_{\mathrm{symb}}^{\mathrm{slot}} N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$. Each frame is divided into two equally-sized half-frames of five subframes each with half-frame 0 consisting of subframes 0 – 4 and half-frame 1 consisting of subframes 5 – 9.

There is one set of frames in the uplink and one set of frames in the downlink on a carrier.

Uplink frame number i for transmission from the UE shall start $T_{\mathrm{TA}} = (N_{\mathrm{TA}} + N_{\mathrm{TA,offset}}) T_{\mathrm{c}}$ before the start of the corresponding downlink frame at the UE where $N_{\mathrm{TA,offset}}$ is given by [5, TS 38.213], except for msgA transmission on PUSCH where $N_{\mathrm{TA}} = 0$ shall be used.

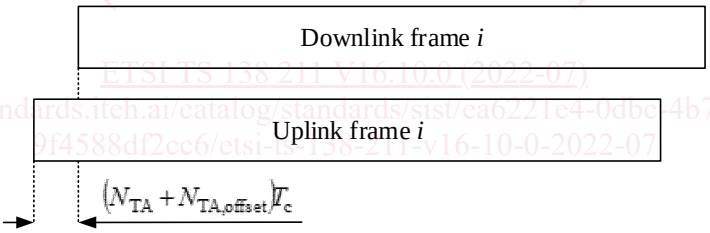

Figure 4.3.1-1: Uplink-downlink timing relation.

4.3.2 Slots

For subcarrier spacing configuration μ, slots are numbered $n_{\mathrm{s}}^{\mu} \in \{0, \ldots, N_{\mathrm{slot}}^{\mathrm{subframe},\mu} - 1\}$ in increasing order within a subframe and $n_{\mathrm{s,f}}^{\mu} \in \{0, \ldots, N_{\mathrm{slot}}^{\mathrm{frame},\mu} - 1\}$ in increasing order within a frame. There are $N_{\mathrm{symb}}^{\mathrm{slot}}$ consecutive OFDM symbols in a slot where $N_{\mathrm{symb}}^{\mathrm{slot}}$ depends on the cyclic prefix as given by Tables 4.3.2-1 and 4.3.2-2. The start of slot n_{s}^{μ} in a subframe is aligned in time with the start of OFDM symbol $n_{\mathrm{s}}^{\mu} N_{\mathrm{symb}}^{\mathrm{slot}}$ in the same subframe.

OFDM symbols in a slot in a downlink or uplink frame can be classified as 'downlink', 'flexible', or 'uplink'. Signaling of slot formats is described in clause 11.1 of [5, TS 38.213].

In a slot in a downlink frame, the UE shall assume that downlink transmissions only occur in 'downlink' or 'flexible' symbols.

In a slot in an uplink frame, the UE shall only transmit in 'uplink' or 'flexible' symbols.

A UE not capable of full-duplex communication and not supporting simultaneous transmission and reception as defined by parameter *simultaneousRxTxInterBandENDC, simultaneousRxTxInterBandCA or simultaneousRxTxSUL* [10, TS 38.306] among all cells within a group of cells is not expected to transmit in the uplink in one cell within the group of

cells earlier than $N_{\text{Rx-Tx}}T_c$ after the end of the last received downlink symbol in the same or different cell within the group of cells where $N_{\text{Rx-Tx}}$ is given by Table 4.3.2-3.

A UE not capable of full-duplex communication and not supporting simultaneous transmission and reception as defined by parameter *simultaneousRxTxInterBandENDC*, *simultaneousRxTxInterBandCA or simultaneousRxTxSUL* [10, TS 38.306] among all cells within a group of cells is not expected to receive in the downlink in one cell within the group of cells earlier than $N_{\text{Tx-Rx}}T_c$ after the end of the last transmitted uplink symbol in the same or different cell within the group of cells where $N_{\text{Tx-Rx}}$ is given by Table 4.3.2-3.

For DAPS handover operation, a UE not capable of full-duplex communication is not expected to transmit in the uplink to a cell earlier than $N_{\text{Rx-Tx}}T_c$ after the end of the last received downlink symbol in the different cell where $N_{\text{Rx-Tx}}$ is given by Table 4.3.2-3.

For DAPS handover operation, a UE not capable of full-duplex communication is not expected to receive in the downlink from a cell earlier than $N_{\text{Tx-Rx}}T_c$ after the end of the last transmitted uplink symbol in the different cell where $N_{\text{Tx-Rx}}$ is given by Table 4.3.2-3.

A UE not capable of full-duplex communication is not expected to transmit in the uplink earlier than $N_{\text{Rx-Tx}}T_c$ after the end of the last received downlink symbol in the same cell where $N_{\text{Rx-Tx}}$ is given by Table 4.3.2-3.

A UE not capable of full-duplex communication is not expected to receive in the downlink earlier than $N_{\text{Tx-Rx}}T_c$ after the end of the last transmitted uplink symbol in the same cell where $N_{\text{Tx-Rx}}$ is given by Table 4.3.2-3.

Table 4.3.2-1: Number of OFDM symbols per slot, slots per frame, and slots per subframe for normal cyclic prefix.

μ	$N_{\text{symb}}^{\text{slot}}$	$N_{\text{slot}}^{\text{frame},\mu}$	$N_{\text{slot}}^{\text{subframe},\mu}$
0	14	10	1
1	14	20	2
2	14	40	4
3	14	80	8
4	14	160	16

Table 4.3.2-2: Number of OFDM symbols per slot, slots per frame, and slots per subframe for extended cyclic prefix.

μ	$N_{\text{symb}}^{\text{slot}}$	$N_{\text{slot}}^{\text{frame},\mu}$	$N_{\text{slot}}^{\text{subframe},\mu}$
2	12	40	4

Table 4.3.2-3: Transition time $N_{\text{Rx-Tx}}$ and $N_{\text{Tx-Rx}}$

Transition time	FR1	FR2
$N_{\text{Tx-Rx}}$	25600	13792
$N_{\text{Rx-Tx}}$	25600	13792

4.4 Physical resources

4.4.1 Antenna ports

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.

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, average delay, and spatial Rx parameters.

4.4.2 Resource grid

For each numerology and carrier, a resource grid of $N_{\text{grid},x}^{\text{size},\mu} N_{\text{sc}}^{\text{RB}}$ subcarriers and $N_{\text{symb}}^{\text{subframe},\mu}$ OFDM symbols is defined, starting at common resource block $N_{\text{grid}}^{\text{start},\mu}$ indicated by higher-layer signalling. There is one set of resource grids per transmission direction (uplink, downlink, or sidelink) with the subscript x set to DL, UL, and SL for downlink, uplink, and sidelink, respectively. When there is no risk for confusion, the subscript x may be dropped. There is one resource grid for a given antenna port p, subcarrier spacing configuration μ, and transmission direction (downlink, uplink, or sidelink).

For uplink and downlink, the carrier bandwidth $N_{\text{grid}}^{\text{size},\mu}$ for subcarrier spacing configuration μ is given by the higher-layer parameter *carrierBandwidth* in the *SCS-SpecificCarrier* IE. The starting position $N_{\text{grid}}^{\text{start},\mu}$ for subcarrier spacing configuration μ is given by the higher-layer parameter *offsetToCarrier* in the *SCS-SpecificCarrier* IE.

The frequency location of a subcarrier refers to the center frequency of that subcarrier.

For the downlink, the higher-layer parameter *txDirectCurrentLocation* in the *SCS-SpecificCarrier* IE indicates the location of the transmitter DC subcarrier in the downlink for each of the numerologies configured in the downlink. Values in the range 0 – 3299 represent the number of the DC subcarrier and the value 3300 indicates that the DC subcarrier is located outside the resource grid.

For the uplink, the higher-layer parameter *txDirectCurrentLocation* in the *UplinkTxDirectCurrentBWP* IE indicates the location of the transmitter DC subcarrier in the uplink for each of the configured bandwidth parts, including whether the DC subcarrier location is offset by 7.5 kHz relative to the center of the indicated subcarrier or not. Values in the range 0 – 3299 represent the number of the DC subcarrier, the value 3300 indicates that the DC subcarrier is located outside the resource grid, and the value 3301 indicates that the position of the DC subcarrier in the uplink is undetermined.

4.4.3 Resource elements

Each element in the resource grid for antenna port p and subcarrier spacing configuration μ is called a resource element and is uniquely identified by $(k, l)_{p,\mu}$ where k is the index in the frequency domain and l refers to the symbol position in the time domain relative to some reference point. Resource element $(k, l)_{p,\mu}$ corresponds to a physical resource and the complex value $a_{k,l}^{(p,\mu)}$. When there is no risk for confusion, or no particular antenna port or subcarrier spacing is specified, the indices p and μ may be dropped, resulting in $a_{k,l}^{(p)}$ or $a_{k,l}$.

4.4.4 Resource blocks

4.4.4.1 General

A resource block is defined as $N_{\text{sc}}^{\text{RB}} = 12$ consecutive subcarriers in the frequency domain.

4.4.4.2 Point A

Point A serves as a common reference point for resource block grids and is obtained from:

- *offsetToPointA* for a PCell downlink where *offsetToPointA* represents the frequency offset between point A and the lowest subcarrier of the lowest resource block, which overlaps with the SS/PBCH block used by the UE for initial cell selection, expressed in units of resource blocks assuming 15 kHz subcarrier spacing for FR1 and 60 kHz subcarrier spacing for FR2;
  - for operation without shared spectrum channel access, the lowest resource block has the subcarrier spacing provided by the higher layer parameter *subCarrierSpacingCommon*;
  - for operation with shared spectrum channel access, the lowest resource block has the subcarrier spacing same as the SS/PBCH block used by the UE for initial cell selection;
- *absoluteFrequencyPointA* for all other cases where *absoluteFrequencyPointA* represents the frequency-location of point A expressed as in ARFCN.