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NR;
Physical channels and modulation
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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"

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, $\Delta f = 2^\mu \cdot 15 \text{ [kHz]}$

$M_{\text{bit}}^{(q)}$	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
ν	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
$N_{\text{TA},\text{offset}}$	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 $T_s = 1/(\Delta f_{\text{ref}} \cdot N_{f,\text{ref}})$, $\Delta f_{\text{ref}} = 15 \cdot 10^3$ Hz and $N_{f,\text{ref}} = 2048$.

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 parameter *subcarrierSpacing* and *cyclicPrefix*, respectively.

Table 4.2-1: Supported transmission numerologies.

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

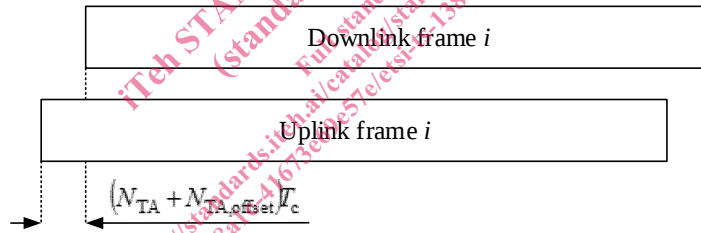
4.3 Frame structure

4.3.1 Frames and subframes

Downlink, uplink, and sidelink transmissions are organized into frames with $T_f = (\Delta f_{\max} N_f / 100) \cdot T_c = 10 \text{ ms}$ duration, each consisting of ten subframes of $T_{sf} = (\Delta f_{\max} N_f / 1000) \cdot T_c = 1 \text{ ms}$ duration. The number of consecutive OFDM symbols per subframe is $N_{\text{subframe},\mu}^{\text{subframe}} = N_{\text{slot}}^{\text{slot}} N_{\text{subframe},\mu}^{\text{subframe}}$. 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 $T_{TA} = (N_{TA} + N_{TA,\text{offset}}) T_c$ before the start of the corresponding downlink frame at the UE where $N_{TA,\text{offset}}$ is given by [5, TS 38.213], except for msgA transmission on PUSCH where $N_{TA} = 0$ shall be used.

**Figure 4.3.1-1: Uplink-downlink timing relation.**

4.3.2 Slots

For subcarrier spacing configuration μ , slots are numbered $n_s^\mu \in \{0, \dots, N_{\text{slot}}^{\text{subframe},\mu} - 1\}$ in increasing order within a subframe and $n_{s,f}^\mu \in \{0, \dots, N_{\text{slot}}^{\text{frame},\mu} - 1\}$ in increasing order within a frame. There are $N_{\text{slot}}^{\text{slot}}$ consecutive OFDM symbols in a slot where $N_{\text{slot}}^{\text{slot}}$ 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 $n_s^\mu N_{\text{slot}}^{\text{slot}}$ 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