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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
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Contents

Foreword

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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"

[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"

[14] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"

[15] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"

[16] 3GPP TS 38.101-5: "NR; User Equipment (UE) radio transmission and reception; Part 5: Satellite access Radio Frequency (RF) and performance requirements"

[17] 3GPP TS 38.108: "Satellite Access Node radio transmission and reception"

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, $\Delta f = 2^{\mu} \cdot 15\ [kHz]$
$M_{\mathrm{bit}}^{(q)}$	Number of coded bits to transmit on a physical channel [for codeword q]
$M_{\mathrm{symb}}^{(q)}$	Number of modulation symbols to transmit on a physical channel [for codeword q]
$M_{\mathrm{symb}}^{\mathrm{layer}}$	Number of modulation symbols to transmit per layer for a physical channel
$M_{\mathrm{sc}}^{\mathrm{PUSCH}}$	Scheduled bandwidth for uplink transmission, expressed as a number of subcarriers
$M_{\mathrm{RB}}^{\mathrm{PUSCH}}$	Scheduled bandwidth for uplink transmission, expressed as a number of resource blocks
$M_{\mathrm{symb}}^{\mathrm{ap}}$	Number of modulation symbols to transmit per antenna port for a physical channel
υ	Number of transmission layers
$N_{\mathrm{BWP},i}^{\mathrm{size}}$	Size of bandwidth part i; see clause 4.4.4.4
$N_{\mathrm{BWP},i}^{\mathrm{start}}$	Start of bandwidth part i; see clause 4.4.4.4
$N_{\mathrm{CP},l}^{\mu}$	Cyclic prefix length; see clause 5.3.1
$N_{\mathrm{grid},x}^{\mathrm{size},\mu}$	The size of the resource grid; see clauses 4.4.2 and 5.3
$N_{\mathrm{grid},x}^{\mathrm{start},\mu}$	The start of the resource grid; see clause 4.4.2
$N_{\mathrm{group}}^{\mathrm{PT\text{-}RS}}$	The number of PT-RS groups; see clause 6.3.1.4
$N_{\mathrm{ID}}^{\mathrm{cell}}$	Physical layer cell identity; see clause 7.4.2.1
$N_{\mathrm{ID}}^{\mathrm{SL}}$	Physical-layer sidelink identity; see clause 8.4.2.1
$N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Frequency-domain size of a control resource set; see clause 7.3.2.2
$N_{\mathrm{REG}}^{\mathrm{CORESET}}$	Number of resource-element groups in a CORESET; see clause 7.3.2.2
$N_{\mathrm{samp}}^{\mathrm{group}}$	Number of samples per PT-RS group; see clause 6.3.1.4
$N_{\mathrm{sc}}^{\mathrm{RB}}$	Number of subcarriers per resource block, see clause 4.4.4.1
$N_{\mathrm{slot}}^{\mathrm{subframe},\mu}$	Number of slots per subframe for subcarrier spacing configuration μ, see clause 4.3.2
$N_{\mathrm{slot}}^{\mathrm{frame},\mu}$	Number of slots per frame for subcarrier spacing configuration μ, see clause 4.3.2
$N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Time duration of a control resource set; see clause 7.3.2.2
$N_{\mathrm{symb}}^{\mathrm{PUCCH}}$	Length of the PUCCH transmission in OFDM symbols; see clause 6.3.2.1
$N_{\mathrm{symb}}^{\mathrm{subframe},\mu}$	Number of OFDM symbols per subframe for subcarrier spacing configuration μ; see clause 4.3.1
$N_{\mathrm{symb}}^{\mathrm{slot}}$	Number of symbols per slot
N_{TA}	Timing advance between downlink and uplink; see clause 4.3.1
$N_{\mathrm{TA,offset}}$	A fixed offset used to calculate the timing advance; see clause 4.3.1
$N_{\mathrm{TA,adj}}^{\mathrm{common}}$	Network-controlled timing correction; see clause 4.3.1
$N_{\mathrm{TA,adj}}^{\mathrm{UE}}$	UE-derived timing correction; see clause 4.3.1
$N_{\mathrm{Rx\text{-}Tx}}$	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
$n_{\mathrm{s,f}}^{\mu}$	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
5	480	Normal
6	960	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 $T_{\mathrm{TA}} = \left(N_{\mathrm{TA}} + N_{\mathrm{TA,offset}} + N_{\mathrm{TA,adj}}^{\mathrm{common}} + N_{\mathrm{TA,adj}}^{\mathrm{UE}}\right) T_{\mathrm{c}}$ before the start of the corresponding downlink frame at the UE where

- N_{TA} and $N_{\mathrm{TA,offset}}$ are given by clause 4.2 of [5, TS 38.213], except for msgA transmission on PUSCH where $N_{\mathrm{TA}} = 0$ shall be used;
- $N_{\mathrm{TA,adj}}^{\mathrm{common}}$ given by clause 4.2 of [5, TS 38.213] is derived from the higher-layer parameters *ta-Common*, *ta-CommonDrift*, and *ta-CommonDriftVariant* if configured, otherwise $N_{\mathrm{TA,adj}}^{\mathrm{common}} = 0$;
- $N_{\mathrm{TA,adj}}^{\mathrm{UE}}$ given by clause 4.2 of [5, TS 38.213] is computed by the UE based on UE position and serving-satellite-ephemeris-related higher-layers parameters if configured, otherwise $N_{\mathrm{TA,adj}}^{\mathrm{UE}} = 0$.

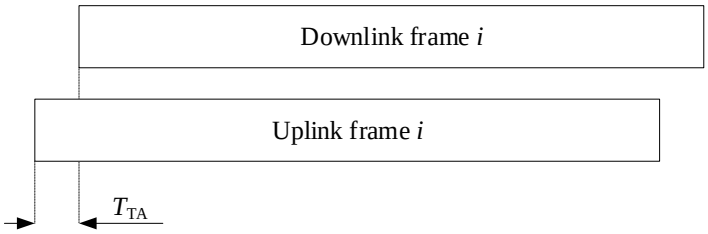

Figure 4.3.1-1: Uplink-downlink timing relation.

4.3.2 Slots

For subcarrier spacing configuration μ, slots are numbered $n_s^\mu \in \{0, \ldots, N_{slot}^{subframe,\mu} - 1\}$ in increasing order within a subframe and $n_{s,f}^\mu \in \{0, \ldots, N_{slot}^{frame,\mu} - 1\}$ in increasing order within a frame. There are N_{symb}^{slot} consecutive OFDM symbols in a slot where N_{symb}^{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 $n_s^\mu N_{symb}^{slot}$ 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 $N_{Rx\text{-}Tx}T_c$ after the end of the last received downlink symbol in the same or different cell within the group of cells where $N_{Rx\text{-}Tx}$ 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 $N_{Tx\text{-}Rx}T_c$ after the end of the last transmitted uplink symbol in the same or different cell within the group of cells where $N_{Tx\text{-}Rx}$ 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 $N_{Rx\text{-}Tx}T_c$ after the end of the last received downlink symbol in the different cell where $N_{Rx\text{-}Tx}$ 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 $N_{Tx\text{-}Rx}T_c$ after the end of the last transmitted uplink symbol in the different cell where $N_{Tx\text{-}Rx}$ 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 $N_{Rx\text{-}Tx}T_c$ after the end of the last received downlink symbol in the same cell where $N_{Rx\text{-}Tx}$ 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 $N_{Tx\text{-}Rx}T_c$ after the end of the last transmitted uplink symbol in the same cell where $N_{Tx\text{-}Rx}$ 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_{symb}^{slot}	$N_{slot}^{frame,\mu}$	$N_{slot}^{subframe,\mu}$
0	14	10	1
1	14	20	2
2	14	40	4
3	14	80	8
4	14	160	16
5	14	320	32
6	14	640	64

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

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