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Contents

Foreword

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1 Scope

The present document specifies and establishes the characteristics of the physicals layer procedures of data channels 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 38.211: "NR; Physical channels and modulation"

[5] 3GPP TS 38.212: "NR; Multiplexing and channel coding"

[6] 3GPP TS 38.213: "NR; Physical layer procedures for control"

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

[8] 3GPP TS 38.101: "NR; User Equipment (UE) radio transmission and reception"

[9] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception"

[10] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

[11] 3GPP TS 38.133: "NR; Requirements for support of radio resource management"

[12] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification"

[13] 3GPP TS 38.306: "NR; User Equipment (UE) radio access capabilities"

[14] 3GPP TS 38.423: "NG-RAN; Xn Application Protocol (XnAP)"

[15] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation"

[16] 3GPP TS 37.213: "Physical layer procedures for shared spectrum channel access"

[17] 3GPP TS 37.355: "LTE Positioning Protocol (LPP)"

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

3.2 Symbols

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

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

BWP	Bandwidth part
CBG	Code block group
CLI	Cross Link Interference
CP	Cyclic prefix
CQI	Channel quality indicator
CPU	CSI processing unit
CRB	Common resource block
CRC	Cyclic redundancy check
CRI	CSI-RS Resource Indicator
CSI	Channel state information
CSI-RS	Channel state information reference signal
CSI-RSRP	CSI reference signal received power
CSI-RSRQ	CSI reference signal received quality
CSI-SINR	CSI signal-to-noise and interference ratio
CW	Codeword
DCI	Downlink control information
DL	Downlink
DM-RS	Dedicated demodulation reference signals
EPRE	Energy per resource element
IAB-MT	Integrated Access and Backhaul – Mobile Terminal
L1-RSRP	Layer 1 reference signal received power
LI	Layer Indicator
MCS	Modulation and coding scheme
PDCCH	Physical downlink control channel
PDSCH	Physical downlink shared channel
PSS	Primary Synchronisation signal
PUCCH	Physical uplink control channel
QCL	Quasi co-location
PMI	Precoding Matrix Indicator
PRB	Physical resource block
PRG	Precoding resource block group
PRS	Positioning reference signal
PT-RS	Phase-tracking reference signal
RB	Resource block
RBG	Resource block group
RI	Rank Indicator
RIV	Resource indicator value
RS	Reference signal
SLIV	Start and length indicator value
SR	Scheduling Request
SRS	Sounding reference signal

SS	Synchronisation signal
SSS	Secondary Synchronisation signal
SS-RSRP	SS reference signal received power
SS-RSRQ	SS reference signal received quality
SS-SINR	SS signal-to-noise and interference ratio
TB	Transport Block
TCI	Transmission Configuration Indicator
TDM	Time division multiplexing
UE	User equipment
UL	Uplink

4 Power control

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

4.1 Power allocation for downlink

The gNB determines the downlink transmit EPRE.

For the purpose of SS-RSRP, SS-RSRQ and SS-SINR measurements, the UE may assume downlink EPRE is constant across the bandwidth. For the purpose of SS-RSRP, SS-RSRQ and SS-SINR measurements, the UE may assume downlink EPRE is constant over SSS carried in different SS/PBCH blocks. For the purpose of SS-RSRP, SS-RSRQ and SS-SINR measurements, the UE may assume that the ratio of SSS EPRE to PBCH DM-RS EPRE is 0 dB.

For the purpose of CSI-RSRP, CSI-RSRQ and CSI-SINR measurements, the UE may assume downlink EPRE of a port of CSI-RS resource configuration is constant across the configured downlink bandwidth and constant across all configured OFDM symbols.

The downlink SS/PBCH SSS EPRE can be derived from the SS/PBCH downlink transmit power given by the parameter *ss-PBCH-BlockPower* provided by higher layers. The downlink SSS transmit power is defined as the linear average over the power contributions (in [W]) of all resource elements that carry the SSS within the operating system bandwidth.

The downlink CSI-RS EPRE can be derived from the SS/PBCH block downlink transmit power given by the parameter *ss-PBCH-BlockPower* and CSI-RS power offset given by the parameter *powerControlOffsetSS* provided by higher layers. The downlink reference-signal transmit power is defined as the linear average over the power contributions (in [W]) of the resource elements that carry the configured CSI-RS within the operating system bandwidth.

For downlink DM-RS associated with PDSCH, the UE may assume the ratio of PDSCH EPRE to DM-RS EPRE (β_{DMRS} [dB]) is given by Table 4.1-1 according to the number of DM-RS CDM groups without data as described in Clause 5.1.6.2. The DM-RS scaling factor β_{PDSCH}^{DMRS} specified in Clause 7.4.1.1.2 of [4, TS 38.211] is given by $\beta_{PDSCH}^{DMRS} = 10^{-\frac{\beta_{DMRS}}{20}}$.

Table 4.1-1: The ratio of PDSCH EPRE to DM-RS EPRE

Number of DM-RS CDM groups without data	DM-RS configuration type 1	DM-RS configuration type 2
1	0 dB	0 dB
2	-3 dB	-3 dB
3	-	-4.77 dB

When the UE is scheduled with one or two PT-RS ports associated with the PDSCH,

- if the UE is configured with the higher layer parameter *epre-Ratio*, the ratio of PT-RS EPRE to PDSCH EPRE per layer per RE for each PT-RS port (ρ_{PTRS}) is given by Table 4.1-2 according to the *epre-Ratio*, the PT-RS scaling factor β_{PTRS} specified in clause 7.4.1.2.2 of [4, TS 38.211] is given by $\beta_{PTRS} = 10^{\frac{\rho_{PTRS}}{20}}$.

- otherwise, the UE shall assume *epre-Ratio* is set to state '0' in Table 4.1-2 if not configured.

Table 4.1-2: PT-RS EPRE to PDSCH EPRE per layer per RE (ρ_{PTRS})

epre-Ratio	The number of PDSCH layers with DM-RS associated to the PT-RS port					
	1	2	3	4	5	6
0	0	3	4.77	6	7	7.78
1	0	0	0	0	0	0
2	reserved					
3	reserved					

For link recovery, as described in clause 6 of [6, TS 38.213] the ratio of the PDCCH EPRE to NZP CSI-RS EPRE is assumed as 0 dB.

5 Physical downlink shared channel related procedures

5.1 UE procedure for receiving the physical downlink shared channel

For downlink, a maximum of 16 HARQ processes per cell is supported by the UE. The number of processes the UE may assume will at most be used for the downlink is configured to the UE for each cell separately by higher layer parameter *nrofHARQ-ProcessesForPDSCH*, and when no configuration is provided the UE may assume a default number of 8 processes.

A UE shall upon detection of a PDCCH with a configured DCI format 1_0, 1_1 or 1_2 decode the corresponding PDSCHs as indicated by that DCI. For any HARQ process ID(s) in a given scheduled cell, the UE is not expected to receive a PDSCH that overlaps in time with another PDSCH. The UE is not expected to receive another PDSCH for a given HARQ process until after the end of the expected transmission of HARQ-ACK for that HARQ process, where the timing is given by Clause 9.2.3 of [6]. In a given scheduled cell, the UE is not expected to receive a first PDSCH and a second PDSCH, starting later than the first PDSCH, with its corresponding HARQ-ACK assigned to be transmitted on a resource ending before the start of a different resource for the HARQ-ACK assigned to be transmitted for the first PDSCH, where the two resources are in different slots for the associated HARQ-ACK transmissions, each slot is composed of N_{sym}^{slot} symbols [4] or a number of symbols indicated by *subslotLengthForPUCCH-r16* if provided, and the HARQ-ACK for the two PDSCHs are associated with the HARQ-ACK codebook of the same priority. In a given scheduled cell, the UE is not expected to receive a first PDSCH, and a second PDSCH, starting later than the first PDSCH, with its corresponding HARQ-ACK assigned to be transmitted on a resource ending before the start of a different resource for the HARQ-ACK assigned to be transmitted for the first PDSCH if the HARQ-ACK for the two PDSCHs are associated with HARQ-ACK codebooks of different priorities. For any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start receiving a first PDSCH starting in symbol j by a PDCCH ending in symbol i, the UE is not expected to be scheduled to receive a PDSCH starting earlier than the end of the first PDSCH with a PDCCH that ends later than symbol i. In a given scheduled cell, for any PDSCH corresponding to SI-RNTI, the UE is not expected to decode a re-transmission of an earlier PDSCH with a starting symbol less than N symbols after the last symbol of that PDSCH, where the value of N depends on the PDSCH subcarrier spacing configuration μ, with N=13 for μ=0, N=13 for μ=1, N=20 for μ=2, and N=24 for μ=3.

When receiving PDSCH scheduled with SI-RNTI or P-RNTI, the UE may assume that the DM-RS port of PDSCH is quasi co-located with the associated SS/PBCH block with respect to Doppler shift, Doppler spread, average delay, delay spread, spatial RX parameters when applicable.

When receiving PDSCH scheduled with RA-RNTI, or MsgB-RNTI, the UE may assume that the DM-RS port of PDSCH is quasi co-located with the SS/PBCH block or the CSI-RS resource the UE used for RACH association as applicable, and transmission with respect to Doppler shift, Doppler spread, average delay, delay spread, spatial RX parameters when applicable. When receiving a PDSCH scheduled with RA-RNTI in response to a random access procedure triggered by a PDCCH order which triggers contention-free random access procedure for the SpCell [10, TS 38.321], the UE may assume that the DM-RS port of the received PDCCH order and the DM-RS ports of the

corresponding PDSCH scheduled with RA-RNTI are quasi co-located with the same SS/PBCH block or CSI-RS with respect to Doppler shift, Doppler spread, average delay, delay spread, spatial RX parameters when applicable.

When receiving PDSCH in response to a PUSCH transmission scheduled by a RAR UL grant or corresponding PUSCH retransmission, or when receiving PDSCH in response to a PUSCH for Type-2 random access procedure, or a PUSCH scheduled by a fallbackRAR UL grant or corresponding PUSCH retransmission, the UE may assume that the DM-RS port of PDSCH is quasi co-located with the SS/PBCH block the UE selected for RACH association and transmission with respect to Doppler shift, Doppler spread, average delay, delay spread, spatial RX parameters when applicable.

If the UE is not configured for PUSCH/PUCCH transmission for at least one serving cell configured with slot formats comprised of DL and UL symbols, and if the UE is not capable of simultaneous reception and transmission on serving cell c_1 and serving cell c_2, the UE is not expected to receive PDSCH on serving cell c_1 if the PDSCH overlaps in time with SRS transmission (including any interruption due to uplink or downlink RF retuning time [10]) on serving cell c_2 not configured for PUSCH/PUCCH transmission.

The UE is not expected to decode a PDSCH in a serving cell scheduled by a PDCCH with C-RNTI, CS-RNTI or MCS-C-RNTI and one or multiple PDSCH(s) required to be received according to this Clause in the same serving cell without a corresponding PDCCH transmission if the PDSCHs partially or fully overlap in time except if the PDCCH scheduling the PDSCH ends at least 14 symbols before the earliest starting symbol of the PDSCH(s) without the corresponding PDCCH transmission, where the symbol duration is based on the smallest numerology between the scheduling PDCCH and the PDSCH, in which case the UE shall decode the PDSCH scheduled by the PDCCH.

The UE is not expected to decode a PDSCH scheduled with C-RNTI, MCS-C-RNTI, or CS-RNTI if another PDSCH in the same cell scheduled with RA-RNTI or MsgB-RNTI partially or fully overlap in time.

The UE in RRC_IDLE and RRC_INACTIVE modes shall be able to decode two PDSCHs each scheduled with SI-RNTI, P-RNTI, RA-RNTI or TC-RNTI, with the two PDSCHs partially or fully overlapping in time in non-overlapping PRBs.

On a frequency range 1 cell, the UE shall be able to decode a PDSCH scheduled with C-RNTI, MCS-C-RNTI, or CS-RNTI and, during a process of P-RNTI triggered SI acquisition, another PDSCH scheduled with SI-RNTI that partially or fully overlap in time in non-overlapping PRBs, unless the PDSCH scheduled with C-RNTI, MCS-C-RNTI, or CS-RNTI requires Capability 2 processing time according to clause 5.3 in which case the UE may skip decoding of the scheduled PDSCH with C-RNTI, MCS-C-RNTI, or CS-RNTI.

On a frequency range 2 cell, the UE is not expected to decode a PDSCH scheduled with C-RNTI, MCS-C-RNTI, or CS-RNTI if in the same cell, during a process of P-RNTI triggered SI acquisition, another PDSCH scheduled with SI-RNTI partially or fully overlap in time.

The UE is expected to decode a PDSCH scheduled with C-RNTI, MCS-C-RNTI, or CS-RNTI during a process of autonomous SI acquisition.

If the UE is configured by higher layers to decode a PDCCH with its CRC scrambled by a CS-RNTI, the UE shall receive PDSCH transmissions without corresponding PDCCH transmissions using the higher-layer-provided PDSCH configuration for those PDSCHs.

If a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *CORESETPoolIndex* in *ControlResourceSet*, the UE may expect to receive multiple PDCCHs scheduling fully/partially/non-overlapped PDSCHs in time and frequency domain. The UE may expect the reception of full/partially-overlapped PDSCHs in time only when PDCCHs that schedule two PDSCHs are associated to different *ControlResourceSets* having different values of *CORESETPoolIndex*. For a *ControlResourceSet* without *CORESETPoolIndex*, the UE may assume that the *ControlResourceSet* is assigned with *CORESETPoolIndex* as 0. When the UE is scheduled with full/partially/non-overlapped PDSCHs in time and frequency domain, the full scheduling information for receiving a PDSCH is indicated and carried only by the corresponding PDCCH, the UE is expected to be scheduled with the same active BWP and the same SCS. When the UE is scheduled with full/partially-overlapped PDSCHs in time and frequency domain, the UE can be scheduled with at most two codewords simultaneously. When PDCCHs that schedule two PDSCHs are associated to different *ControlResourceSets* having different values of *CORESETPoolIndex*, the following operations are allowed:

- For any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start receiving a first PDSCH starting in symbol *j* by a PDCCH associated with a value of *CORESETpoolIndex* ending in symbol *i*, the UE can be scheduled to receive a PDSCH starting earlier than the end of the first PDSCH with a PDCCH associated with a different value of *CORESETpoolIndex* that ends later than symbol *i*.

- In a given scheduled cell, the UE can receive a first PDSCH in slot *i*, with the corresponding HARQ-ACK assigned to be transmitted in slot *j*, and a second PDSCH associated with a value of *CORESETpoolindex* different from that of the first PDSCH starting later than the first PDSCH with its corresponding HARQ-ACK assigned to be transmitted in a slot before slot *j*.

If PDCCHs that schedule corresponding PDSCHs are associated to the same or different *ControlResourceSets* having the same value of *CORESETPoolIndex*, the UE procedure for receiving the PDSCH upon detection of a PDCCH follows Clause 5.1.

A UE does not expect to be configured with *repetitionScheme-r16* if the UE is configured with higher layer parameter *repetitionNumber-r16*.

When a UE is configured by higher layer parameter *RepetitionScheme-r16* set to one of '*FDMSchemeA*', '*FDMSchemeB*', '*TDMSchemeA*', if the UE is indicated with two TCI states in a codepoint of the DCI field *'Transmission Configuration Indication'* and DM-RS port(s) within one CDM group in the DCI field "*Antenna Port(s)*".

- When two TCI states are indicated in a DCI and the UE is set to '*FDMSchemeA*', the UE shall receive a single PDSCH transmission occasion of the TB with each TCI state associated to a non-overlapping frequency domain resource allocation as described in Clause 5.1.2.3.

- When two TCI states are indicated in a DCI and the UE is set to '*FDMSchemeB*', the UE shall receive two PDSCH transmission occasions of the same TB with each TCI state associated to a PDSCH transmission occasion which has non-overlapping frequency domain resource allocation with respect to the other PDSCH transmission occasion as described in Clause 5.1.2.3.

- When two TCI states are indicated in a DCI and the UE is set to '*TDMSchemeA*', the UE shall receive two PDSCH transmission occasions of the same TB with each TCI state associated to a PDSCH transmission occasion which has non-overlapping time domain resource allocation with respect to the other PDSCH transmission occasion and both PDSCH transmission occasions shall be received within a given slot as described in Clause 5.1.2.1.

When a UE is configured by the higher layer parameter *repetitionNumber-r16* in *PDSCH-TimeDomainResourceAllocation-r16*, the UE may expect to be indicated with one or two TCI states in a codepoint of the DCI field *'Transmission Configuration Indication'* together with the DCI field "*Time domain resource assignment*' indicating an entry which contains *repetitionNumber-r16* in *PDSCH-TimeDomainResourceAllocation-r16* and DM-RS port(s) within one CDM group in the DCI field "*Antenna Port(s)*".

- When two TCI states are indicated in a DCI with '*Transmission Configuration Indication*' field, the UE may expect to receive multiple slot level PDSCH transmission occasions of the same TB with two TCI states used across multiple PDSCH transmission occasions in the *repetitionNumber-r16* consecutive slots as defined in Clause 5.1.2.1.

- When one TCI state is indicated in a DCI with '*Transmission Configuration Indication*' field, the UE may expect to receive multiple slot level PDSCH transmission occasions of the same TB with one TCI state used across multiple PDSCH transmission occasions in the *repetitionNumber-r16* consecutive slots as defined in Clause 5.1.2.1.

When a UE is not indicated with a DCI that DCI field '*Time domain resource assignment*' indicating an entry which contains *repetitionNumber-r16* in *PDSCH-TimeDomainResourceAllocation-r16*, and it is indicated with two TCI states in a codepoint of the DCI field *'Transmission Configuration Indication'* and DM-RS port(s) within two CDM groups in the DCI field "*Antenna Port(s)*", the UE may expect to receive a single PDSCH where the association between the DM-RS ports and the TCI states are as defined in Clause 5.1.6.2.

When a UE is not indicated with a DCI that DCI field '*Time domain resource assignment*' indicating an entry which contains *repetitionNumber-r16* in *PDSCH-TimeDomainResourceAllocation-r16*, and it is indicated with one TCI states in a codepoint of the DCI field *'Transmission Configuration Indication'*, the UE procedure for receiving the PDSCH upon detection of a PDCCH follows Clause 5.1.

If more than one PDSCH on a serving cell each without a corresponding PDCCH transmission are in a slot, after resolving overlapping with symbols in the slot indicated as uplink by *tdd-UL-DL-ConfigurationCommon*, or by *tdd-UL-DL-ConfigurationDedicated*, a UE receives one or more PDSCHs without corresponding PDCCH transmissions in the slot as specified below.