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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"

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
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	Demodulation reference signals
EPRE	Energy per resource element
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
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

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 a PT-RS port 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 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					
	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 or 1_1 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 in slot *i*, with the corresponding HARQ-ACK assigned to be transmitted in slot *j*, and a second PDSCH starting later than the first PDSCH with its corresponding HARQ-ACK assigned to be transmitted in a slot before slot *j*. 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 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 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 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 scheduled in a serving cell with C-RNTI or MCS-C-RNTI and another PDSCH scheduled in the same serving cell with CS-RNTI if the PDSCHs partially or fully overlap in time except if the PDCCH scheduling the PDSCH with C-RNTI or MCS-C-RNTI ends at least 14 symbols before the start of the PDSCH with CS-RNTI without the corresponding DCI, in which case the UE shall decode the PDSCH scheduled with C-RNTI or MCS-C-RNTI.

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 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.

5.1.1 Transmission schemes

Only one transmission scheme is defined for the PDSCH, and is used for all PDSCH transmissions.

5.1.1.1 Transmission scheme 1

For transmission scheme 1 of the PDSCH, the UE may assume that a gNB transmission on the PDSCH would be performed with up to 8 transmission layers on antenna ports 1000-1011 as defined in clause 7.3.1.4 of [4, TS 38.211], subject to the DM-RS reception procedures in clause 5.1.6.2.

5.1.2 Resource allocation

5.1.2.1 Resource allocation in time domain

When the UE is scheduled to receive PDSCH by a DCI, the *Time domain resource assignment* field value *m* of the DCI provides a row index *m* + 1 to an allocation table. The determination of the used resource allocation table is defined in clause 5.1.2.1.1. The indexed row defines the slot offset K_0, the start and length indicator *SLIV*, or directly the start symbol *S* and the allocation length *L*, and the PDSCH mapping type to be assumed in the PDSCH reception.

Given the parameter values of the indexed row:

- The slot allocated for the PDSCH is $\left\lfloor n \cdot \frac{2^{\mu_{PDSCH}}}{2^{\mu_{PDCCH}}} \right\rfloor + K_0$, where *n* is the slot with the scheduling DCI, and K_0 is based on the numerology of PDSCH, and μ_{PDSCH} and μ_{PDCCH} are the subcarrier spacing configurations for PDSCH and PDCCH, respectively, and

- The starting symbol S relative to the start of the slot, and the number of consecutive symbols L counting from the symbol S allocated for the PDSCH are determined from the start and length indicator $SLIV$:

  if $(L-1) \leq 7$ then

  $$SLIV = 14 \cdot (L-1) + S$$

  else

  $$SLIV = 14 \cdot (14-L+1) + (14-1-S)$$

  where $0 < L \leq 14-S$, and

- The PDSCH mapping type is set to Type A or Type B as defined in clause 7.4.1.1.2 of [4, TS 38.211].

The UE shall consider the S and L combinations defined in table 5.1.2.1-1 as valid PDSCH allocations:

Table 5.1.2.1-1: Valid *S* and *L* combinations

PDSCH mapping type	Normal cyclic prefix			Extended cyclic prefix		
	S	***L***	***S+L***	***S***	***L***	***S+L***
Type A	{0,1,2,3} (Note 1)	{3,…,14}	{3,…,14}	{0,1,2,3} (Note 1)	{3,…,12}	{3,…,12}
Type B	{0,…,12}	{2,4,7}	{2,…,14}	{0,…,10}	{2,4,6}	{2,…,12}
Note 1: S = 3 is applicable only if *dmrs-TypeA-Position* = 3						

When receiving PDSCH scheduled by DCI format 1_1 in PDCCH with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI, or PDSCH scheduled without corresponding PDCCH transmission using *sps-Config* and activated by DCI format 1_1, if the UE is configured with *pdsch-AggregationFactor*, the same symbol allocation is applied across the *pdsch-AggregationFactor* consecutive slots. The UE may expect that the TB is repeated within each symbol allocation among each of the *pdsch-AggregationFactor* consecutive slots and the PDSCH is limited to a single transmission layer. The redundancy version to be applied on the n^{th} transmission occasion of the TB, where n = 0, 1, …*pdsch-AggregationFactor* -1, is determined according to table 5.1.2.1-2 and "rv_{id} indicated by the DCI scheduling the PDSCH" in table 5.1.2.1-2 is assumed to be 0 for PDSCH scheduled without corresponding PDCCH transmission using *sps-Config* and activated by DCI format 1_1.

Table 5.1.2.1-2: Applied redundancy version when *pdsch-AggregationFactor* is present

rv_{id} indicated by the DCI scheduling the PDSCH	rv_{id} to be applied to n^{th} transmission occasion			
	n **mod 4 = 0**	***n*** **mod 4 = 1**	***n*** **mod 4 = 2**	***n*** **mod 4 = 3**
0	0	2	3	1
2	2	3	1	0
3	3	1	0	2
1	1	0	2	3

A PDSCH reception in a slot of a multi-slot PDSCH reception is omitted according to the conditions in clause 11.1 of [6, TS38.213].

The UE is not expected to receive a PDSCH with mapping type A in a slot, if the PDCCH scheduling the PDSCH was received in the same slot and was not contained within the first three symbols of the slot.

The UE is not expected to receive a PDSCH with mapping type B in a slot, if the first symbol of the PDCCH scheduling the PDSCH was received in a later symbol than the first symbol indicated in the PDSCH time domain resource allocation.

5.1.2.1.1 Determination of the resource allocation table to be used for PDSCH

Table 5.1.2.1.1-1 defines which PDSCH time domain resource allocation configuration to apply. Either a default PDSCH time domain allocation A, B or C according to tables 5.1.2.1.1-2, 5.1.2.1.1-3, 5.1.2.1.1-4 and 5.1.2.1.1-5 is applied, or the higher layer configured *pdsch-TimeDomainAllocationList* in either *pdsch-ConfigCommon* or *pdsch-Config* is applied.

Table 5.1.2.1.1-1: Applicable PDSCH time domain resource allocation

RNTI	PDCCH search space	SS/PBCH block and CORESET multiplexing pattern	*pdsch-ConfigCommon* includes *pdsch-TimeDomainAllocationList*	*pdsch-Config* includes *pdsch-TimeDomainAllocationList*	PDSCH time domain resource allocation to apply
SI-RNTI	Type0 common	1	-	-	Default A for normal CP
		2	-	-	Default B
		3	-	-	Default C
SI-RNTI	Type0A common	1	No	-	Default A
		2	No	-	Default B
		3	No	-	Default C
		1,2,3	Yes	-	*pdsch-TimeDomainAllocationList provided in pdsch-ConfigCommon*
RA-RNTI, TC-RNTI	Type1 common	1, 2, 3	No	-	Default A
		1, 2, 3	Yes	-	*pdsch-TimeDomainAllocationList* provided in *pdsch-ConfigCommon*
P-RNTI	Type2 common	1	No	-	Default A
		2	No	-	Default B
		3	No	-	Default C
		1,2,3	Yes	-	*pdsch-TimeDomainAllocationList provided in pdsch-ConfigCommon*
C-RNTI, MCS-C-RNTI, CS-RNTI	Any common search space associated with CORESET 0	1, 2, 3	No	-	Default A
		1, 2, 3	Yes	-	*pdsch-TimeDomainAllocationList* provided in *pdsch-ConfigCommon*
C-RNTI, MCS-C-RNTI, CS-RNTI	Any common search space not associated with CORESET 0 UE specific search space	1,2,3	No	No	Default A
		1,2,3	Yes	No	*pdsch-TimeDomainAllocationList* provided in *pdsch-ConfigCommon*
		1,2,3	No/Yes	Yes	*pdsch-TimeDomainAllocationList* provided in *pdsch-Config*

Table 5.1.2.1.1-2: Default PDSCH time domain resource allocation A for normal CP

Row index	*dmrs-TypeA-Position*	PDSCH mapping type	K_0	*S*	*L*
1	2	Type A	0	2	12
	3	Type A	0	3	11
2	2	Type A	0	2	10
	3	Type A	0	3	9
3	2	Type A	0	2	9
	3	Type A	0	3	8
4	2	Type A	0	2	7
	3	Type A	0	3	6
5	2	Type A	0	2	5
	3	Type A	0	3	4
6	2	Type B	0	9	4
	3	Type B	0	10	4
7	2	Type B	0	4	4
	3	Type B	0	6	4
8	2,3	Type B	0	5	7
9	2,3	Type B	0	5	2
10	2,3	Type B	0	9	2
11	2,3	Type B	0	12	2
12	2,3	Type A	0	1	13
13	2,3	Type A	0	1	6
14	2,3	Type A	0	2	4
15	2,3	Type B	0	4	7
16	2,3	Type B	0	8	4

Table 5.1.2.1.1-3: Default PDSCH time domain resource allocation A for extended CP

Row index	*dmrs-TypeA-Position*	PDSCH mapping type	K_0	*S*	*L*
1	2	Type A	0	2	6
	3	Type A	0	3	5
2	2	Type A	0	2	10
	3	Type A	0	3	9
3	2	Type A	0	2	9
	3	Type A	0	3	8
4	2	Type A	0	2	7
	3	Type A	0	3	6
5	2	Type A	0	2	5
	3	Type A	0	3	4
6	2	Type B	0	6	4
	3	Type B	0	8	2
7	2	Type B	0	4	4
	3	Type B	0	6	4
8	2,3	Type B	0	5	6
9	2,3	Type B	0	5	2
10	2,3	Type B	0	9	2
11	2,3	Type B	0	10	2
12	2,3	Type A	0	1	11
13	2,3	Type A	0	1	6
14	2,3	Type A	0	2	4
15	2,3	Type B	0	4	6
16	2,3	Type B	0	8	4