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**5G;
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Physical layer procedures for data
(3GPP TS 38.214 version 18.5.0 Release 18)**

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Contents

Intellectual Property Rights	2
Legal Notice	2
Modal verbs terminology.....	2
Foreword.....	7
1 Scope	8
2 References	8
3 Definitions of terms, symbols and abbreviations	9
3.1 Terms.....	9
3.2 Symbols.....	9
3.3 Abbreviations	9
4 Power control	10
4.1 Power allocation for downlink	10
5 Physical downlink shared channel related procedures	11
5.1 UE procedure for receiving the physical downlink shared channel	11
5.1.1 Transmission schemes	17
5.1.1.1 Transmission scheme 1	17
5.1.2 Resource allocation.....	17
5.1.2.1 Resource allocation in time domain	17
5.1.2.1.1 Determination of the resource allocation table to be used for PDSCH.....	22
5.1.2.2 Resource allocation in frequency domain	27
5.1.2.2.1 Downlink resource allocation type 0	27
5.1.2.2.2 Downlink resource allocation type 1	28
5.1.2.2.3 Downlink resource allocation type 1 for multicast/broadcast.....	29
5.1.2.3 Physical resource block (PRB) bundling.....	30
5.1.3 Modulation order, target code rate, redundancy version and transport block size determination.....	31
5.1.3.1 Modulation order and target code rate determination	33
5.1.3.2 Transport block size determination	39
5.1.4 PDSCH resource mapping	43
5.1.4.1 PDSCH resource mapping with RB symbol level granularity	43
5.1.4.2 PDSCH resource mapping with RE level granularity	45
5.1.5 Antenna ports quasi co-location.....	47
5.1.6 UE procedure for receiving reference signals.....	56
5.1.6.1 CSI-RS reception procedure.....	56
5.1.6.1.1 CSI-RS for tracking.....	57
5.1.6.1.2 CSI-RS for L1-RSRP and L1-SINR computation	60
5.1.6.1.3 CSI-RS for mobility	60
5.1.6.2 DM-RS reception procedure	61
5.1.6.3 PT-RS reception procedure	65
5.1.6.4 SRS reception procedure for CLI.....	67
5.1.6.5 PRS reception procedure.....	67
5.1.6.5.1 PRS receiver frequency hopping	74
5.1.6.5.2 PRS for carrier phase positioning.....	75
5.1.6.5.3 PRS bandwidth aggregation for positioning measurements	75
5.1.7 Code block group based PDSCH transmission.....	76
5.1.7.1 UE procedure for grouping of code blocks to code block groups	76
5.1.7.2 UE procedure for receiving code block group based transmissions.....	76
5.2 UE procedure for reporting channel state information (CSI)	77
5.2.1 Channel state information framework.....	77
5.2.1.1 Reporting settings	77
5.2.1.2 Resource settings.....	78
5.2.1.3 (void).....	79
5.2.1.4 Reporting configurations.....	79
5.2.1.4.1 Resource Setting configuration	82

5.2.1.4.2	Report quantity configurations	84
5.2.1.4.3	L1-RSRP Reporting.....	91
5.2.1.4.4	L1-SINR Reporting	91
5.2.1.4.5	TDCP Reporting.....	92
5.2.1.5	Triggering/activation of CSI Reports and CSI-RS	93
5.2.1.5.1	Aperiodic CSI Reporting/Aperiodic CSI-RS when the triggering PDCCH and the CSI-RS have the same numerology	93
5.2.1.5.1a	Aperiodic CSI Reporting/Aperiodic CSI-RS when the triggering PDCCH and the CSI-RS have different numerologies	99
5.2.1.5.2	Semi-persistent CSI/Semi-persistent CSI-RS	101
5.2.1.5.3	Aperiodic CSI-RS for tracking for fast SCell activation	103
5.2.1.6	CSI processing criteria	103
5.2.2	Channel state information.....	105
5.2.2.1	Channel quality indicator (CQI).....	105
5.2.2.1.1	(void)	108
5.2.2.2	Precoding matrix indicator (PMI)	108
5.2.2.2.1	Type I Single-Panel Codebook.....	108
5.2.2.2.2	Type I Multi-Panel Codebook	115
5.2.2.2.3	Type II Codebook.....	119
5.2.2.2.4	Type II Port Selection Codebook	126
5.2.2.2.5	Enhanced Type II Codebook	128
5.2.2.2.6	Enhanced Type II Port Selection Codebook.....	135
5.2.2.2.7	Further enhanced Type II port selection codebook.....	137
5.2.2.2.8	Enhanced Type II codebook for CJT	141
5.2.2.2.9	Further enhanced Type II port selection codebook for CJT	147
5.2.2.2.10	Enhanced Type II codebook for predicted PMI.....	153
5.2.2.2.11	Further enhanced Type II port selection codebook for predicted PMI	157
5.2.2.3	Reference signal (CSI-RS).....	158
5.2.2.3.1	NZP CSI-RS	158
5.2.2.4	Channel State Information – Interference Measurement (CSI-IM).....	159
5.2.2.5	CSI reference resource definition.....	160
5.2.2.5.1	UE assumptions for CQI/PMI/RI calculation	162
5.2.2.5.1a	UE assumptions for CQI/PMI/RI calculation for NCJT	163
5.2.2.5.1b	UE assumptions for CQI/PMI/RI calculation for CJT.....	164
5.2.2.5.1c	UE assumptions for CQI/PMI/RI calculation for predicted CSI	164
5.2.3	CSI reporting using PUSCH	164
5.2.4	CSI reporting using PUCCH.....	171
5.2.5	Priority rules for CSI reports.....	172
5.3	UE PDSCH processing procedure time	173
5.3.1	Application delay of the minimum scheduling offset restriction	176
5.4	UE CSI computation time	176
5.5	UE PDSCH reception preparation time with different subcarrier spacings for PDCCH and PDSCH in different cells	178
6	Physical uplink shared channel related procedure.....	179
6.1	UE procedure for transmitting the physical uplink shared channel	179
6.1.1	Transmission schemes	183
6.1.1.1	Codebook based UL transmission.....	183
6.1.1.2	Non-Codebook based UL transmission.....	186
6.1.2	Resource allocation.....	188
6.1.2.1	Resource allocation in time domain	188
6.1.2.1.1	Determination of the resource allocation table to be used for PUSCH.....	200
6.1.2.2	Resource allocation in frequency domain	203
6.1.2.2.1	Uplink resource allocation type 0	203
6.1.2.2.2	Uplink resource allocation type 1	204
6.1.2.2.3	Uplink resource allocation type 2	205
6.1.2.3	Resource allocation for uplink transmission with configured grant	207
6.1.2.3.1	Transport Block repetition for uplink transmissions of PUSCH repetition Type A with a configured grant.....	209
6.1.2.3.2	Transport Block repetition for uplink transmissions of PUSCH repetition Type B with a configured grant.....	211

6.1.2.3.3	Transport Block repetition for uplink transmissions of TB processing over multiple slots with a configured grant.....	211
6.1.3	UE procedure for applying transform precoding on PUSCH	212
6.1.4	Modulation order, redundancy version and transport block size determination	213
6.1.4.1	Modulation order and target code rate determination	215
6.1.4.2	Transport block size determination	220
6.1.5	Code block group based PUSCH transmission	221
6.1.5.1	UE procedure for grouping of code blocks to code block groups	222
6.1.5.2	UE procedure for transmitting code block group based transmissions	222
6.1.6	Uplink switching.....	222
6.1.6.1	Uplink switching for EN-DC	223
6.1.6.2	Uplink switching for carrier aggregation	224
6.1.6.2.0	Uplink switching with two uplink bands	224
6.1.6.2.1	void.....	225
6.1.6.2.2	Uplink switching with 3 or 4 uplink bands.....	225
6.1.6.3	Uplink switching with two uplink bands for supplementary uplink.....	226
6.1.7	UE procedure for determining time domain windows for bundling DM-RS.....	226
6.2	UE reference signal (RS) procedure.....	229
6.2.1	UE sounding procedure	229
6.2.1.1	UE SRS frequency hopping procedure	238
6.2.1.2	UE sounding procedure for DL CSI acquisition	238
6.2.1.3	UE sounding procedure between component carriers	243
6.2.1.4	UE sounding procedure for positioning purposes	245
6.2.1.4.1	SRS frequency hopping for positioning	247
6.2.1.4.2	SRS bandwidth aggregation for positioning measurements	248
6.2.2	UE DM-RS transmission procedure	249
6.2.3	UE PT-RS transmission procedure	251
6.2.3.1	UE PT-RS transmission procedure when transform precoding is not enabled.....	251
6.2.3.2	UE PT-RS transmission procedure when transform precoding is enabled.....	255
6.3	UE PUSCH frequency hopping procedure.....	256
6.3.1	Frequency hopping for PUSCH repetition Type A and for TB processing over multiple slots.....	256
6.3.2	Frequency hopping for PUSCH repetition Type B.....	257
6.4	UE PUSCH preparation procedure time.....	258
7	UE procedures for transmitting and receiving on a carrier with intra-cell guard bands.....	259
8	Physical sidelink shared channel related procedures.....	260
8.1	UE procedure for transmitting the physical sidelink shared channel	262
8.1.1	Transmission schemes	264
8.1.2	Resource allocation.....	264
8.1.2.1	Resource allocation in time domain	264
8.1.2.2	Resource allocation in frequency domain	265
8.1.3	Modulation order, target code rate, redundancy version and transport block size determination.....	266
8.1.3.1	Modulation order and target code rate determination	266
8.1.3.2	Transport block size determination	267
8.1.4	UE procedure for determining the subset of resources to be reported to higher layers in PSSCH resource selection in sidelink resource allocation mode 2	268
8.1.4A	UE procedure for determining a set of preferred or non-preferred resources for another UE's transmission	276
8.1.4B	Void	277
8.1.4C	UE procedure for using a received non-preferred resource set.....	277
8.1.5	UE procedure for determining slots and resource blocks for PSSCH transmission associated with an SCI format 1-A	277
8.1.5A	UE procedure for determining slots and resource blocks indicated by a preferred or non-preferred resource set	279
8.1.6	Sidelink congestion control in sidelink resource allocation mode 2.....	280
8.1.7	UE procedure for determining the number of logical slots for a reservation period.....	281
8.2	UE procedure for transmitting sidelink reference signals	281
8.2.1	CSI-RS transmission procedure.....	281
8.2.2	PSSCH DM-RS transmission procedure.....	281
8.2.3	PT-RS transmission procedure	281
8.2.4	SL PRS transmission procedure.....	282

8.2.4.1	Resource allocation	282
8.2.4.1.1	Resource allocation in time domain	282
8.2.4.1.2	Resource allocation in frequency domain.....	283
8.2.4.2	UE procedure for determining the subset of resources to be reported to higher layers in SL PRS resource selection in a dedicated SL PRS resource pool in sidelink resource allocation mode 2	283
8.2.4.2A	UE procedure for determining slots and SL PRS resource(s) associated with an SCI format 1-B in a dedicated SL PRS resource pool	284
8.2.4.3	Sidelink congestion control in a dedicated SL PRS resource pool in sidelink resource allocation mode 2.....	285
8.3	UE procedure for receiving the physical sidelink shared channel	286
8.4	UE procedure for receiving reference signals	286
8.4.1	CSI-RS reception procedure	286
8.4.2	DM-RS reception procedure for RSRP computation.....	286
8.4.3	PT-RS reception procedure.....	286
8.4.4	SL PRS reception procedure.....	286
8.5	UE procedure for reporting channel state information (CSI)	287
8.5.1	Channel state information framework.....	287
8.5.1.1	Reporting configurations.....	287
8.5.1.2	Triggering of sidelink CSI reports	288
8.5.2	Channel state information.....	288
8.5.2.1	CSI reporting quantities	288
8.5.2.1.1	Channel quality indicator (CQI).....	288
8.5.2.2	Reference signal (CSI-RS).....	288
8.5.2.3	CSI reference resource definition.....	289
8.5.3	CSI reporting	289
8.6	UE PSSCH preparation procedure time	289
9	UE procedures for transmitting and receiving for RTT-based propagation delay compensation	290
9.1	PRS reception procedure for RTT-based propagation delay compensation	291
Annex <A> (informative): Change history		293
History		305

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 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"
- [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)"
- [18] 3GPP TS 38.822: "NR; User Equipment (UE) feature list"
- [19] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures"
- [20] 3GPP TS 38.305: "NG Radio Access Network (NG-RAN); Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN"
- [21] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"
- [22] 3GPP TS 38.101-5: "NR; User Equipment (UE) radio transmission and reception; Part 5: Satellite access Radio Frequency (RF) and performance requirements"

3 Definitions of terms, symbols and abbreviations

3.1 Terms

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].

ARP	Antenna Reference Point
BWP	Bandwidth Part
CBG	Code Block Group
CJT	Coherent Joint Transmission
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-Interference-plus-Noise Ratio
CW	Codeword
DCI	Downlink Control Information
DL	Downlink
DM-RS	Demodulation Reference Signal
DRX	Discontinuous Reception
EPRE	Energy Per Resource Element
FR2-NTN	Frequency Range 2 for Non-terrestrial networks as defined in TS 38.101-5 [22]
IAB-MT	Integrated Access and Backhaul – Mobile Termination
L1-RSRP	Layer 1 Reference Signal Received Power
LI	Layer Indicator
LoS	Line of Sight
MCS	Modulation and Coding Scheme
NCJT	Non-Coherent Joint Transmission
NCR	Network-controlled Repeater
NCR-MT	Network controlled repeater – Mobile Termination
NLoS	Non-Line of Sight
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
SCI	Sidelink Control Information
SL PRS	Sidelink Positioning 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-Interference-plus-Noise Ratio
TB	Transport Block
TCI	Transmission Configuration Indicator
TDCP	Time Domain Channel Properties
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 and to the NCR-MT part of an NCR 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 if the SS/PBCH block is associated with serving cell PCI, or derived from *ss-PBCH-BlockPower-r17* in *SSB-MTC-AdditionalPCI-r17* and *powerControlOffsetSS* provided by higher layers if the SS/PBCH block is associated with additional PCI different from serving cell PCI, where the CSI-RS is QCLed with the SS/PBCH block. 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 $\beta_{\text{PDSCH}}^{\text{DMRS}}$ specified in Clause 7.4.1.1.2 of [4, TS 38.211] is given by

$$\beta_{\text{PDSCH}}^{\text{DMRS}} = 10^{\frac{\beta_{\text{DMRS}}}{20}}.$$

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 and enhanced type 1	DM-RS configuration type 2 and enhanced 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 or Table 4.1-2A 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}), if *dmrs-TypeEnh* is not configured in *DMRS-DownlinkConfig*

<i>epre-Ratio</i>	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					

Table 4.1-2A: PT-RS EPRE to PDSCH EPRE per layer per RE (ρ_{PTRS}), if *dmrs-TypeEnh* is configured in *DMRS-DownlinkConfig*

<i>epre-Ratio</i>	The number of PDSCH layers with DM-RS associated to the PT-RS port							
	1	2	3	4	5	6	7	8
0	0	3	4.77	6	7	7.78	8.45	9
1	0	0	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 are supported by the UE, or subject to UE capability, a maximum of 32 HARQ processes per cell as defined in [13, TS 38.306]. 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* or *nrofHARQ-ProcessesForPDSCH-v1700*, 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, 1_2, 1_3, 4_0, 4_1, or 4_2 decode the corresponding PDSCHs as indicated by that DCI. When the UE is scheduled with multiple PDSCHs on a serving cell by a DCI, HARQ process ID indicated by this DCI applies to the first PDSCH not overlapping with a UL symbol indicated by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* if provided, HARQ process ID is then incremented by 1 for each subsequent PDSCH(s) in the scheduled order, with modulo operation of *nrofHARQ-*

ProcessesForPDSCH applied if *nrofHARQ-ProcessesForPDSCH* is provided, or with modulo operation of *nrofHARQ-ProcessesForPDSCH-v1700* applied if or *nrofHARQ-ProcessesForPDSCH-v1700* is provided, or with modulo operation of 8 applied, otherwise. HARQ process ID is not incremented for PDSCH(s) not received if at least one of the symbols indicated by the indexed row of the used resource allocation table in the slot overlaps with a UL symbol indicated by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* if provided. When a UE is configured by the higher layer parameter *repetitionScheme* set to 'tdmSchemeA', the PDSCH includes two PDSCH transmission occasions. For each PDSCH, if either PDSCH occasion overlaps with a UL symbol indicated by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* if provided, the PDSCH is not received and HARQ process ID is not increment for the PDSCH. 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 if the UE is not capable of receiving FDMed unicast and multicast PDSCH per slot per carrier. When HARQ feedback for the HARQ process ID is not disabled, or for the HARQ process associated with the first SPS PDSCH when *HARQ-feedbackEnablingforSPSActive* is provided and enabled, 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, TS 38.213]. For HARQ-ACK subject to HARQ-ACK deferral described in Clause 9.2.5.4 of [6 TS 38.213], the expected transmission of HARQ-ACK corresponds to the expected transmission HARQ-ACK in a first slot. When HARQ feedback for the HARQ process ID is disabled, the UE is not expected to receive another PDCCH carrying a DCI scheduling a PDSCH or set of slot-aggregated PDSCH scheduled for the given HARQ process or to receive another PDSCH without corresponding PDCCH for the given HARQ process that starts until $T_{\text{proc},1}$ after the end of the reception of the last PDSCH or slot-aggregated PDSCH for that HARQ process. Except for the case when a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet* and PDCCHs that schedule two PDSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex* and the UE reports its capability of *outOfOrderOperationDL-r16*, 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 $N_{\text{sym}}^{\text{slot}}$ symbols [4] or a number of symbols indicated by *subslotLengthForPUCCH* if provided, and the HARQ-ACK for the two PDSCHs are associated with the HARQ-ACK codebook of the same priority. Except for the case when a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet* and PDCCHs that schedule two PDSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex* and the UE reports its capability of *outOfOrderOperationDL-r16*, 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 on a scheduling cell, 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 of a scheduling cell,. When the PDCCH reception includes two PDCCH candidates from two respective search space sets, as described in clause 10.1 of [6, TS 38.213], the PDCCH ending in symbol i is determined based on the PDCCH candidate that ends later in time. 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 $\mu=0$, $N=13$ for $\mu=1$, $N=20$ for $\mu=2$, $N=24$ for $\mu=3$, $N=96$ for $\mu=5$, and $N=192$ for $\mu=6$.

When receiving PDSCH scheduled with SI-RNTI, P-RNTI, MCCH-RNTI, G-RNTI for broadcast, or Multicast MCCH-RNTI, G-RNTI for multicast in RRC_INACTIVE state, 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. If a UE is configured with *SSB-MTC-AdditionalPCI* and with *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet*, and if the UE is configured with *tag2-Id* for the SpCell, if the UE attempts to detect the DCI format 1_0 with CRC scrambled by the corresponding RA-RNTI or 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], and if the CORESET used for the PDCCH order transmission is not associated with the serving cell physical cell ID, the UE may assume that the DM-RS ports of the received PDSCH are quasi co-located with the DM-RS antenna port associated with PDCCH receptions in the CORESET for Type1-PDCCH CSS set with respect to Doppler shift, Doppler spread, average delay, delay spread, and 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, TS 38.321]) 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, MCS-C-RNTI, G-RNTI, G-CS-RNTI or MCCH-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 $14 \cdot 2^{\max(0, \mu-3)}$ symbols before the earliest starting symbol of the PDSCH(s) without the corresponding PDCCH transmission, where μ and the symbol duration are 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. When the PDCCH reception includes two PDCCH candidates from two respective search space sets, as described in clause 10 of [6, TS 38.213], for the purpose of determining the PDCCH with C-RNTI, CS-RNTI or MCS-C-RNTI scheduling the PDSCH ends at least $14 \cdot 2^{\max(0, \mu-3)}$ symbols before the earliest starting symbol of the PDSCH(s) without the corresponding PDCCH transmission, the PDCCH candidate that ends later in time is used.

The UE is not expected to decode a PDSCH scheduled with C-RNTI, MCS-C-RNTI, G-RNTI for multicast or broadcast, MCCH-RNTI, Multicast MCCH-RNTI, G-CS-RNTI or CS-RNTI if another PDSCH in the same cell scheduled with RA-RNTI or MSGB-RNTI partially or fully overlap in time.

If cell DTX is activated for the serving cell, the UE is not expected to decode a PDSCH scheduled without corresponding PDCCH transmission using SPS-Config that overlap in time with any non-active periods of cell DTX for the serving cell.

Furthermore, a UE indicating *supportOfRedCap* capability but not indicating *eRedCapNotReducedBB-BW* is not expected to decode a PDSCH scheduled with C-RNTI, MCS-C-RNTI, G-RNTI for multicast or broadcast, MCCH-RNTI, Multicast MCCH-RNTI, G-CS-RNTI or CS-RNTI in the same or next slot if another PDSCH in the same cell is scheduled with RA-RNTI or MSGB-RNTI, when the PDSCH scheduled with RA-RNTI or MSGB-RNTI is allocated more than 25 PRBs when configured with SCS $\mu = 0$ or more than 12 PRBs when configured with SCS $\mu = 1$.

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, where the PDSCH scheduled with TC-RNTI for a reduced capability UE that indicates *supportOfRedCap* is allocated no more than 25 PRBs when configured with SCS $\mu = 0$ or no more than 12 PRBs when configured with SCS $\mu = 1$, with the two PDSCHs partially or fully overlapping in time in non-overlapping PRBs.

The UE:

- is expected to decode PDSCH scheduled with MCCH-RNTI or Multicast MCCH-RNTI, and PBCH in PCell that partially or fully overlaps in time in non-overlapping PRBs in PCell.
- is not expected to decode PDSCH scheduled with G-RNTI for broadcast and PBCH in PCell that partially or fully overlaps in time in non-overlapping PRBs in PCell.
- is not expected to decode PDSCH scheduled with G-RNTI for multicast and PBCH in PCell that partially or fully overlaps in time in non-overlapping PRBs in PCell.

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-