

ETSI TS 138 214 V17.4.0 (2023-01)



5G;
NR;
Physical layer procedures for data
(3GPP TS 38.214 version 17.4.0 Release 17)

ETSI TS 138 214 V17.4.0 (2023-01)

<https://standards.iteh.ai/catalog/standards/sist/4140b15d-e610-4f9b-abc8-4c7b008b4ef9/etsi-ts-138-214-v17-4-0-2023-01>



Reference

RTS/TSGR-0138214vh40

Keywords

5G

ETSI

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
Sous-Préfecture de Grasse (06) N° w061004871

Important notice

The present document can be downloaded from:

<http://www.etsi.org/standards-search>

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the prevailing version of an ETSI deliverable is the one made publicly available in PDF format at www.etsi.org/deliver.

Users of the present document should be aware that the document may be subject to revision or change of status.

Information on the current status of this and other ETSI documents is available at

<https://portal.etsi.org/TB/ETSIDeliverableStatus.aspx>

If you find errors in the present document, please send your comment to one of the following services:

<https://portal.etsi.org/People/CommitteeSupportStaff.aspx>

If you find a security vulnerability in the present document, please report it through our

Coordinated Vulnerability Disclosure Program:

<https://www.etsi.org/standards/coordinated-vulnerability-disclosure>

Notice of disclaimer & limitation of liability

The information provided in the present deliverable is directed solely to professionals who have the appropriate degree of experience to understand and interpret its content in accordance with generally accepted engineering or other professional standard and applicable regulations.

No recommendation as to products and services or vendors is made or should be implied.

No representation or warranty is made that this deliverable is technically accurate or sufficient or conforms to any law and/or governmental rule and/or regulation and further, no representation or warranty is made of merchantability or fitness for any particular purpose or against infringement of intellectual property rights.

In no event shall ETSI be held liable for loss of profits or any other incidental or consequential damages.

Any software contained in this deliverable is provided "AS IS" with no warranties, express or implied, including but not limited to, the warranties of merchantability, fitness for a particular purpose and non-infringement of intellectual property rights and ETSI shall not be held liable in any event for any damages whatsoever (including, without limitation, damages for loss of profits, business interruption, loss of information, or any other pecuniary loss) arising out of or related to the use of or inability to use the software.

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

© ETSI 2023.
All rights reserved.

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (<https://ipr.etsi.org/>).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM®** and the GSM logo are trademarks registered and owned by the GSM Association.

Legal Notice

This Technical Specification (TS) has been produced by ETSI 3rd Generation Partnership Project (3GPP).

The present document may refer to technical specifications or reports using their 3GPP identities. These shall be interpreted as being references to the corresponding ETSI deliverables.

The cross reference between 3GPP and ETSI identities can be found under <http://webapp.etsi.org/key/queryform.asp>.

Modal verbs terminology

In the present document **"shall"**, **"shall not"**, **"should"**, **"should not"**, **"may"**, **"need not"**, **"will"**, **"will not"**, **"can"** and **"cannot"** are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

"must" and **"must not"** are **NOT** allowed in ETSI deliverables except when used in direct citation.

Contents

Intellectual Property Rights	2
Legal Notice	2
Modal verbs terminology.....	2
Foreword.....	7
1 Scope	8
2 References	8
3 Definitions, symbols and abbreviations	9
3.1 Definitions	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	15
5.1.1.1 Transmission scheme 1	15
5.1.2 Resource allocation.....	16
5.1.2.1 Resource allocation in time domain	16
5.1.2.1.1 Determination of the resource allocation table to be used for PDSCH.....	20
5.1.2.2 Resource allocation in frequency domain	24
5.1.2.2.1 Downlink resource allocation type 0.....	25
5.1.2.2.2 Downlink resource allocation type 1	25
5.1.2.2.3 Downlink resource allocation type 1 for multicast/broadcast.....	26
5.1.2.3 Physical resource block (PRB) bundling.....	27
5.1.3 Modulation order, target code rate, redundancy version and transport block size determination.....	29
5.1.3.1 Modulation order and target code rate determination	31
5.1.3.2 Transport block size determination	36
5.1.4 PDSCH resource mapping	39
5.1.4.1 PDSCH resource mapping with RB symbol level granularity	40
5.1.4.2 PDSCH resource mapping with RE level granularity	41
5.1.5 Antenna ports quasi co-location.....	43
5.1.6 UE procedure for receiving reference signals	50
5.1.6.1 CSI-RS reception procedure.....	50
5.1.6.1.1 CSI-RS for tracking.....	51
5.1.6.1.2 CSI-RS for L1-RSRP and L1-SINR computation	54
5.1.6.1.3 CSI-RS for mobility	54
5.1.6.2 DM-RS reception procedure	55
5.1.6.3 PT-RS reception procedure	57
5.1.6.4 SRS reception procedure for CLI.....	59
5.1.6.5 PRS reception procedure.....	59
5.1.7 Code block group based PDSCH transmission.....	66
5.1.7.1 UE procedure for grouping of code blocks to code block groups	66
5.1.7.2 UE procedure for receiving code block group based transmissions.....	66
5.2 UE procedure for reporting channel state information (CSI)	67
5.2.1 Channel state information framework.....	67
5.2.1.1 Reporting settings	67
5.2.1.2 Resource settings.....	68
5.2.1.3 (void).....	69
5.2.1.4 Reporting configurations.....	69
5.2.1.4.1 Resource Setting configuration	71
5.2.1.4.2 Report Quantity Configurations	73
5.2.1.4.3 L1-RSRP Reporting.....	76
5.2.1.4.4 L1-SINR Reporting	77

5.2.1.5	Triggering/activation of CSI Reports and CSI-RS	78
5.2.1.5.1	Aperiodic CSI Reporting/Aperiodic CSI-RS when the triggering PDCCH and the CSI-RS have the same numerology	78
5.2.1.5.1a	Aperiodic CSI Reporting/Aperiodic CSI-RS when the triggering PDCCH and the CSI-RS have different numerologies	82
5.2.1.5.2	Semi-persistent CSI/Semi-persistent CSI-RS	84
5.2.1.5.3	Aperiodic CSI-RS for tracking for fast SCell activation	86
5.2.1.6	CSI processing criteria	86
5.2.2	Channel state information	87
5.2.2.1	Channel quality indicator (CQI)	87
5.2.2.1.1	(void)	90
5.2.2.2	Precoding matrix indicator (PMI)	90
5.2.2.2.1	Type I Single-Panel Codebook	90
5.2.2.2.2	Type I Multi-Panel Codebook	97
5.2.2.2.3	Type II Codebook	101
5.2.2.2.4	Type II Port Selection Codebook	108
5.2.2.2.5	Enhanced Type II Codebook	110
5.2.2.2.6	Enhanced Type II Port Selection Codebook	117
5.2.2.2.7	Further enhanced Type II port selection codebook	119
5.2.2.3	Reference signal (CSI-RS)	123
5.2.2.3.1	NZP CSI-RS	123
5.2.2.4	Channel State Information – Interference Measurement (CSI-IM)	125
5.2.2.5	CSI reference resource definition	125
5.2.3	CSI reporting using PUSCH	128
5.2.4	CSI reporting using PUCCH	131
5.2.5	Priority rules for CSI reports	132
5.3	UE PDSCH processing procedure time	133
5.3.1	Application delay of the minimum scheduling offset restriction	135
5.4	UE CSI computation time	136
5.5	UE PDSCH reception preparation time with cross carrier scheduling with different subcarrier spacings for PDCCH and PDSCH	137
6	Physical uplink shared channel related procedure	138
6.1	UE procedure for transmitting the physical uplink shared channel	138
6.1.1	Transmission schemes	140
6.1.1.1	Codebook based UL transmission	140
6.1.1.2	Non-Codebook based UL transmission	142
6.1.2	Resource allocation	143
6.1.2.1	Resource allocation in time domain	143
6.1.2.1.1	Determination of the resource allocation table to be used for PUSCH	154
6.1.2.2	Resource allocation in frequency domain	157
6.1.2.2.1	Uplink resource allocation type 0	157
6.1.2.2.2	Uplink resource allocation type 1	158
6.1.2.2.3	Uplink resource allocation type 2	159
6.1.2.3	Resource allocation for uplink transmission with configured grant	160
6.1.2.3.1	Transport Block repetition for uplink transmissions of PUSCH repetition Type A with a configured grant	162
6.1.2.3.2	Transport Block repetition for uplink transmissions of PUSCH repetition Type B with a configured grant	164
6.1.2.3.3	Transport Block repetition for uplink transmissions of TB processing over multiple slots with a configured grant	165
6.1.3	UE procedure for applying transform precoding on PUSCH	166
6.1.4	Modulation order, redundancy version and transport block size determination	166
6.1.4.1	Modulation order and target code rate determination	168
6.1.4.2	Transport block size determination	173
6.1.5	Code block group based PUSCH transmission	174
6.1.5.1	UE procedure for grouping of code blocks to code block groups	174
6.1.5.2	UE procedure for transmitting code block group based transmissions	175
6.1.6	Uplink switching	175
6.1.6.1	Uplink switching for EN-DC	175
6.1.6.2	Uplink switching for carrier aggregation	176
6.1.6.2.1	void	177

6.1.6.3	Uplink switching for supplementary uplink.....	177
6.1.7	UE procedure for determining time domain windows for bundling DM-RS.....	177
6.2	UE reference signal (RS) procedure.....	180
6.2.1	UE sounding procedure	180
6.2.1.1	UE SRS frequency hopping procedure	187
6.2.1.2	UE sounding procedure for DL CSI acquisition	188
6.2.1.3	UE sounding procedure between component carriers	193
6.2.1.4	UE sounding procedure for positioning purposes	195
6.2.2	UE DM-RS transmission procedure	196
6.2.3	UE PT-RS transmission procedure	198
6.2.3.1	UE PT-RS transmission procedure when transform precoding is not enabled.....	198
6.2.3.2	UE PT-RS transmission procedure when transform precoding is enabled.....	200
6.3	UE PUSCH frequency hopping procedure	201
6.3.1	Frequency hopping for PUSCH repetition Type A and for TB processing over multiple slots	201
6.3.2	Frequency hopping for PUSCH repetition Type B	202
6.4	UE PUSCH preparation procedure time.....	203
7	UE procedures for transmitting and receiving on a carrier with intra-cell guard bands.....	204
8	Physical sidelink shared channel related procedures.....	205
8.1	UE procedure for transmitting the physical sidelink shared channel	206
8.1.1	Transmission schemes	208
8.1.2	Resource allocation.....	208
8.1.2.1	Resource allocation in time domain	208
8.1.2.2	Resource allocation in frequency domain	209
8.1.3	Modulation order, target code rate, redundancy version and transport block size determination.....	209
8.1.3.1	Modulation order and target code rate determination	209
8.1.3.2	Transport block size determination	209
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	210
8.1.4A	UE procedure for determining a set of preferred or non-preferred resources for another UE's transmission	215
8.1.4B	Void	216
8.1.4C	UE procedure for using a received non-preferred resource set	216
8.1.5	UE procedure for determining slots and resource blocks for PSSCH transmission associated with an SCI format 1-A	217
8.1.5A	UE procedure for determining slots and resource blocks indicated by a preferred or non-preferred resource set	218
8.1.6	Sidelink congestion control in sidelink resource allocation mode 2	218
8.1.7	UE procedure for determining the number of logical slots for a reservation period.....	219
8.2	UE procedure for transmitting sidelink reference signals	219
8.2.1	CSI-RS transmission procedure.....	219
8.2.2	PSSCH DM-RS transmission procedure.....	220
8.2.3	PT-RS transmission procedure	220
8.3	UE procedure for receiving the physical sidelink shared channel	220
8.4	UE procedure for receiving reference signals	221
8.4.1	CSI-RS reception procedure	221
8.4.2	DM-RS reception procedure for RSRP computation.....	221
8.4.3	PT-RS reception procedure.....	221
8.5	UE procedure for reporting channel state information (CSI)	221
8.5.1	Channel state information framework.....	221
8.5.1.1	Reporting configurations.....	221
8.5.1.2	Triggering of sidelink CSI reports	222
8.5.2	Channel state information.....	222
8.5.2.1	CSI reporting quantities	222
8.5.2.1.1	Channel quality indicator (CQI)	222
8.5.2.2	Reference signal (CSI-RS).....	222
8.5.2.3	CSI reference resource definition.....	222
8.5.3	CSI reporting	223
8.6	UE PSSCH preparation procedure time	223
9	UE procedures for transmitting and receiving for RTT-based propagation delay compensation	224
9.1	PRS reception procedure for RTT-based propagation delay compensation	224

Annex <A> (informative): Change history227

History235

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ETSI TS 138 214 V17.4.0 (2023-01)
<https://standards.iteh.ai/catalog/standards/sist/4140b15d-e610-4f9b-abc8-4c7b008b4ef9/etsi-ts-138-214-v17-4-0-2023-01>

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

- x the first digit:
 - 1 presented to TSG for information;
 - 2 presented to TSG for approval;
 - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ETSI TS 138 214 V17.4.0 (2023-01)

<https://standards.iteh.ai/catalog/standards/sist/4140b15d-e610-4f9b-abc8-4c7b008b4ef9/etsi-ts-138-214-v17-4-0-2023-01>

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)"
- [18] 3GPP TS 38.822: "NR; User Equipment (UE) feature list"

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	Demodulation reference signals
DRX	Discontinuous Reception
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
SCI	Sidelink control information
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 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	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 *epr-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 *epr-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 *epr-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})

<i>epr-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					

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, 4_0, 4_1, 4_2 or 1_2 decode the corresponding PDSCHs as indicated by that DCI. When the UE is scheduled with multiple PDSCHs 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. 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 $T_{proc,1}$ 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*, 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*, 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, G-RNTI for broadcast or MCCH-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 fallback 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 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 $14 \cdot 2^{\max(0, \mu-3)}$ 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, 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.

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.

The UE:

- is expected to decode PDSCH scheduled with 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-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.

The maximum number of PDSCHs scheduled per slot per component carrier with C-RNTI/CS-RNTI and G-RNTI/G-CS-RNTI/MCCH-RNTI that the UE shall be able to decode is the same as the indicated UE capability for the number of unicast PDSCHs per slot per component carrier. If the UE is capable of receiving FDMed unicast and multicast PDSCH per slot per carrier, the UE shall be able to decode a PDSCH scheduled with C-RNTI/CS-RNTI and a PDSCH scheduled with G-RNTI for multicast/G-CS-RNTI that partially or fully overlap in time in non-overlapping PRBs. If the UE is capable of receiving FDMed unicast and broadcast PDSCH per slot per carrier, the UE shall be able to decode a PDSCH scheduled with C-RNTI/CS-RNTI and a PDSCH scheduled with G-RNTI for broadcast/MCCH-RNTI that partially or fully overlap in time in non-overlapping PRBs.

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

The UE it is not expected to support reception of FDMed MCCH PDSCH and broadcast MTCH PDSCH in PCell or SCell, or FDMed multiple broadcast MTCH PDSCHs in PCell or SCell, or FDMed MCCH/broadcast MTCH/multicast PDSCH and SIB PDSCH in PCell, or FDMed multicast PDSCHs in PCell or SCell, or FDMed multicast PDSCH and MCCH/broadcast MTCH PDSCH in PCell or SCell, or FDMed MCCH/broadcast MTCH/multicast PDSCH and paging PDSCH.

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 configured with *SSB-MTC-AdditionalPCI*, *ControlResourceSets* corresponding to different *coresetPoolIndex* values may be associated with different physical cell IDs via activated TCI states of the *ControlResourceSets*, where *ControlResourceSets* corresponding to one *coresetPoolIndex* is associated with the serving cell physical cell ID and *ControlResourceSets* corresponding to another *coresetPoolIndex* can be associated with another physical cell ID. 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* if the UE is configured with higher layer parameter *repetitionNumber* for the same PDSCH.

When a UE is configured by higher layer parameter *repetitionScheme* 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* in *PDSCH-TimeDomainResourceAllocation*, 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* in *PDSCH-TimeDomainResourceAllocation* 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* 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* 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* in *PDSCH-TimeDomainResourceAllocation*, 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)*' and it is not configured with higher layer parameter *sfnSchemePdsch*, 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* in *PDSCH-TimeDomainResourceAllocation*, 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.