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Foreword

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1 Scope

The present document specifies and establishes the characteristics of the physicals layer procedures of data channels for 5G-NR.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications"

[2] 3GPP TS 38.201: " NR; Physical Layer – General Description"

[3] 3GPP TS 38.202: "NR; Services provided by the physical layer"

[4] 3GPP TS 38.211: "NR; Physical channels and modulation"

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

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

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

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

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

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

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

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

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

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

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

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

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

3 Definitions, symbols and abbreviations

3.1 Definitions

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

3.2 Symbols

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

3.3 Abbreviations

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

BWP	Bandwidth part
CBG	Code block group
CLI	Cross Link Interference
CP	Cyclic prefix
CQI	Channel quality indicator
CPU	CSI processing unit
CRB	Common resource block
CRC	Cyclic redundancy check
CRI	CSI-RS Resource Indicator
CSI	Channel state information
CSI-RS	Channel state information reference signal
CSI-RSRP	CSI reference signal received power
CSI-RSRQ	CSI reference signal received quality
CSI-SINR	CSI signal-to-noise and interference ratio
CW	Codeword
DCI	Downlink control information
DL	Downlink
DM-RS	Dedicated demodulation reference signals
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. The downlink reference-signal transmit power is defined as the linear average over the power contributions (in [W]) of the resource elements that carry the configured CSI-RS within the operating system bandwidth.

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

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

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

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

- if the UE is configured with the higher layer parameter *epre-Ratio*, the ratio of PT-RS EPRE to PDSCH EPRE per layer per RE for each PT-RS port (ρ_{PTRS}) is given by Table 4.1-2 according to the *epre-Ratio*, the PT-RS scaling factor β_{PTRS} specified in clause 7.4.1.2.2 of [4, TS 38.211] is given by $\beta_{PTRS} = 10^{\frac{\rho_{PTRS}}{20}}$.
- otherwise, the UE shall assume *epre-Ratio* is set to state '0' in Table 4.1-2 if not configured.

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

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

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

5 Physical downlink shared channel related procedures

5.1 UE procedure for receiving the physical downlink shared channel

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

A UE shall upon detection of a PDCCH with a configured DCI format 1_0, 1_1 or 1_2 decode the corresponding PDSCHs as indicated by that DCI. For any HARQ process ID(s) in a given scheduled cell, the UE is not expected to receive a PDSCH that overlaps in time with another PDSCH. The UE is not expected to receive another PDSCH for a given HARQ process until after the end of the expected transmission of HARQ-ACK for that HARQ process, where the timing is given by Clause 9.2.3 of [6]. 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_{sym}^{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, the UE is not expected to be scheduled to receive a PDSCH starting earlier than the end of the first PDSCH with a PDCCH that ends later than symbol i. In a given scheduled cell, for any PDSCH corresponding to SI-RNTI, the UE is not expected to decode a re-transmission of an earlier PDSCH with a starting symbol less than N symbols after the last symbol of that PDSCH, where the value of N depends on the PDSCH subcarrier spacing configuration μ, with N=13 for μ=0, N=13 for μ=1, N=20 for μ=2, and N=24 for μ=3.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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)'*, 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.

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

– Step 0: set $j=0$, where j is the number of selected PDSCH(s) for decoding. Q is the set of activated PDSCHs without corresponding PDCCH transmissions within the slot

– Step 1: A UE receives one PDSCH with the lowest configured *sps-ConfigIndex* within *Q*, set $j=j+1$. Designate the received PDSCH as survivor PDSCH.

– Step 2: The survivor PDSCH in step 1 and any other PDSCH(s) overlapping (even partially) with the survivor PDSCH in step 1 are excluded from *Q*.

– Step 3: Repeat step 1 and 2 until *Q* is empty or *j* is equal to the number of unicast PDSCHs in a slot supported by the UE

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 K_s, where $K_S = \left\lfloor n \cdot \frac{2^{\mu_{PDSCH}}}{2^{\mu_{PDCCH}}} \right\rfloor + K_0 + \left\lfloor \left(\frac{N_{slot,offset,PDCCH}^{CA}}{2^{\mu_{offset,PDCCH}}} - \frac{N_{slot,offset,PDSCH}^{CA}}{2^{\mu_{offset,PDSCH}}} \right) \cdot 2^{\mu_{PDSCH}} \right\rfloor$, if UE is configured with *ca-SlotOffset* for at least one of the scheduled and scheduling cell, and $K_s = \left\lfloor n \cdot \frac{2^{\mu_{PDSCH}}}{2^{\mu_{PDCCH}}} \right\rfloor + K_0$, otherwise, and

  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

- $N_{\mathrm{slot,\,offset,\,PDCCH}}^{\mathrm{CA}}$ and $\mu_{\mathrm{offset,\,PDCCH}}$ are the $N_{\mathrm{slot,\,offset}}^{\mathrm{CA}}$ and the μ_{offset}, respectively, which are determined by higher-layer configured *ca-SlotOffset,* for the cell receiving the PDCCH respectively, $N_{\mathrm{slot,\,offset,\,PDSCH}}^{\mathrm{CA}}$ and $\mu_{\mathrm{offset,\,PDSCH}}$ are the $N_{\mathrm{slot,\,offset}}^{\mathrm{CA}}$ and the μ_{offset}, respectively, which are determined by higher-layer configured *ca-SlotOffset* for the cell receiving the PDSCH, as defined in clause 4.5 of [4, TS 38.211].

- The reference point S_0 for starting symbol *S* is defined as:

  - if configured with *referenceOfSLIVDCI-1-2*, and when receiving PDSCH scheduled by DCI format 1_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI with $K_0=0$, and PDSCH mapping Type B, the starting symbol *S* is relative to the starting symbol S_0 of the PDCCH monitoring occasion where DCI format 1_2 is detected;

  - otherwise, the starting symbol *S* is relative to the start of the slot using $S_0=0$.

- The number of consecutive symbols *L* counting from the starting 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 $0 < L \le 14 - S$, 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 satisfying $S_0 + S + L \le 14$ for normal cyclic prefix and $S_0 + S + L \le 12$ for extended cyclic prefix 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,…,13}	{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 or 1_2 in PDCCH with CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI with NDI=1, if the UE is configured with *pdsch-AggregationFactor* in *pdsch-config*, the same symbol allocation is applied across the *pdsch-AggregationFactor* consecutive slots. When receiving PDSCH scheduled by DCI format 1_1 or 1_2 in PDCCH with CRC scrambled by CS-RNTI with NDI=0, or PDSCH scheduled without corresponding PDCCH transmission using *sps-Config* and activated by DCI format 1_1 or 1_2, the same symbol allocation is applied across the *pdsch-AggregationFactor,* in *sps-Config* if configured, or across the *pdsch-AggregationFactor* in *pdsch-config* otherwise, 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. For PDSCH scheduled by DCI format 1_1 or 1_2 in PDCCH with CRC scrambled by CS-RNTI with NDI=0, or PDSCH scheduled without corresponding PDCCH transmission using *sps-Config* and activated by DCI format 1_1 or 1_2, the UE is not expected to be configured with the time duration for the reception of *pdsch-AggregationFactor* repetitions, in *sps-Config* if configured, or across the *pdsch-AggregationFactor* in *pdsch-config* otherwise, larger than the time duration derived by the periodicity P obtained from the corresponding *sps-Config*. 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 or 1_2.

If a UE is configured with higher layer parameter *repetitionNumber* or if the UE is configured by *repetitionScheme* set to one of ' fdmSchemeA', ' fdmSchemeB' and 'tdmSchemeA', the UE does not expect to be configured with *pdsch-AggregationFactor.*

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.

When the UE is configured with *minimumSchedulingOffsetK0* in an active DL BWP it applies a minimum scheduling offset restriction indicated by the 'Minimum applicable scheduling offset indicator' field in DCI format 1_1 or DCI format 0_1 if the same field is available. When the UE is configured with *minimumSchedulingOffsetK0* in an active DL BWP and it has not received 'Minimum applicable scheduling offset indicator' field in DCI format 0_1 or 1_1, the UE shall apply a minimum scheduling offset restriction indicated based on 'Minimum applicable scheduling offset indicator' value '0'. When the minimum scheduling offset restriction is applied the UE is not expected to be scheduled with a DCI in slot n to receive a PDSCH scheduled with C-RNTI, CS-RNTI or MCS-C-RNTI with K_0 smaller than $\left\lceil K_{0min} \cdot \frac{2^{\mu'}}{2^{\mu}} \right\rceil$, where $K_{0\min}$ and μ are the applied minimum scheduling offset restriction and the numerology of the active DL BWP of the scheduled cell when receiving the DCI in slot n, respectively, and μ' is the numerology of the new active DL BWP in case of active DL BWP change in the scheduled cell and is equal to μ, otherwise. The minimum scheduling offset restriction is not applied when PDSCH transmission is scheduled with C-RNTI, CS-RNTI or MCS-C-RNTI in common search space associated with CORESET0 and default PDSCH time domain resource allocation is used, in the search space set provided by *recoverySearchSpaceId* when monitoring PDCCH as described in [6, TS 38.213] or when PDSCH transmission is scheduled with SI-RNTI, MSGB-RNTI or RA-RNTI. The application delay of the change of the minimum scheduling offset restriction is determined in Clause 5.3.1.

The UE is not expected to be configured with *referenceOfSLIVDCI-1-2* for serving cells configured for cross-carrier scheduling with a scheduling cell of a different downlink SCS configuration.

When a UE is configured by the higher layer parameter *repetitionScheme* set to 'tdmSchemeA' and indicated DM-RS port(s) within one CDM group in the DCI field '*Antenna Port(s)*', the number of PDSCH transmission occasions is derived by the number of TCI states indicated by the DCI field *'Transmission Configuration Indication'* of the scheduling DCI.

- If two TCI states are indicated by the DCI field '*Transmission Configuration Indication*', the UE is expected to receive two PDSCH transmission occasions, where the first TCI state is applied to the first PDSCH transmission occasion and resource allocation in time domain for the first PDSCH transmission occasion follows Clause 5.1.2.1. The second TCI state is applied to the second PDSCH transmission occasion, and the second PDSCH transmission occasion shall have the same number of symbols as the first PDSCH transmission occasion. If the UE is configured by the higher layers with a value $\overline{K}$ in *StartingSymbolOffsetK*, it shall determine that the first symbol of the second PDSCH transmission occasion starts after $\overline{K}$ symbols from the last symbol of the first PDSCH transmission occasion. If the value $\overline{K}$ is not configured via the higher layer parameter *StartingSymbolOffsetK*, $\overline{K}$ = 0 shall be assumed by the UE. The UE is not expected to receive more than two PDSCH transmission layers for each PDSCH transmission occasion. For two PDSCH transmission occasions, the redundancy version to be applied is derived according to Table 5.1.2.1-2, where $n = 0, 1$ applied respectively to the first and second TCI state. The UE expects the PDSCH mapping type indicated by DCI field '*Time domain resource assignment*' to be mapping type B, and the indicated PDSCH mapping type is applied to both PDSCH transmission occasions.

- Otherwise, the UE is expected to receive a single PDSCH transmission occasion, and the resource allocation in the time domain follows Clause 5.1.2.1.

When a UE configured by the higher layer parameter *PDSCH-config* that indicates at least one entry contains *repetitionNumber* in *PDSCH-TimeDomainResourceAllocation*,

- If two TCI states are indicated by 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)', the same SLIV is applied for all PDSCH transmission occasions across the *repetitionNumber* consecutive slots, the first TCI state is applied to the first PDSCH transmission occasion and resource allocation in time domain for the first PDSCH transmission occasion follows Clause 5.1.2.1.

  When the value indicated by *repetitionNumber* in *PDSCH-TimeDomainResourceAllocation* equals to two, the second TCI state is applied to the second PDSCH transmission occasion. When the value indicated by *repetitionNumber* in *PDSCH-TimeDomainResourceAllocation* is larger than two, the UE may be further configured to enable *cyclicMapping* or *sequenticalMapping* in *tciMapping*.

  - When *cyclicMapping* is enabled, the first and second TCI states are applied to the first and second PDSCH transmission occasions, respectively, and the same TCI mapping pattern continues to the remaining PDSCH transmission occasions.

  - When *sequenticalMapping* is enabled, first TCI state is applied to the first and second PDSCH transmission occasions, and the second TCI state is applied to the third and fourth PDSCH transmission occasions, and the same TCI mapping pattern continues to the remaining PDSCH transmission occasions.

The UE may expect that each PDSCH transmission occasion is limited to two transmission layers. For all PDSCH transmission occasions associated with the first TCI state, the redundancy version to be applied is derived according to Table 5.1.2.1-2, where n is counted only considering PDSCH transmission occasions associated with the first TCI state. The redundancy version for PDSCH transmission occasions associated with the second TCI state is derived according to Table 5.1.2.1-3, where additional shifting operation for each redundancy version rv_s is configured by higher layer parameter *sequenceOffsetforRV* and n is counted only considering PDSCH transmission occasions associated with the second TCI state.

Table 5.1.2.1-3: Applied redundancy version for the second TCI state when *sequenceOffsetforRV* is present

rv_{id} indicated by the DCI scheduling the PDSCH	rv_{id} to be applied to n^{th} transmission occasion with second TCI state			
	n mod 4 = 0	n mod 4 = 1	n mod 4 = 2	n mod 4 = 3
0	$(0 + rv_s) \bmod 4$	$(2 + rv_s) \bmod 4$	$(3 + rv_s) \bmod 4$	$(1 + rv_s) \bmod 4$
2	$(2 + rv_s) \bmod 4$	$(3 + rv_s) \bmod 4$	$(1 + rv_s) \bmod 4$	$(0 + rv_s) \bmod 4$
3	$(3 + rv_s) \bmod 4$	$(1 + rv_s) \bmod 4$	$(0 + rv_s) \bmod 4$	$(2 + rv_s) \bmod 4$
1	$(1 + rv_s) \bmod 4$	$(0 + rv_s) \bmod 4$	$(2 + rv_s) \bmod 4$	$(3 + rv_s) \bmod 4$

- If one TCI state is indicated by 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)', the same SLIV is applied for all PDSCH transmission occasions across the *repetitionNumber* consecutive slots, the first PDSCH transmission occasion follows Clause 5.1.2.1, the same TCI state is applied to all PDSCH transmission occasions. The UE may expect that each PDSCH transmission occasion is limited to two transmission layers. For all PDSCH transmission occasions, the redundancy version to be applied is derived according to Table 5.1.2.1-2, where n is counted considering PDSCH transmission occasions.

- Otherwise, the UE is expected to receive a single PDSCH transmission occasion, and the resource allocation in the time domain follows Clause 5.1.2.1.

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

Table 5.1.2.1.1-1 and Table 5.1.2.1.1-1A define 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* or *pdsch-TimeDomainAllocationListDCI-1-2* is applied. For operation with shared spectrum channel access, as described in [16, TS 37.213], UE reinterprets *S* and *L* in row 9 of Table 5.1.2.1.1-2 as *S=6* and *L=7*.

Table 5.1.2.1.1-1: Applicable PDSCH time domain resource allocation for DCI formats 1_0 and 1_1

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, MSGB-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	1,2,3	No	No	Default A
		1,2,3	Yes	No	*pdsch-TimeDomainAllocationList* provided in *PDSCH-ConfigCommon*
	UE specific search space	1,2,3	No/Yes	Yes	*pdsch-TimeDomainAllocationList* provided in *PDSCH-Config*

Table 5.1.2.1.1-1A: Applicable PDSCH time domain resource allocation for DCI format 1_2

PDSCH-ConfigCommon includes *pdsch-TimeDomainAllocationList*	*PDSCH-Config includes pdsch-TimeDomainAllocationList*	*PDSCH-Config* includes *pdsch-TimeDomainAllocationListForDCI-Format1-2*	PDSCH time domain resourc allocation to apply
No	No	No	Default A
Yes	No	No	*pdsch-TimeDomainAllocationLi* provided in *PDSCH-ConfigCommon*
No/Yes	Yes	No	*pdsch-TimeDomainAllocationLi* provided in *PDSCH-Config*
No/Yes	No/Yes	Yes	*pdsch-TimeDomainAllocationListDCI-1* 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

Table 5.1.2.1.1-4: Default PDSCH time domain resource allocation B

Row index	*dmrs-TypeA-Position*	PDSCH mapping type	K_0	*S*	*L*
1	2,3	Type B	0	2	2
2	2,3	Type B	0	4	2
3	2,3	Type B	0	6	2
4	2,3	Type B	0	8	2
5	2,3	Type B	0	10	2
6	2,3	Type B	1	2	2
7	2,3	Type B	1	4	2
8	2,3	Type B	0	2	4
9	2,3	Type B	0	4	4
10	2,3	Type B	0	6	4
11	2,3	Type B	0	8	4
12 (Note 1)	2,3	Type B	0	10	4
13 (Note 1)	2,3	Type B	0	2	7
14 (Note 1)	2	Type A	0	2	12
	3	Type A	0	3	11
15	2,3	Type B	1	2	4
16	Reserved				
Note 1: If the PDSCH was scheduled with SI-RNTI in PDCCH Type0 common search space, the UE may assume that this PDSCH resource allocation is not applied					

Table 5.1.2.1.1-5: Default PDSCH time domain resource allocation C

Row index	*dmrs-TypeA-Position*	PDSCH mapping type	K_0	*S*	*L*
1 (Note 1)	2,3	Type B	0	2	2
2	2,3	Type B	0	4	2
3	2,3	Type B	0	6	2
4	2,3	Type B	0	8	2
5	2,3	Type B	0	10	2
6	Reserved				
7	Reserved				
8	2,3	Type B	0	2	4
9	2,3	Type B	0	4	4
10	2,3	Type B	0	6	4
11	2,3	Type B	0	8	4
12	2,3	Type B	0	10	4
13 (Note 1)	2,3	Type B	0	2	7
14 (Note 1)	2	Type A	0	2	12
	3	Type A	0	3	11
15 (Note 1)	2,3	Type A	0	0	6
16 (Note 1)	2,3	Type A	0	2	6
Note 1: The UE may assume that this PDSCH resource allocation is not used, if the PDSCH was scheduled with SI-RNTI in PDCCH Type0 common search space					

5.1.2.2 Resource allocation in frequency domain

Two downlink resource allocation schemes, type 0 and type 1, are supported. The UE shall assume that when the scheduling grant is received with DCI format 1_0, then downlink resource allocation type 1 is used.

If the scheduling DCI is configured to indicate the downlink resource allocation type as part of the '*Frequency domain resource assignment'* field by setting a higher layer parameter *resourceAllocation* in *PDSCH-Config* to 'dynamicSwitch', for DCI format 1_1 or setting a higher layer parameter *resourceAllocationDCI-1-2* in *PDSCH-Config* to 'dynamicSwitch' for DCI format 1_2, the UE shall use downlink resource allocation type 0 or type 1 as defined by this DCI field. Otherwise the UE shall use the downlink frequency resource allocation type as defined by the higher layer parameter *resourceAllocation* for DCI format 1_1 or by the higher layer parameter *resourceAllocationDCI-1-2* for DCI format 1_2.

If a bandwidth part indicator field is not configured in the scheduling DCI or the UE does not support active BWP change via DCI, the RB indexing for downlink type 0 and type 1 resource allocation is determined within the UE's active bandwidth part. If a bandwidth part indicator field is configured in the scheduling DCI and the UE supports active BWP change via DCI, the RB indexing for downlink type 0 and type 1 resource allocation is determined within the UE's bandwidth part indicated by bandwidth part indicator field value in the DCI. The UE shall upon detection of PDCCH intended for the UE determine first the downlink bandwidth part and then the resource allocation within the bandwidth part.

For a PDSCH scheduled with a DCI format 1_0 in any type of PDCCH common search space, regardless of which bandwidth part is the active bandwidth part, RB numbering starts from the lowest RB of the CORESET in which the DCI was received; otherwise RB numbering starts from the lowest RB in the determined downlink bandwidth part.

5.1.2.2.1 Downlink resource allocation type 0

In downlink resource allocation of type 0, the resource block assignment information includes a bitmap indicating the Resource Block Groups (RBGs) that are allocated to the scheduled UE where a RBG is a set of consecutive virtual resource blocks defined by higher layer parameter *rbg-Size* configured by *PDSCH-Config* and the size of the bandwidth part as defined in Table 5.1.2.2.1-1.

Table 5.1.2.2.1-1: Nominal RBG size *P*

Bandwidth Part Size	Configuration 1	Configuration 2
1 – 36	2	4
37 – 72	4	8
73 – 144	8	16
145 – 275	16	16

The total number of RBGs (N_{RBG}) for a downlink bandwidth part *i* of size $N_{\mathrm{BWP},i}^{size}$ PRBs is given by

$N_{RBG} = \left\lceil \left(N_{BWP,i}^{size} + \left(N_{BWP,i}^{start} \bmod P \right) \right) / P \right\rceil$, where

- the size of the first RBG is $RBG_0^{size} = P - N_{BWP,i}^{start} \bmod P$,
- the size of last RBG is $RBG_{last}^{size} = \left(N_{BWP,i}^{start} + N_{BWP,i}^{size} \right) \bmod P$ if $\left(N_{BWP,i}^{start} + N_{BWP,i}^{size} \right) \bmod P > 0$ and *P* otherwise,
- the size of all other RBGs is *P*.

The bitmap is of size N_{RBG} bits with one bitmap bit per RBG such that each RBG is addressable. The RBGs shall be indexed in the order of increasing frequency and starting at the lowest frequency of the bandwidth part. The order of RBG bitmap is such that RBG 0 to RBG $N_{\mathrm{RBG}} - 1$ are mapped from MSB to LSB. The RBG is allocated to the UE if the corresponding bit value in the bitmap is 1, the RBG is not allocated to the UE otherwise.

5.1.2.2.2 Downlink resource allocation type 1

In downlink resource allocation of type 1, the resource block assignment information indicates to a scheduled UE a set of contiguously allocated non-interleaved or interleaved virtual resource blocks within the active bandwidth part of size N_{BWP}^{size} PRBs except for the case when DCI format 1_0 is decoded in any common search space in which case the size of CORESET 0 shall be used if CORESET 0 is configured for the cell and the size of initial DL bandwidth part shall be used if CORESET 0 is not configured for the cell.

A downlink type 1 resource allocation field consists of a resource indication value (*RIV*) corresponding to a starting virtual resource block (RB_{start}) and a length in terms of contiguously allocated resource blocks L_{RBs} . The resource indication value is defined by

if $(L_{RBs} - 1) \le \left\lfloor N_{BWP}^{size} / 2 \right\rfloor$ then

$RIV = N_{BWP}^{size}(L_{RBs} - 1) + RB_{start}$

else

$$RIV = N_{BWP}^{size}(N_{BWP}^{size} - L_{RBs} + 1) + (N_{BWP}^{size} - 1 - RB_{start})$$

where $L_{RBs} \geq 1$ and shall not exceed $N_{BWP}^{size} - RB_{start}$.

When the DCI size for DCI format 1_0 in USS is derived from the size of DCI format 1_0 in CSS but applied to an active BWP with size of $N_{\mathrm{BWP}}^{active}$, a downlink type 1 resource block assignment field consists of a resource indication value (*RIV*) corresponding to a starting resource block $RB_{start} = 0, K, 2 \cdot K, \ldots, (N_{\mathrm{BWP}}^{initial} - 1) \cdot K$ and a length in terms of virtually contiguously allocated resource blocks $L_{RBs} = K, 2 \cdot K, \ldots, N_{\mathrm{BWP}}^{initial} \cdot K$, where $N_{\mathrm{BWP}}^{initial}$ is given by

- the size of CORESET 0 if CORESET 0 is configured for the cell;
- the size of initial DL bandwidth part if CORESET 0 is not configured for the cell.

The resource indication value is defined by:

if $(L'_{RBs} - 1) \leq \lfloor N_{BWP}^{initial} / 2 \rfloor$ then

$$RIV = N_{BWP}^{initial}(L'_{RBs} - 1) + RB'_{start}$$

else

$$RIV = N_{BWP}^{initial}(N_{BWP}^{initial} - L'_{RBs} + 1) + (N_{BWP}^{initial} - 1 - RB'_{start})$$

where $L'_{RBs} = L_{RBs}/K$, $RB'_{start} = RB_{start}/K$ and where L'_{RBs} shall not exceed $N_{BWP}^{initial} - RB'_{start}$.

If $N_{BWP}^{active} > N_{BWP}^{initial}$, K is the maximum value from set {1, 2, 4, 8} which satisfies $K \leq \lfloor N_{BWP}^{active} / N_{BWP}^{initial} \rfloor$; otherwise K = 1.

When the scheduling grant is received with DCI format 1_2, a downlink type 1 resource allocation field consists of a resource indication value (*RIV*) corresponding to a starting resource block group RBG_{start}=0, 1, …, N_{RBG}-1 and a length in terms of virtually contiguously allocated resource block groups L_{RBGs}=1, …, N_{RBG}, where the resource block groups are defined as in 5.1.2.2.1 with *P* defined by *resourceAllocationType1GranularityDCI-1-2* if the UE is configured with higher layer parameter *resourceAllocationType1GranularityDCI-1-2*, and *P*=1 otherwise. The resource indication value is defined by

if $(L_{RBGs} - 1) \leq \lfloor N_{RBG} / 2 \rfloor$ then

$$RIV = N_{RBG}(L_{RBGs} - 1) + RBG_{start}$$

else

$$RIV = N_{RBG}(N_{RBG} - L_{RBGs} + 1) + (N_{RBG} - 1 - RBG_{start})$$

where $L_{RBGs} \geq 1$ and shall not exceed $N_{RBG} - RBG_{start}$.

5.1.2.3 Physical resource block (PRB) bundling

The PRB bundling procedures for PDSCH scheduled by PDCCH with DCI format 1_1 described in this clause equally apply to PDSCH scheduled by PDCCH with DCI format 1_2, by applying the parameters of *prb-BundlingTypeDCI-1-2* instead of *prb-BundlingType* as well as *vrb-ToPRB-InterleaverDCI-1-2* instead of *vrb-ToPRB-Interleaver*.

A UE may assume that precoding granularity is $P'_{BWP,i}$ consecutive resource blocks in the frequency domain. $P'_{BWP,i}$ can be equal to one of the values among {2, 4, wideband}.

If $P'_{BWP,i}$ is determined as "wideband", the UE is not expected to be scheduled with non-contiguous PRBs and the UE may assume that the same precoding is applied to the allocated resource associated with a same TCI state or a same QCL assumption.

If $P'_{BWP,i}$ is determined as one of the values among {2, 4}, Precoding Resource Block Group (PRGs) partitions the bandwidth part *i* with $P'_{BWP,i}$ consecutive PRBs. Actual number of consecutive PRBs in each PRG could be one or more.

The first PRG size is given by $P'_{BWP,i} - N^{start}_{BWP,i} \bmod P'_{BWP,i}$ and the last PRG size given by $(N^{start}_{BWP,i} + N^{size}_{BWP,i}) \bmod P'_{BWP,i}$ if $(N^{start}_{BWP,i} + N^{size}_{BWP,i}) \bmod P'_{BWP,i} \neq 0$, and the last PRG size is $P'_{BWP,i}$ if $(N^{start}_{BWP,i} + N^{size}_{BWP,i}) \bmod P'_{BWP,i} = 0$.

The UE may assume the same precoding is applied for any downlink contiguous allocation of PRBs in a PRG.

For PDSCH carrying SIB1 scheduled by PDCCH with CRC scrambled by SI-RNTI, a PRG is partitioned from the lowest numbered resource block of CORESET 0 if the corresponding PDCCH is associated with CORESET 0 and Type0-PDCCH common search space and is addressed to SI-RNTI; otherwise, a PRG is partitioned from common resource block 0.

If a UE is scheduled a PDSCH with DCI format 1_0, the UE shall assume that $P'_{BWP,i}$ is equal to 2 PRBs.

When receiving PDSCH scheduled by PDCCH with DCI format 1_1 with CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI, $P'_{BWP,i}$ for bandwidth part is equal to 2 PRBs unless configured by the higher layer parameter *prb-BundlingType* given by *PDSCH-Config*.

When receiving PDSCH scheduled by PDCCH with DCI format 1_1 with CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI, if the higher layer parameter *prb-BundlingType* is set to 'dynamicBundling', the higher layer parameters *bundleSizeSet1* and *bundleSizeSet2* configure two sets of $P'_{BWP,i}$ values, the first set can take one or two $P'_{BWP,i}$ values among {2, 4, wideband}, and the second set can take one $P'_{BWP,i}$ value among {2, 4, wideband}.

If the PRB *'bundling size indicator'* signalled in DCI format 1_1 as defined in Clause 7.3.1.2.2 of [5, TS 38.212]

- is set to '0', the UE shall use the $P'_{BWP,i}$ value from the second set of $P'_{BWP,i}$ values when receiving PDSCH scheduled by the same DCI.
- is set to '1' and one value is configured for the first set of $P'_{BWP,i}$ values, the UE shall use this $P'_{BWP,i}$ value when receiving PDSCH scheduled by the same DCI
- is set to '1' and two values are configured for the first set of $P'_{BWP,i}$ values as 'n2-wideband' (corresponding to two $P'_{BWP,i}$ values 2 and wideband) or 'n4-wideband' (corresponding to two $P'_{BWP,i}$ values 4 and wideband), the UE shall use the value when receiving PDSCH scheduled by the same DCI as follows:
  - If the scheduled PRBs are contiguous and the size of the scheduled PRBs is larger than $N^{size}_{BWP,i}/2$, $P'_{BWP,i}$ is the same as the scheduled bandwidth, otherwise $P'_{BWP,i}$ is set to the remaining configured value of 2 or 4, respectively.

When receiving PDSCH scheduled by PDCCH with DCI format 1_1 with CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI, if the higher layer parameter *prb-BundlingType* is set to 'staticBundling', the $P'_{BWP,i}$ value is configured with the single value indicated by the higher layer parameter *bundleSize*.

When a UE is configured with nominal RBG size $P = 2$ for bandwidth part *i* according to Clause 5.1.2.2.1, or when a UE is configured with interleaving unit of 2 for VRB to PRB mapping provided by the higher layer parameter *vrb-ToPRB-Interleaver* given by *PDSCH-Config* for bandwidth part *i*, the UE is not expected to be configured with $P'_{BWP,i}$ = 4.

For a UE configured by the higher layer parameter *repetitionScheme* set to 'fdmSchemeA*' or* 'fdmSchemeB'*, and* when 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)*',

- If $P'_{BWP,i}$ is determined as "wideband", the first $\left\lceil \frac{n_{PRB}}{2} \right\rceil$ PRBs are assigned to the first TCI state and the remaining $\left\lfloor \frac{n_{PRB}}{2} \right\rfloor$ PRBs are assigned to the second TCI state, where n_{PRB} is the total number of allocated PRBs for the UE.

- If $P'_{BWP,i}$ is determined as one of the values among {2, 4}, even PRGs within the allocated frequency domain resources are assigned to the first TCI state and odd PRGs within the allocated frequency domain resources are assigned to the second TCI state, wherein the PRGs are numbered continuously in increasing order with the first PRG index equal to 0.

- The UE is not expected to receive more than two PDSCH transmission layers for each PDSCH transmission occasion.

For a UE configured by the higher layer parameter *repetitionScheme* set to 'fdmSchemeB', and when 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)'*, each PDSCH transmission occasion shall follow the Clause 7.3.1 of [4, TS 38.211] with the mapping to resource elements determined by the assigned PRBs for corresponding TCI state of the PDSCH transmission occasion, and the UE shall only expect at most two code blocks per PDSCH transmission occasion when a single transmission layer is scheduled and a single code block per PDSCH transmission occasion when two transmission layers are scheduled. For two PDSCH transmission occasions, the redundancy version to be applied is derived according to Table 5.1.2.1-2, where $n = 0, 1$ are applied to the first and second TCI state, respectively.

5.1.3 Modulation order, target code rate, redundancy version and transport block size determination

To determine the modulation order, target code rate, and transport block size(s) in the physical downlink shared channel, the UE shall first

- read the 5-bit modulation and coding scheme field (I_{MCS}) in the DCI to determine the modulation order (Q_m) and target code rate (R) based on the procedure defined in Clause 5.1.3.1, and

- read '*redundancy version'* field (*rv*) in the DCI to determine the redundancy version.

and second

- the UE shall use the number of layers (υ), the total number of allocated PRBs before rate matching (n_{PRB}) to determine to the transport block size based on the procedure defined in Clause 5.1.3.2.

The UE may skip decoding a transport block in an initial transmission if the effective channel code rate is higher than 0.95, where the effective channel code rate is defined as the number of downlink information bits (including CRC bits) divided by the number of physical channel bits on PDSCH.

The UE is not expected to handle any transport blocks (TBs) in a 14 consecutive-symbol duration for normal CP (or 12 for extended CP) ending at the last symbol of the latest PDSCH transmission within an active BWP on a serving cell whenever

$$2^{\max(0,\mu-\mu')}.\sum_{i\in S}\left\lceil\frac{C_i'}{L_i}\right\rceil x_i.F_i > \left\lceil\frac{X}{4}\right\rceil.\frac{1}{R_{LBRM}}.TBS_{LBRM}$$

where, for the serving cell,

- S is the set of TBs belonging to PDSCH(s) that are partially or fully contained in the consecutive-symbol duration

- for the *i*th TB

  - C_i' is the number of scheduled code blocks for as defined in [5, 38.212].

  - L_i is the number of OFDM symbols assigned to the PDSCH

  - x_i is the number of OFDM symbols of the PDSCH contained in the consecutive-symbol duration

  - $F_i = \max_{j=0,\ldots,J-1}(\min(k_{0,i}^j + E_i^j, N_{cb,i}))$ based on the values defined in Clause 5.4.2.1 [5, TS 38.212]

    - $k_{0,i}^j$ is the starting location of RV for the jth transmission

    - $E_i^j = \min(E_r)$ of the scheduled code blocks for the jth transmission

    - $N_{cb,i}$ is the circular buffer length

  - $J-1$ is the current (re)transmission for the *i*th TB
- μ' corresponds to the subcarrier spacing of the BWP (across all configured BWPs of a carrier) that has the largest configured number of PRBs
  - in case there is more than one BWP corresponding to the largest configured number of PRBs, μ' follows the BWP with the largest subcarrier spacing.
- μ corresponds to the subcarrier spacing of the active BWP
- R_{LBRM} = 2/3 as defined in Clause 5.4.2.1 [5, TS 38.212]
- TBS_{LBRM} as defined in Clause 5.4.2.1 [5, TS 38.212]
- X as defined for downlink in Clause 5.4.2.1 [5, TS 38.212].

If the UE skips decoding, the physical layer indicates to higher layer that the transport block is not successfully decoded.

Within a cell group, a UE is not required to handle PDSCH(s) transmissions in slot s_j in serving cell-*j*, and for *j* = 0,1,2.. *J-1*, slot s_j overlapping with any given point in time, if the following condition is not satisfied at that point in time:

$$\sum_{j=0}^{J-1} \frac{\sum_{m=0}^{M-1} V_{j,m}}{T_{slot}^{\mu(j)}} \leq DataRate$$

where,

- *J* is the number of configured serving cells belonging to a frequency range
- for the *j-th* serving cell,
  - *M* is the number of TB(s) transmitted in slot s_j. If there are two PDSCH transmission occasions of the same TB (in time domain or in frequency domain) in the slot s_j, each transmission occasion is counted separately.
  - $T_{slot}^{\mu(j)} = 10^{-3}/2^{\mu(j)}$, where $\mu(j)$ is the numerology for PDSCH(s) in slot s_j of the *j*-th serving cell.
  - for the *m*-th TB, $V_{j,m} = C' \cdot \left\lfloor \frac{A}{C} \right\rfloor$
    - *A* is the number of bits in the transport block as defined in Clause 7.2.1 [5, TS 38.212]
    - *C* is the total number of code blocks for the transport block defined in Clause 5.2.2 [5, TS 38.212].
    - C' is the number of scheduled code blocks for the transport block as defined in Clause 5.4.2.1 [5, TS 38.212]
- $DataRate$ [Mbps] is computed as the maximum data rate summed over all the carriers in the frequency range for any signaled band combination and feature set consistent with the configured servings cells, where the data rate value is given by the formula in Clause 4.1.2 in [13, TS 38.306], including the scaling factor *f(i)*.

For a *j*-th serving cell, if higher layer parameter *processingType2Enabled* of *PDSCH-ServingCellConfig* is configured for the serving cell and set to '*enable*', or if at least one $I_{MCS} > W$ for a PDSCH, where *W* = 28 for MCS tables 5.1.3.1-1 and 5.1.3.1-3, and *W* = 27 for MCS table 5.1.3.1-2, the UE is not required to handle PDSCH transmissions, if the following condition is not satisfied:

$$\frac{\sum_{m=0}^{M-1} V_{j,m}}{L \times T_s^{\mu}} \leq DataRateCC$$

where

- L is the number of symbols assigned to the PDSCH. For a PDSCH that consists of two PDSCH transmission occasions in time domain in one slot, L is the number of symbols of one transmission occasion.
- M is the number of TB(s) in the PDSCH

- $T_s^\mu = \frac{10^{-3}}{2^\mu \cdot N_{symb}^{slot}}$ where μ is the numerology of the PDSCH

- for the *m*-th TB, $V_{j,m} = C' \cdot \left\lceil \frac{A}{C} \right\rceil$

  - A is the number of bits in the transport block as defined in Clause 7.2.1 [5, TS 38.212]

  - C is the total number of code blocks for the transport block defined in Clause 5.2.2 [5, TS 38.212]

  - C' is the number of scheduled code blocks for the transport block as defined in Clause 5.4.2.1 [5, TS 38.212]

- $DataRateCC$ [Mbps] is computed as the maximum data rate for a carrier in the frequency band of the serving cell for any signaled band combination and feature set consistent with the serving cell, where the data rate value is given by the formula in Clause 4.1.2 in [13, TS 38.306], including the scaling factor *f(i)*.

5.1.3.1 Modulation order and target code rate determination

For the PDSCH scheduled by a PDCCH with DCI format 1_0, format 1_1 or format 1_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, TC-RNTI, CS-RNTI, SI-RNTI, RA-RNTI, MSGB-RNTI, or P-RNTI, or for the PDSCH scheduled without corresponding PDCCH transmissions using the higher-layer-provided PDSCH configuration *SPS-Config*,

if the higher layer parameter *mcs-TableDCI-1-2* given by *PDSCH-Config* is set to 'qam256', and the PDSCH is scheduled by a PDCCH with DCI format 1_2 with CRC scrambled by C-RNTI

- the UE shall use I_{MCS} and Table 5.1.3.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

elseif the UE is not configured with MCS-C-RNTI, the higher layer parameter *mcs-TableDCI-1-2* given by *PDSCH-Config* is set to 'qam64LowSE', and the PDSCH is scheduled by a PDCCH with DCI format 1_2 scrambled by C-RNTI

- the UE shall use I_{MCS} and Table 5.1.3.1-3 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

elseif the higher layer parameter *mcs-Table* given by *PDSCH-Config* is set to 'qam256', and the PDSCH is scheduled by a PDCCH with DCI format 1_1 with CRC scrambled by C-RNTI

- the UE shall use I_{MCS} and Table 5.1.3.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

elseif the UE is not configured with MCS-C-RNTI, the higher layer parameter *mcs-Table* given by *PDSCH-Config* is set to 'qam64LowSE', and the PDSCH is scheduled by a PDCCH with a DCI format other than DCI format 1_2 in a UE-specific search space with CRC scrambled by C-RNTI

- the UE shall use I_{MCS} and Table 5.1.3.1-3 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

elseif the UE is configured with MCS-C-RNTI, and the PDSCH is scheduled by a PDCCH with CRC scrambled by MCS-C-RNTI

- the UE shall use I_{MCS} and Table 5.1.3.1-3 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

elseif the UE is not configured with the higher layer parameter *mcs-Table* given by *SPS-config*, and the higher layer parameter *mcs-TableDCI-1-2* given by *PDSCH-Config* is set to 'qam256',

- if the PDSCH is scheduled by a PDCCH with DCI format 1_2 with CRC scrambled by CS-RNTI or

- if the PDSCH with SPS activated by DCI format 1_2 is scheduled without corresponding PDCCH transmission using *SPS-Config*,

- the UE shall use I_{MCS} and Table 5.1.3.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

elseif the UE is not configured with the higher layer parameter *mcs-Table* given by *SPS-Config*, and the higher layer parameter *mcs-Table* given by *PDSCH-Config* is set to 'qam256',

- if the PDSCH is scheduled by a PDCCH with DCI format 1_1 with CRC scrambled by CS-RNTI or
- if the PDSCH with SPS activated by DCI format 1_1 is scheduled without corresponding PDCCH transmission using *SPS-Config*,
  - the UE shall use I_{MCS} and Table 5.1.3.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

elseif the UE is configured with the higher layer parameter *mcs-Table* given by *SPS-Config* set to 'qam64LowSE'

- if the PDSCH is scheduled by a PDCCH with CRC scrambled by CS-RNTI or
- if the PDSCH is scheduled without corresponding PDCCH transmission using *SPS-Config*,
  - the UE shall use I_{MCS} and Table 5.1.3.1-3 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

else

- the UE shall use I_{MCS} and Table 5.1.3.1-1 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

end

The UE is not expected to decode a PDSCH scheduled with P-RNTI, RA-RNTI, SI-RNTI and $Q_m > 2$

For a UE configured with the higher layer parameter *repetitionScheme* set to 'fdmSchemeB', and when 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)*', the determined modulation order of PDSCH transmission occasion associated with the first TCI state is applied to the PDSCH transmission occasion associated with the second TCI state.

Table 5.1.3.1-1: MCS index table 1 for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	Target code Rate R x [1024]	Spectral efficiency
0	2	120	0.2344
1	2	157	0.3066
2	2	193	0.3770
3	2	251	0.4902
4	2	308	0.6016
5	2	379	0.7402
6	2	449	0.8770
7	2	526	1.0273
8	2	602	1.1758
9	2	679	1.3262
10	4	340	1.3281
11	4	378	1.4766
12	4	434	1.6953
13	4	490	1.9141
14	4	553	2.1602
15	4	616	2.4063
16	4	658	2.5703
17	6	438	2.5664
18	6	466	2.7305
19	6	517	3.0293
20	6	567	3.3223
21	6	616	3.6094
22	6	666	3.9023
23	6	719	4.2129
24	6	772	4.5234
25	6	822	4.8164
26	6	873	5.1152
27	6	910	5.3320
28	6	948	5.5547
29	2	reserved	
30	4	reserved	
31	6	reserved	

Table 5.1.3.1-2: MCS index table 2 for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	Target code Rate R x [1024]	Spectral efficiency
0	2	120	0.2344
1	2	193	0.3770
2	2	308	0.6016
3	2	449	0.8770
4	2	602	1.1758
5	4	378	1.4766
6	4	434	1.6953
7	4	490	1.9141
8	4	553	2.1602
9	4	616	2.4063
10	4	658	2.5703
11	6	466	2.7305
12	6	517	3.0293
13	6	567	3.3223
14	6	616	3.6094
15	6	666	3.9023
16	6	719	4.2129
17	6	772	4.5234
18	6	822	4.8164
19	6	873	5.1152
20	8	682.5	5.3320
21	8	711	5.5547
22	8	754	5.8906
23	8	797	6.2266
24	8	841	6.5703
25	8	885	6.9141
26	8	916.5	7.1602
27	8	948	7.4063
28	2	reserved	
29	4	reserved	
30	6	reserved	
31	8	reserved	

Table 5.1.3.1-3: MCS index table 3 for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	Target code Rate *R* x [1024]	Spectral efficiency
0	2	30	0.0586
1	2	40	0.0781
2	2	50	0.0977
3	2	64	0.1250
4	2	78	0.1523
5	2	99	0.1934
6	2	120	0.2344
7	2	157	0.3066
8	2	193	0.3770
9	2	251	0.4902
10	2	308	0.6016
11	2	379	0.7402
12	2	449	0.8770
13	2	526	1.0273
14	2	602	1.1758
15	4	340	1.3281
16	4	378	1.4766
17	4	434	1.6953
18	4	490	1.9141
19	4	553	2.1602
20	4	616	2.4063
21	6	438	2.5664
22	6	466	2.7305
23	6	517	3.0293
24	6	567	3.3223
25	6	616	3.6094
26	6	666	3.9023
27	6	719	4.2129
28	6	772	4.5234
29	2	reserved	
30	4	reserved	
31	6	reserved	

5.1.3.2 Transport block size determination

In case the higher layer parameter *maxNrofCodeWordsScheduledByDCI* indicates that two codeword transmission is enabled, then one of the two transport blocks is disabled by DCI format 1_1 if I_{MCS} = 26 and if rv_{id} = 1 for the corresponding transport block. If both transport blocks are enabled, transport block 1 and 2 are mapped to codeword 0 and 1 respectively. If only one transport block is enabled, then the enabled transport block is always mapped to the first codeword.

For the PDSCH assigned by a PDCCH with DCI format 1_0, format 1_1 or format 1_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, TC-RNTI, CS-RNTI, or SI-RNTI, if Table 5.1.3.1-2 is used and $0 \le I_{MCS} \le 27$, or a table other than Table 5.1.3.1-2 is used and $0 \le I_{MCS} \le 28$, the UE shall, except if the transport block is disabled in DCI format 1_1, first determine the TBS as specified below:

1) The UE shall first determine the number of REs (N_{RE}) within the slot.

- A UE first determines the number of REs allocated for PDSCH within a PRB (N'_{RE}) by $N'_{RE} = N^{RB}_{sc} \cdot N^{sh}_{symb} - N^{PRB}_{DMRS} - N^{PRB}_{oh}$, where $N^{RB}_{sc} = 12$ is the number of subcarriers in a physical resource block, N^{sh}_{symb} is the number of symbols of the PDSCH allocation within the slot, N^{PRB}_{DMRS} is the number of REs for DM-RS per PRB in the scheduled duration including the overhead of the DM-RS CDM groups without data, as indicated by DCI format 1_1 or format 1_2 or as described for format 1_0 in Clause 5.1.6.2, and N^{PRB}_{oh} is the overhead configured by higher layer parameter *xOverhead* in *PDSCH-ServingCellConfig*.

  If the *xOverhead* in *PDSCH-ServingCellconfig* is not configured (a value from 6, 12, or 18), the N^{PRB}_{oh} is set to 0. If the PDSCH is scheduled by PDCCH with a CRC scrambled by SI-RNTI, RA-RNTI, MSGB-RNTI or P-RNTI, N_{oh}^{PRB} is assumed to be 0.

- A UE determines the total number of REs allocated for PDSCH (N_{RE}) by $N_{RE} = \min\left(156, N_{RE}^{'}\right) \cdot n_{PRB}$, where n_{PRB} is the total number of allocated PRBs for the UE.

2) Unquantized intermediate variable (N_{info}) is obtained by $N_{info} = N_{RE} \cdot R \cdot Q_m \cdot \upsilon$.

If $N_{info} \le 3824$

Use step 3 as the next step of the TBS determination

else

Use step 4 as the next step of the TBS determination

end if

3) When $N_{info} \le 3824$, TBS is determined as follows

- quantized intermediate number of information bits $N_{info}^{'} = \max\left(24, 2^n \cdot \left\lfloor \frac{N_{info}}{2^n} \right\rfloor\right)$, where $n = \max\left(3, \left\lfloor \log_2\left(N_{info}\right)\right\rfloor - 6\right)$.

- use Table 5.1.3.2-1 find the closest TBS that is not less than $N_{info}^{'}$.

Table 5.1.3.2-1: TBS for $N_{info} \le 3824$

Index	TBS	Index	TBS	Index	TBS	Index	TBS
1	24	31	336	61	1288	91	3624
2	32	32	352	62	1320	92	3752
3	40	33	368	63	1352	93	3824
4	48	34	384	64	1416		
5	56	35	408	65	1480		
6	64	36	432	66	1544		
7	72	37	456	67	1608		
8	80	38	480	68	1672		
9	88	39	504	69	1736		
10	96	40	528	70	1800		
11	104	41	552	71	1864		
12	112	42	576	72	1928		
13	120	43	608	73	2024		
14	128	44	640	74	2088		
15	136	45	672	75	2152		
16	144	46	704	76	2216		
17	152	47	736	77	2280		
18	160	48	768	78	2408		
19	168	49	808	79	2472		
20	176	50	848	80	2536		
21	184	51	888	81	2600		
22	192	52	928	82	2664		
23	208	53	984	83	2728		
24	224	54	1032	84	2792		
25	240	55	1064	85	2856		
26	256	56	1128	86	2976		
27	272	57	1160	87	3104		
28	288	58	1192	88	3240		
29	304	59	1224	89	3368		
30	320	60	1256	90	3496		

4) When $N_{info} > 3824$, TBS is determined as follows.

- quantized intermediate number of information bits $N'_{info} = \max\left(3840, 2^n \times round\left(\frac{N_{info} - 24}{2^n}\right)\right)$, where $n = \lfloor \log_2(N_{info} - 24) \rfloor - 5$ and ties in the round function are broken towards the next largest integer.

- if $R \le 1/4$

$$TBS = 8 \cdot C \cdot \left\lceil \frac{N'_{info} + 24}{8 \cdot C} \right\rceil - 24 \text{ , where } C = \left\lceil \frac{N'_{info} + 24}{3816} \right\rceil$$

else

if $N'_{info} > 8424$

$$TBS = 8 \cdot C \cdot \left\lceil \frac{N'_{info} + 24}{8 \cdot C} \right\rceil - 24 \text{ , where } C = \left\lceil \frac{N'_{info} + 24}{8424} \right\rceil$$

else

$$TBS = 8 \cdot \left\lceil \frac{N'_{info} + 24}{8} \right\rceil - 24$$

end if

end if

else if Table 5.1.3.1-2 is used and $28 \le I_{MCS} \le 31$,

- the TBS is assumed to be as determined from the DCI transported in the latest PDCCH for the same transport block using $0 \le I_{MCS} \le 27$. If there is no PDCCH for the same transport block using $0 \le I_{MCS} \le 27$, and if the initial PDSCH for the same transport block is semi-persistently scheduled, the TBS shall be determined from the most recent semi-persistent scheduling assignment PDCCH.

else

- the TBS is assumed to be as determined from the DCI transported in the latest PDCCH for the same transport block using $0 \le I_{MCS} \le 28$. If there is no PDCCH for the same transport block using $0 \le I_{MCS} \le 28$, and if the initial PDSCH for the same transport block is semi-persistently scheduled, the TBS shall be determined from the most recent semi-persistent scheduling assignment PDCCH.

The UE is not expected to receive a PDSCH assigned by a PDCCH with CRC scrambled by SI-RNTI with a TBS exceeding 2976 bits.

For a UE configured with the higher layer parameter *repetitionScheme* set to 'fdmSchemeB' and 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)*', the TBS determination follows the steps 1-4 with the following modification in step 1: a UE determines the total number of REs allocated for PDSCH (N_{RE}) by $N_{RE} = \min\left(156, N'_{RE}\right) \cdot n_{PRB}$, where n_{PRB} is the total number of allocated PRBs corresponding to the first TCI state, and the determined TBS of PDSCH transmission occasion associated with the first TCI state is also applied to the PDSCH transmission occasion associated with the second TCI state. For a UE configured with the higher layer parameter *repetitionScheme* set to 'tdmSchemeA' and 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)*', the TBS determination follows the steps 1-4 with the following modification in step 1: a UE determines the number of REs allocated for PDSCH within a PRB (N'_{RE}) by $N'_{RE} = N^{RB}_{sc} \cdot N^{sh}_{symb} - N^{PRB}_{DMRS} - N^{PRB}_{oh}$, where N^{sh}_{symb} is the number of symbols of the PDSCH allocation within the slot corresponding to the first TCI state, and the determined TBS of PDSCH transmission occasion associated with the first TCI state is also applied to the PDSCH transmission occasion associated with the second TCI state.

For the PDSCH assigned by a PDCCH with DCI format 1_0 with CRC scrambled by P-RNTI, or RA-RNTI, MsgB-RNTI, TBS determination follows the steps 1-4 with the following modification in step 2: a scaling $N_{info} = S \cdot N_{RE} \cdot R \cdot Q_m \cdot \upsilon$ is applied in the calculation of N_{info}, where the scaling factor is determined based on the *TB scaling* field in the DCI as in Table 5.1.3.2-2.

Table 5.1.3.2-2: Scaling factor of N_{info} for P-RNTI, RA-RNTI and MSGB-RNTI

TB scaling field	Scaling factor S
00	1
01	0.5
10	0.25
11	

The NDI and HARQ process ID, as signalled on PDCCH, and the TBS, as determined above, shall be reported to higher layers.

5.1.4 PDSCH resource mapping

When receiving the PDSCH scheduled with SI-RNTI and the system information indicator in DCI is set to 0, the UE shall assume that no SS/PBCH block is transmitted in REs used by the UE for a reception of the PDSCH.

When receiving the PDSCH scheduled with SI-RNTI and the system information indicator in DCI is set to 1, RA-RNTI, MSGB-RNTI, P-RNTI or TC-RNTI, the UE assumes SS/PBCH block transmission according to *ssb-PositionsInBurst*, and if the PDSCH resource allocation overlaps with PRBs containing SS/PBCH block transmission resources the UE shall assume that the PRBs containing SS/PBCH block transmission resources are not available for PDSCH in the OFDM symbols where SS/PBCH block is transmitted.

A UE expects a configuration provided by *ssb-PositionsInBurst* in *ServingCellConfigCommon* to be same as a configuration provided by *ssb-PositionsInBurst* in *SIB1*.

When receiving PDSCH scheduled by PDCCH with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI, or PDSCHs with SPS, the REs corresponding to the configured or dynamically indicated resources in Clauses 5.1.4.1, 5.1.4.2 are not available for PDSCH. Furthermore, the UE assumes SS/PBCH block transmission according to *ssb-PositionsInBurst* if the PDSCH resource allocation overlaps with PRBs containing SS/PBCH block transmission resources, the UE shall assume that the PRBs containing SS/PBCH block transmission resources are not available for PDSCH in the OFDM symbols where SS/PBCH block is transmitted.

A UE is not expected to handle the case where PDSCH DM-RS REs are overlapping, even partially, with any RE(s) not available for PDSCH.

For operation with shared spectrum channel access, SS/PBCH block transmission according to *ssb-PositionsInBurst* represents all of the candidate SS/PBCH blocks corresponding to SS/PBCH block indices provided by *ssb-PositionsInBurst* as described in Clause 4.1 of [6, TS 38.213].

5.1.4.1 PDSCH resource mapping with RB symbol level granularity

The procedures for PDSCH scheduled by PDCCH with DCI format 1_1 described in this clause equally apply to PDSCH scheduled by PDCCH with DCI format 1_2, by applying the parameters of *rateMatchPatternGroup1DCI-1-2*, *rateMatchPatternGroup2DCI-1-2* instead of *rateMatchPatternGroup1* and *rateMatchPatternGroup2*.

A UE may be configured with any of the following higher layer parameters indicating REs declared as not available for PDSCH:

- *rateMatchPatternToAddModList* given by *PDSCH-Config*, by *ServingCellConfig* or by *ServingCellConfigCommon* and configuring up to 4 *RateMatchPattern(s)* per BWP and up to 4 *RateMatchPattern(s)* per serving-cell. A *RateMatchPattern* may contain:
  - within a BWP, when provided by *PDSCH-Config* or within a serving cell when provided by *ServingCellConfig* or *ServingCellConfigCommon*, a pair of reserved resources with numerology provided by higher layer parameter *subcarrierSpacing* given by *RateMatchPattern* when configured per serving cell or by

numerology of associated BWP when configured per BWP. The pair of reserved resources are respectively indicated by an RB level bitmap (higher layer parameter *resourceBlocks* given by *RateMatchPattern*) with 1RB granularity and a symbol level bitmap spanning one or two slots (higher layer parameters *symbolsInResourceBlock* given by *RateMatchPattern*) for which the reserved RBs apply. A bit value equal to 1 in the RB and symbol level bitmaps indicates that the corresponding resource is not available for PDSCH. For each pair of RB and symbol level bitmaps, a UE may be configured with a time-domain pattern (higher layer parameter *periodicityAndPattern* given by *RateMatchPattern*), where each bit of *periodicityAndPattern* corresponds to a unit equal to a duration of the symbol level bitmap, and a bit value equal to 1 indicates that the pair is present in the unit. The *periodicityAndPattern* can be {1, 2, 4, 5, 8, 10, 20 or 40} units long, but maximum of 40 msec. The first symbol of *periodicityAndPattern* every 40 msec/P periods is a first symbol in frame n_f mod 4 = 0, where P is the duration of *periodicityAndPattern* in units of msec. When *periodicityAndPattern* is not configured for a pair, for a symbol level bitmap spanning two slots, the bits of the first and second slots correspond respectively to even and odd slots of a radio frame, and for a symbol level bitmap spanning one slot, the bits of the slot correspond to every slot of a radio frame. The pair can be included in one or two groups of resource sets (higher layer parameters *rateMatchPatternGroup1* and *rateMatchPatternGroup2*). The *rateMatchPatternToAddModList* given by *ServingCellConfig* or *ServingCellConfigCommon* configuration in numerology μ applies only to PDSCH of the same numerology μ.

- within a BWP, a frequency domain resource of a CORESET configured by *ControlResourceSet* with *controlResourceSetId* or *ControlResourceSetZero* and time domain resource determined by the higher layer parameters *monitoringSlotPeriodicityAndOffset*, *duration* and *monitoringSymbolsWithinSlot* of all search-space-sets configured by *SearchSpace* and time domain resource of search-space-set zero configured by *searchSpaceZero* associated with the CORESET as well as CORESET duration configured by *ControlResourceSet* with *controlResourceSetId* or *ControlResourceSetZero*. This resource not available for PDSCH can be included in one or two groups of resource sets (higher layer parameters *rateMatchPatternGroup1* and *rateMatchPatternGroup2*).

A configured group *rateMatchPatternGroup1* or *rateMatchPatternGroup2* contains a list of indices of *RateMatchPattern(s)* forming a union of resource-sets not available for a PDSCH dynamically if a corresponding bit of the '*Rate matching indicator*' field of the DCI format 1_1 scheduling the PDSCH is equal to 1. The REs corresponding to the union of resource-sets configured by *RateMatchPattern(s)* that are not included in either of the two groups are not available for a PDSCH scheduled by a DCI format 1_0, a PDSCH scheduled by a DCI format 1_1, and PDSCHs with SPS. When receiving a PDSCH scheduled by a DCI format 1_0 or PDSCHs with SPS activated by a DCI format 1_0, the REs corresponding to configured resources in *rateMatchPatternGroup1* or *rateMatchPatternGroup2* are not available for the scheduled PDSCH or the activated PDSCHs with SPS. When receiving PDSCHs with SPS activated by a DCI format 1_1, the REs corresponding to configured resources in *rateMatchPatternGroup1* or *rateMatchPatternGroup2* are not available for the PDSCHs with SPS if a corresponding bit of the Rate matching indicator field of the DCI format 1_1 activating the PDSCHs with SPS is equal to 1.

For a bitmap pair included in one or two groups of resource sets, the dynamic indication of availability for PDSCH applies to a set of slot(s) where the *rateMatchPatternToAddModList* is present among the slots of scheduled PDSCH.

If a UE monitors PDCCH candidates of aggregation levels 8 and 16 with the same starting CCE index in non-interleaved CORESET spanning one OFDM symbol and if a detected PDCCH scheduling the PDSCH has aggregation level 8, the resources corresponding to the aggregation level 16 PDCCH candidate are not available for the PDSCH.

If a PDSCH scheduled by a PDCCH would overlap with resources in the CORESET containing the PDCCH, the resources corresponding to a union of the detected PDCCH that scheduled the PDSCH and associated PDCCH DM-RS are not available for the PDSCH. When *precoderGranularity* configured in a CORESET where the PDCCH was detected is set to 'allContiguousRBs', the associated PDCCH DM-RS are DM-RS in all REGs of the CORESET. Otherwise, the associated DM-RS are the DM-RS in REGs of the PDCCH.

5.1.4.2 PDSCH resource mapping with RE level granularity

The procedures for PDSCH scheduled by PDCCH with DCI format 1_1 described in this clause equally apply to PDSCH scheduled by PDCCH with DCI format 1_2, by applying the parameters of *aperiodicZP-CSI-RS-ResourceSetsToAddModListDCI-1-2* instead of *aperiodic-ZP-CSI-RS-ResourceSetsToAddModList*.

A UE may be configured with any of the following higher layer parameters:

- REs indicated by the '*RateMatchPatternLTE-CRS*' in *lte-CRS-ToMatchAround* in *ServingCellConfig* or *ServingCellConfigCommon* configuring cell-specific RS, in 15 kHz subcarrier spacing applicable only to 15 kHz subcarrier spacing PDSCH, of one LTE carrier in a serving cell are declared as not available for PDSCH.

- REs indicated by *'RateMatchPatternLTE-CRS'* in *lte-CRS-PatternList1-r16* in *ServingCellConfig* configuring cell-specific RS, in 15 kHz subcarrier spacing applicable only to 15 kHz subcarrier spacing PDSCH, of one LTE carrier in a serving cell are declared as not available for PDSCH.

- Each *RateMatchPatternLTE-CRS* configuration contains *v-Shift* consisting of LTE-CRS-vshift(s), *nrofCRS-Ports* consisting of LTE-CRS antenna ports 1, 2 or 4 ports, *carrierFreqDL* representing the offset in units of 15 kHz subcarriers from (reference) point A to the LTE carrier centre subcarrier location, *carrierBandwidthDL* representing the LTE carrier bandwidth, and may also configure *mbsfn-SubframeConfigList* representing MBSFN subframe configuration. A UE determines the CRS position within the slot according to Clause 6.10.1.2 in [15, TS 36.211], where slot corresponds to LTE subframe.

- If the UE is configured by higher layer parameter *PDCCH-Config* with two different values of *coresetPoolIndex* in *ControlResourceSet* and is also configured by the higher layer parameter *lte-CRS-PatternList1-r16* and *lte-CRS-PatternList2-r16* in *ServingCellConfig*, the following REs are declared as not available for PDSCH:

  - if the UE is configured with *crs-RateMatch-PerCoresetPoolIndex*, REs indicated by the CRS pattern(s) in *lte-CRS-PatternList1-r16* if the PDSCH is associated with *coresetPoolIndex* set to '0', or the CRS pattern(s) in *lte-CRS-PatternList2-r16* if PDSCH is associated with *coresetPoolIndex* set to '1';

  - otherwise, REs indicated by *lte-CRS-PatternList1-r16* and *lte-CRS-PatternList2-r16*, in *ServingCellConfig*.

- Within a BWP, the UE can be configured with one or more ZP CSI-RS resource set configuration(s) for aperiodic, semi-persistent and periodic time-domain behaviours (higher layer parameters *aperiodic-ZP-CSI-RS-ResourceSetsToAddModList*, *sp-ZP-CSI-RS-ResourceSetsToAddModList* and *p-ZP-CSI-RS-ResourceSet* respectively comprised in *PDSCH-Config*), with each ZP CSI-RS resource set consisting of at most 16 ZP CSI-RS resources (higher layer parameter *ZP-CSI-RS-Resource*) in numerology of the BWP. The REs indicated by *p-ZP-CSI-RS-ResourceSet* are declared as not available for PDSCH. The REs indicated by *sp-ZP-CSI-RS-ResourceSetsToAddModList* and aperiodic-ZP-CSI-RS-ResourceSetsToAddModList are declared as not available for PDSCH when their triggering and activation are applied, respectively. The following parameters are configured via higher layer signaling for each ZP CSI-RS resource configuration:

  - *zp-CSI-RS-ResourceId* in *ZP-CSI-RS-Resource* determines ZP CSI-RS resource configuration identity.

  - *nrofPorts* in *CSI-RS-ResourceMapping* defines the number of CSI-RS ports, where the allowable values are given in Clause 7.4.1.5 of [4, TS 38.211].

  - *cdm-Type* in *CSI-RS-ResourceMapping* defines CDM values and pattern, where the allowable values are given in Clause 7.4.1.5 of [4, TS 38.211].

  - *resourceMapping* in *ZP-CSI-RS-Resource* defines the OFDM symbol and subcarrier occupancy of the ZP CSI-RS resource within a slot that are given in Clause 7.4.1.5 of [4, TS 38.211].

  - *periodicityAndOffset* in *ZP-CSI-RS-Resource* defines the ZP-CSI-RS periodicity and slot offset for periodic/semi-persistent ZP CSI-RS.

The UE may be configured with a DCI field for triggering the aperiodic ZP CSI-RS. A list of *ZP-CSI-RS-ResourceSet(s)*, provided by higher layer parameter *aperiodic-ZP-CSI-RS-ResourceSetsToAddModList* in *PDSCH-Config*, is configured for aperiodic triggering. The maximum number of aperiodic *ZP-CSI-RS-ResourceSet(s)* configured per BWP is 3. The bit-length of DCI field *ZP CSI-RS trigger* depends on the number of aperiodic *ZP-CSI-RS-ResourceSet(s)*configured (up to 2 bits). Each non-zero codepoint of '*ZP CSI-RS' trigger* in DCI format 1_1 triggers one aperiodic 'ZP-CSI-RS-ResourceSet' in the list *aperiodic-ZP-CSI-RS-ResourceSetsToAddModList* by indicating the aperiodic ZP CSI-RS resource set ID. The DCI codepoint '01' triggers the resource set with 'ZP-CSI-RS-ResourceSetId' set to '1', the DCI codepoint '10' triggers the resource set with 'ZP-CSI-RS-ResourceSetId' set to '2', and the DCI codepoint '11' triggers the resource set with 'ZP-CSI-RS-ResourceSetId' set to '3'. Codepoint '00' is reserved for not triggering aperiodic ZP CSI-RS. When receiving PDSCH scheduled by DCI format 1_0 or PDSCHs with SPS activated by DCI format 1_0, the REs corresponding to configured resources in *aperiodic-ZP-CSI-RS-ResourceSetsToAddModList* or in *aperiodicZP-CSI-RS-ResourceSetsToAddModListDCI-1-2* are available for PDSCH.

When the UE is configured with multi-slot and single-slot PDSCH scheduling, the triggered aperiodic ZP CSI-RS is applied to all the slot(s) of the PDSCH scheduled or the PDSCHs with SPS activated by the PDCCH containing the trigger.

For a UE configured with a list of semi-persistent *ZP-CSI-RS-ResourceSet(s)* provided by higher layer parameter *sp-ZP-CSI-RS-ResourceSetsToAddModList*:

- when the UE would transmit a PUCCH with HARQ-ACK information in slot *n* corresponding to the PDSCH carrying the activation command, as described in clause 6.1.3.19 of [10, TS 38.321], for ZP CSI-RS resource(s), the corresponding action in [10, TS 38.321] and the UE assumption on the PDSCH RE mapping corresponding to the activated ZP CSI-RS resource(s) shall be applied starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$ where μ is the SCS configuration for the PUCCH.
- when the UE would transmit a PUCCH with HARQ-ACK information in slot *n* corresponding to the PDSCH carrying the deactivation command, as described in clause 6.1.3.19 of [10, TS 38.321], for activated ZP CSI-RS resource(s), the corresponding action in [10, TS 38.321] and the UE assumption on cessation of the PDSCH RE mapping corresponding to the de-activated ZP CSI-RS resource(s) shall be applied starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$ where μ is the SCS configuration for the PUCCH.

5.1.5 Antenna ports quasi co-location

The UE can be configured with a list of up to *M TCI-State* configurations within the higher layer parameter *PDSCH-Config* to decode PDSCH according to a detected PDCCH with DCI intended for the UE and the given serving cell, where M depends on the UE capability *maxNumberConfiguredTCIstatesPerCC*. Each *TCI-State* contains parameters for configuring a quasi co-location relationship between one or two downlink reference signals and the DM-RS ports of the PDSCH, the DM-RS port of PDCCH or the CSI-RS port(s) of a CSI-RS resource. The quasi co-location relationship is configured by the higher layer parameter *qcl-Type1* for the first DL RS, and *qcl-Type2* for the second DL RS (if configured). For the case of two DL RSs, the QCL types shall not be the same, regardless of whether the references are to the same DL RS or different DL RSs. The quasi co-location types corresponding to each DL RS are given by the higher layer parameter *qcl-Type* in *QCL-Info* and may take one of the following values:

- 'typeA': {Doppler shift, Doppler spread, average delay, delay spread}
- 'typeB': {Doppler shift, Doppler spread}
- 'typeC': {Doppler shift, average delay}
- 'typeD': {Spatial Rx parameter}

The UE receives an activation command, as described in clause 6.1.3.14 of [10, TS 38.321], used to map up to 8 TCI states to the codepoints of the DCI field *'Transmission Configuration Indication'* in one CC/DL BWP or in a set of CCs/DL BWPs, respectively. When a set of TCI state IDs are activated for a set of CCs/DL BWPs, where the applicable list of CCs is determined by indicated CC in the activation command, the same set of TCI state IDs are applied for all DL BWPs in the indicated CCs.

When a UE supports two TCI states in a codepoint of the DCI field '*Transmission Configuration Indication'* the UE may receive an activation command, as described in clause 6.1.3.24 of [10, TS 38.321], the activation command is used to map up to 8 combinations of one or two TCI states to the codepoints of the DCI field *'Transmission Configuration Indication'*. The UE is not expected to receive more than 8 TCI states in the activation command.

When the DCI field *'Transmission Configuration Indication'* is present in DCI format 1_2 and when the number of codepoints S in the DCI field *'Transmission Configuration Indication'* of DCI format 1_2 is smaller than the number of TCI codepoints that are activated by the activation command, as described in clause 6.1.3.14 and 6.1.3.24 of [10, TS38.321], only the first S activated codepoints are applied for DCI format 1_2.

When the UE would transmit a PUCCH with HARQ-ACK information in slot *n* corresponding to the PDSCH carrying the activation command, the indicated mapping between TCI states and codepoints of the DCI field *'Transmission Configuration Indication'* should be applied starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$ where μ is the SCS configuration for the PUCCH. If *tci-PresentInDCI* is set to 'enabled' or *tci-PresentDCI-1-2* is configured for the CORESET scheduling the PDSCH, and the time offset between the reception of the DL DCI and the corresponding PDSCH is equal to or greater than *timeDurationForQCL* if applicable, after a UE receives an initial higher layer configuration of TCI states and before reception of the activation command, the UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the SS/PBCH block determined in the initial access procedure with respect to *qcl-Type* set to 'typeA', and when applicable, also with respect to *qcl-Type* set to 'typeD'.

If a UE is configured with the higher layer parameter *tci-PresentInDCI* that is set as 'enabled' for the CORESET scheduling the PDSCH, the UE assumes that the TCI field is present in the DCI format 1_1 of the PDCCH transmitted on the CORESET. If a UE is configured with the higher layer parameter *tci-PresentDCI-1-2* for the CORESET scheduling the PDSCH, the UE assumes that the TCI field with a DCI field size indicated by *tci-PresentDCI-1-2* is present in the DCI format 1_2 of the PDCCH transmitted on the CORESET. If the PDSCH is scheduled by a DCI format not having the TCI field present, and the time offset between the reception of the DL DCI and the corresponding PDSCH of a serving cell is equal to or greater than a threshold *timeDurationForQCL* if applicable, where the threshold is based on reported UE capability [13, TS 38.306], for determining PDSCH antenna port quasi co-location, the UE assumes that the TCI state or the QCL assumption for the PDSCH is identical to the TCI state or QCL assumption whichever is applied for the CORESET used for the PDCCH transmission within the active BWP of the serving cell.

If the PDSCH is scheduled by a DCI format having the TCI field present, the TCI field in DCI in the scheduling component carrier points to the activated TCI states in the scheduled component carrier or DL BWP, the UE shall use the *TCI-State* according to the value of the '*Transmission Configuration Indication*' field in the detected PDCCH with DCI for determining PDSCH antenna port quasi co-location. The UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the RS(s) in the TCI state with respect to the QCL type parameter(s) given by the indicated TCI state if the time offset between the reception of the DL DCI and the corresponding PDSCH is equal to or greater than a threshold *timeDurationForQCL*, where the threshold is based on reported UE capability [13, TS 38.306]. When the UE is configured with a single slot PDSCH, the indicated TCI state should be based on the activated TCI states in the slot with the scheduled PDSCH. When the UE is configured with a multi-slot PDSCH, the indicated TCI state should be based on the activated TCI states in the first slot with the scheduled PDSCH, and UE shall expect the activated TCI states are the same across the slots with the scheduled PDSCH. When the UE is configured with CORESET associated with a search space set for cross-carrier scheduling and the UE is not configured with *enableDefaultBeamForCCS*, the UE expects *tci-PresentInDCI* is set as 'enabled' or *tci-PresentDCI-1-2* is configured for the CORESET, and if one or more of the TCI states configured for the serving cell scheduled by the search space set contains *qcl-Type* set to 'typeD', the UE expects the time offset between the reception of the detected PDCCH in the search space set and the corresponding PDSCH is larger than or equal to the threshold *timeDurationForQCL*.

Independent of the configuration of *tci-PresentInDCI* and *tci-PresentDCI-1-2* in RRC connected mode, if the offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold *timeDurationForQCL* and at least one configured TCI state for the serving cell of scheduled PDSCH contains *qcl-Type* set to 'typeD',

- the UE may assume that the DM-RS ports of PDSCH(s) of a serving cell are quasi co-located with the RS(s) with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the CORESET associated with a monitored search space with the lowest *controlResourceSetId* in the latest slot in which one or more CORESETs within the active BWP of the serving cell are monitored by the UE. In this case, if the *qcl-Type* is set to 'typeD' of the PDSCH DM-RS is different from that of the PDCCH DM-RS with which they overlap in at least one symbol, the UE is expected to prioritize the reception of PDCCH associated with that CORESET. This also applies to the intra-band CA case (when PDSCH and the CORESET are in different component carriers).

- If a UE is configured with *enableDefaultTCI-StatePerCoresetPoolIndex* and the UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in different *ControlResourceSets*,

  - the UE may assume that the DM-RS ports of PDSCH associated with a value of *coresetPoolIndex* of a serving cell are quasi co-located with the RS(s) with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the CORESET associated with a monitored search space with the lowest *controlResourceSetId* among CORESETs, which are configured with the same value of *coresetPoolIndex* as the PDCCH scheduling that PDSCH, in the latest slot in which one or more CORESETs associated with the same value of *coresetPoolIndex* as the PDCCH scheduling that PDSCH within the active BWP of the serving cell are monitored by the UE. In this case, if the 'QCL-TypeD' of the PDSCH DM-RS is different from that of the PDCCH DM-RS with which they overlap in at least one symbol and they are associated with same value of *coresetPoolIndex*, the UE is expected to prioritize the reception of PDCCH associated with that CORESET. This also applies to the intra-band CA case (when PDSCH and the CORESET are in different component carriers).

- If a UE is configured with *enableTwoDefaultTCI-States*, and at least one TCI codepoint indicates two TCI states, the UE may assume that the DM-RS ports of PDSCH or PDSCH transmission occasions of a serving cell are quasi co-located with the RS(s) with respect to the QCL parameter(s) associated with the TCI states corresponding to the lowest codepoint among the TCI codepoints containing two different TCI states. When the

UE is configured by higher layer parameter *repetitionScheme* set to 'tdmSchemeA' or is configured with higher layer parameter *repetitionNumber*, and the offset between the reception of the DL DCI and the first PDSCH transmission occasion is less than the threshold *timeDurationForQCL,* the mapping of the TCI states to PDSCH transmission occasions is determined according to clause 5.1.2.1 by replacing the indicated TCI states with the TCI states corresponding to the lowest codepoint among the TCI codepoints containing two different TCI states based on the activated TCI states in the slot with the first PDSCH transmission occasion. In this case, if the 'QCL-TypeD' in both of the TCI states corresponding to the lowest codepoint among the TCI codepoints containing two different TCI states is different from that of the PDCCH DM-RS with which they overlap in at least one symbol, the UE is expected to prioritize the reception of PDCCH associated with that CORESET. This also applies to the intra-band CA case (when PDSCH and the CORESET are in different component carriers)

- In all cases above, if none of configured TCI states for the serving cell of scheduled PDSCH is configured with *qcl-Type* set to 'typeD', the UE shall obtain the other QCL assumptions from the indicated TCI state(s) for its scheduled PDSCH irrespective of the time offset between the reception of the DL DCI and the corresponding PDSCH.

If the PDCCH carrying the scheduling DCI is received on one component carrier, and the PDSCH scheduled by that DCI is on another component carrier:

- The *timeDurationForQCL* is determined based on the subcarrier spacing of the scheduled PDSCH. If $\mu_{PDCCH} < \mu_{PDSCH}$ an additional timing delay $d\frac{2^{\mu_{PDSCH}}}{2^{\mu_{PDCCH}}}$ is added to the *timeDurationForQCL*, where *d* is defined in 5.2.1.5.1a-1, otherwise *d* is zero;

- When the UE is configured with *enableDefaultBeamForCCS*, if the offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold *timeDurationForQCL*, or if the DL DCI does not have the TCI field present, the UE obtains its QCL assumption for the scheduled PDSCH from the activated TCI state with the lowest ID applicable to PDSCH in the active BWP of the scheduled cell.

For a periodic CSI-RS resource in an *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info*, the UE shall expect that a TCI-State indicates one of the following quasi co-location type(s):

- 'typeC' with an SS/PBCH block and, when applicable, 'typeD' with the same SS/PBCH block, or

- 'typeC' with an SS/PBCH block and, when applicable,'typeD' with a CSI-RS resource in an *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *repetition*.

For an aperiodic CSI-RS resource in an *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info,* the UE shall expect that a *TCI-State* indicates *qcl-Type* set to 'typeA' with a periodic CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, *qcl-Type* set to 'typeD' with the same periodic CSI-RS resource.

For a CSI-RS resource in an *NZP-CSI-RS-ResourceSet* configured without higher layer parameter *trs-Info* and without the higher layer parameter *repetition*, the UE shall expect that a *TCI-State* indicates one of the following quasi co-location type(s):

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'typeD' with the same CSI-RS resource, or

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'typeD' with an SS/PBCH block, or

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'typeD' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *repetition*, or

- 'typeB' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* when 'typeD' is not applicable.

For a CSI-RS resource in an *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *repetition,* the UE shall expect that a *TCI-State* indicates one of the following quasi co-location type(s):

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'typeD' with the same CSI-RS resource, or

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'typeD' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *repetition*, or

- 'typeC' with an SS/PBCH block and, when applicable, 'typeD' with the same SS/PBCH block.

For the DM-RS of PDCCH, the UE shall expect that a *TCI-State* indicates one of the following quasi co-location type(s):

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'typeD' with the same CSI-RS resource, or

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'typeD' with a CSI-RS resource in an *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *repetition*, or

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured without higher layer parameter trs-Info and without higher layer parameter *repetition* and, when applicable, 'typeD' with the same CSI-RS resource.

For the DM-RS of PDSCH, the UE shall expect that a *TCI-State* indicates one of the following quasi co-location type(s):

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'typeD' with the same CSI-RS resource, or

- 'typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info* and, when applicable, 'typeD' with a CSI-RS resource in an *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *repetition*,or

- typeA' with a CSI-RS resource in a *NZP-CSI-RS-ResourceSet* configured without higher layer parameter *trs-Info* and without higher layer parameter *repetition* and, when applicable, 'typeD' with the same CSI-RS resource.

5.1.6 UE procedure for receiving reference signals

5.1.6.1 CSI-RS reception procedure

The CSI-RS defined in Clause 7.4.1.5 of [4, TS 38.211], may be used for time/frequency tracking, CSI computation, L1-RSRP computation, L1-SINR computation and mobility.

For a CSI-RS resource associated with a *NZP-CSI-RS-ResourceSet* with the higher layer parameter *repetition* set to 'on', the UE shall not expect to be configured with CSI-RS over the symbols during which the UE is also configured to monitor the CORESET, while for other *NZP-CSI-RS-ResourceSet* configurations, if the UE is configured with a CSI-RS resource and a search space set associated with a CORESET in the same OFDM symbol(s), the UE may assume that the CSI-RS and a PDCCH DM-RS transmitted in all the search space sets associated with CORESET are quasi co-located with 'typeD', if 'typeD' is applicable. This also applies to the case when CSI-RS and the CORESET are in different intra-band component carriers, if 'typeD' is applicable. Furthermore, the UE shall not expect to be configured with the CSI-RS in PRBs that overlap those of the CORESET in the OFDM symbols occupied by the search space set(s).

The UE is not expected to receive CSI-RS and *SIB1* message in the overlapping PRBs in the OFDM symbols where *SIB1* is transmitted.

If the UE is configured with DRX,

- if the UE is configured to monitor DCI format 2_6 and configured by higher layer parameter *ps-TransmitOtherPeriodicCSI* to report CSI with the higher layer parameter *reportConfigType* set to 'periodic' and *reportQuantity* set to quantities other than 'cri-RSRP' and 'ssb-Index-RSRP' when *drx-onDurationTimer* in *DRX-Config* is not started, the most recent CSI measurement occasion occurs in DRX active time or during the time duration indicated by *drx-onDurationTimer* in *DRX-Config* also outside DRX active time for CSI to be reported;

- if the UE is configured to monitor DCI format 2_6 and configured by higher layer parameter *ps-TransmitPeriodicL1-RSRP* to report L1-RSRP with the higher layer parameter *reportConfigType* set to 'periodic' and *reportQuantity* set to cri-RSRP when *drx-onDurationTimer* in *DRX-Config* is not started, the most recent CSI measurement occasion occurs in DRX active time or during the time duration indicated by *drx-onDurationTimer* in *DRX-Config* also outside DRX active time for CSI to be reported;

- otherwise, the most recent CSI measurement occasion occurs in DRX active time for CSI to be reported.

5.1.6.1.1 CSI-RS for tracking

A UE in RRC connected mode is expected to receive the higher layer UE specific configuration of a *NZP-CSI-RS-ResourceSet* configured with higher layer parameter *trs-Info*.

For a *NZP-CSI-RS-ResourceSet* configured with the higher layer parameter *trs-Info*, the UE shall assume the antenna port with the same port index of the configured NZP CSI-RS resources in the *NZP-CSI-RS-ResourceSet* is the same.

- For frequency range 1, the UE may be configured with one or more NZP CSI-RS set(s), where a *NZP-CSI-RS-ResourceSet* consists of four periodic NZP CSI-RS resources in two consecutive slots with two periodic NZP CSI-RS resources in each slot. If no two consecutive slots are indicated as downlink slots by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigDedicated*, then the UE may be configured with one or more NZP CSI-RS set(s), where a *NZP-CSI-RS-ResourceSet* consists of two periodic NZP CSI-RS resources in one slot.

- For frequency range 2 the UE may be configured with one or more NZP CSI-RS set(s), where a *NZP-CSI-RS-ResourceSet* consists of two periodic CSI-RS resources in one slot or with a *NZP-CSI-RS-ResourceSet* of four periodic NZP CSI-RS resources in two consecutive slots with two periodic NZP CSI-RS resources in each slot.

A UE configured with *NZP-CSI-RS-ResourceSet(s)* configured with higher layer parameter *trs-Info* may have the CSI-RS resources configured as:

- Periodic, with the CSI-RS resources in the *NZP-CSI-RS-ResourceSet* configured with same periodicity, bandwidth and subcarrier location.

- Periodic CSI-RS resource in one set and aperiodic CSI-RS resources in a second set, with the aperiodic CSI-RS and periodic CSI-RS resource having the same bandwidth (with same RB location) and the aperiodic CSI-RS being configured with *qcl-Type* set to 'typeA' and 'typeD', where applicable, with the periodic CSI-RS resources. For frequency range 2, the UE does not expect that the scheduling offset between the last symbol of the PDCCH carrying the triggering DCI and the first symbol of the aperiodic CSI-RS resources is smaller than $beamSwitchTiming + d \cdot 2^{\mu_{CSIRS}}/2^{\mu_{PDCCH}}$ in CSI-RS symbols, where *beamSwitchTiming* is UE reported value defined in [13, TS 38.306], the reported value is one of the values of {14, 28, 48}, and the beam switching timing delay *d* is defined in Table 5.2.1.5.1a-1 if $\mu_{PDCCH} < \mu_{CSIRS}$, else *d* is zero. The UE shall expect that the periodic CSI-RS resource set and aperiodic CSI-RS resource set are configured with the same number of CSI-RS resources and with the same number of CSI-RS resources in a slot. For the aperiodic CSI-RS resource set if triggered, and if the associated periodic CSI-RS resource set is configured with four periodic CSI-RS resources with two consecutive slots with two periodic CSI-RS resources in each slot, the higher layer parameter *aperiodicTriggeringOffset* indicates the triggering offset for the first slot for the first two CSI-RS resources in the set.

A UE does not expect to be configured with a *CSI-ReportConfig* that is linked to a *CSI-ResourceConfig* containing an *NZP-CSI-RS-ResourceSet* configured with *trs-Info* and with the *CSI-ReportConfig* configured with the higher layer parameter *timeRestrictionForChannelMeasurements* set to 'configured'.

A UE does not expect to be configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to other than 'none' for aperiodic NZP CSI-RS resource set configured with *trs-Info.*

A UE does not expect to be configured with a *CSI-ReportConfig* for periodic NZP CSI-RS resource set configured with *trs-Info.*

A UE does not expect to be configured with a *NZP-CSI-RS-ResourceSet* configured both with *trs-Info* and *repetition*.

Each CSI-RS resource, defined in Clause 7.4.1.5.3 of [4, TS 38.211], is configured by the higher layer parameter *NZP-CSI-RS-Resource* with the following restrictions:

- the time-domain locations of the two CSI-RS resources in a slot, or of the four CSI-RS resources in two consecutive slots (which are the same across two consecutive slots), as defined by higher layer parameter *CSI-RS-resourceMapping*, is given by one of
  - $l \in \{4,8\}$, $l \in \{5,9\}$, or $l \in \{6,10\}$ for frequency range 1 and frequency range 2,
  - $l \in \{0,4\}$, $l \in \{1,5\}$, $l \in \{2,6\}$, $l \in \{3,7\}$, $l \in \{7,11\}$, $l \in \{8,12\}$ or $l \in \{9,13\}$ for frequency range 2.

- a single port CSI-RS resource with density $\rho = 3$ given by Table 7.4.1.5.3-1 from [4, TS 38.211] and higher layer parameter *density* configured by *CSI-RS-ResourceMapping.*

- if carrier $N_{\text{grid}}^{\text{size},\mu} = 52$, $\text{N}_{\text{BWP,i}}^{\text{size}} = 52$, $\mu = 0$ and the carrier is configured in paired spectrum, the bandwidth of the CSI-RS resource, as given by the higher layer parameter *freqBand* configured by *CSI-RS-ResourceMapping*, is *X* resource blocks, where $X \geq 28$ resources if the UE indicates *trs-AddBW-Set1* for the *trs-AdditionalBandwidth* capability and $X \geq 32$ if the UE indicates *trs-AddBW-Set2* for the *AdditionalBandwidth* capability; in these cases, if the UE is configured with CSI-RS comprising X<52 resource blocks, the UE does not expect that the total number of PRBs allocated for DL transmissions but not overlapped with the PRBs carrying CSI-RS for tracking is more than 4, where all CSI-RS resource configurations shall span the same set of resource blocks; otherwise, the bandwidth of the CSI-RS resource, as given by the higher layer parameter *freqBand* configured by *CSI-RS-ResourceMapping*, is the minimum of 52 and $\text{N}_{\text{BWP,i}}^{\text{size}}$ resource blocks, or is equal to $\text{N}_{\text{BWP,i}}^{\text{size}}$ resource blocks. For operation with shared spectrum channel access, *freqBand* configured by *CSI-RS-ResourceMapping*, is the minimum of 48 and $\text{N}_{\text{BWP,i}}^{\text{size}}$ resource blocks, or is equal to $\text{N}_{\text{BWP,i}}^{\text{size}}$ resource blocks.

- the UE is not expected to be configured with the periodicity of $2^{\mu} \times 10$ slots if the bandwidth of CSI-RS resource is larger than 52 resource blocks.

- the periodicity and slot offset for periodic NZP CSI-RS resources, as given by the higher layer parameter *periodicityAndOffset* configured by *NZP-CSI-RS-Resource*, is one of $2^{\mu} X_p$ slots where $X_p = 10$, 20, 40, or 80 and where μ is defined in Clause 4.3 of [4, TS 38.211].

- same *powerControlOffset* and *powerControlOffsetSS* given by *NZP-CSI-RS-Resource* value across all resources.

5.1.6.1.2 CSI-RS for L1-RSRP and L1-SINR computation

If a UE is configured with a *NZP-CSI-RS-ResourceSet* configured with the higher layer parameter *repetition* set to 'on', the UE may assume that the CSI-RS resources, described in Clause 5.2.2.3.1, within the *NZP-CSI-RS-ResourceSet* are transmitted with the same downlink spatial domain transmission filter, where the CSI-RS resources in the *NZP-CSI-RS-ResourceSet* are transmitted in different OFDM symbols. If *repetition* is set to 'off', the UE shall not assume that the CSI-RS resources within the *NZP-CSI-RS-ResourceSet* are transmitted with the same downlink spatial domain transmission filter.

If the UE is configured with a *CSI-ReportConfig* with *reportQuantity* set to 'cri-RSRP', 'cri-SINR' or 'none' and if the *CSI-ResourceConfig* for channel measurement (higher layer parameter *resourcesForChannelMeasurement*) contains a *NZP-CSI-RS-ResourceSet* that is configured with the higher layer parameter *repetition* and without the higher layer parameter *trs-Info*, the UE can only be configured with the same number (1 or 2) of ports with the higher layer parameter *nrofPorts* for all CSI-RS resources within the set. If the UE is configured with the CSI-RS resource in the same OFDM symbol(s) as an SS/PBCH block, the UE may assume that the CSI-RS and the SS/PBCH block are quasi co-located with 'typeD' if 'typeD' is applicable. Furthermore, the UE shall not expect to be configured with the CSI-RS in PRBs that overlap with those of the SS/PBCH block, and the UE shall expect that the same subcarrier spacing is used for both the CSI-RS and the SS/PBCH block.

5.1.6.1.3 CSI-RS for mobility

If a UE is configured with the higher layer parameter *CSI-RS-Resource-Mobility* and the higher layer parameter *associatedSSB* is not configured, the UE shall perform measurements based on *CSI-RS-Resource-Mobility* and the UE may base the timing of the CSI-RS resource on the timing of the serving cell.

If a UE is configured with the higher layer parameters *CSI-RS-Resource-Mobility* and *associatedSSB*, the UE may base the timing of the CSI-RS resource on the timing of the cell given by the *cellId* of the CSI-RS resource configuration. Additionally, for a given CSI-RS resource, if the associated SS/PBCH block is configured but not detected by the UE, the UE is not required to monitor the corresponding CSI-RS resource. The higher layer parameter *isQuasiColocated* indicates whether the associated SS/PBCH block given by the *associatedSSB* and the CSI-RS resource(s) are quasi co-located with respect to 'typeD', when applicable.

If a UE is configured with the higher layer parameter *CSI-RS-Resource-Mobility* and with periodicity greater than 10 msec in paired spectrum, the UE may assume the absolute value of the time difference between radio frame *i* between any two cells, listed in the configuration with the higher layer parameter *CSI-RS-CellMobility* and with same *refFreqCSI-RS*, is less than 153600 T_s.

If the UE is configured with DRX, the UE is not required to perform measurement of CSI-RS resources other than during the active time for measurements based on *CSI-RS-Resource-Mobility*. When the UE is configured to monitor DCI format 2_6, the UE is not required to perform measurements other than during the active time and during the timer duration indicated by *drx-onDurationTimer* in *DRX-Config* also outside active time based on *CSI-RS-Resource-Mobility*.

If the UE is configured with DRX and DRX cycle in use is larger than 80 msec, the UE may not expect CSI-RS resources are available other than during the active time for measurements based on *CSI-RS-Resource-Mobility*. If the UE is configured with DRX and configured to monitor DCI format 2_6 and DRX cycle in use is larger than 80 msec, the UE may not expect that the CSI-RS resources are available other than during the active time and during the time duration indicated by *drx-onDurationTimer* in *DRX-Config* also outside active time for measurements based on *CSI-RS-Resource-Mobility.* Otherwise, the UE may assume CSI-RS are available for measurements based on *CSI-RS-Resource-Mobility*.

A UE configured with the higher layer parameters *CSI-RS-Resource-Mobility* may expect to be configured

- with no more than 96 CSI-RS resources per higher layer parameter *MeasObjectNR* for UEs not supporting [*increasedNumberofCSIRSPerMO-r16*] when all CSI-RS resources configured by the same higher layer parameter *MeasObjectNR* have been configured with *associatedSSB*, or,

- with no more than 192 CSI-RS resources per higher layer parameter *MeasObjectNR* for UEs supporting [*increasedNumberofCSIRSPerMO-r16*] when all CSI-RS resources configured by the same higher layer parameter *MeasObjectNR* have been configured with *associatedSSB*, or,

- with no more than 64 CSI-RS resources per higher layer parameter *MeasObjectNR* when all CSI-RS resources have been configured without *associatedSSB* or when only some of the CSI-RS resources have been configured with associatedSSB by the same higher layer parameter *MeasObjectNR*

  - For frequency range 1 the *associatedSSB* is optionally present for each CSI-RS resource.

  - For frequency range 2 the *associatedSSB* is either present for all configured CSI-RS resources or not present for any configured CSI-RS resource per higher layer parameter *MeasObjectNR*.

For any CSI-RS resource configuration, the UE shall assume that the value for parameter *cdm-Type* is 'noCDM', and there is only one antenna port.

5.1.6.2 DM-RS reception procedure

The DM-RS reception procedures for PDSCH scheduled by PDCCH with DCI format 1_1 described in this clause equally apply to PDSCH scheduled by PDCCH with DCI format 1_2, by applying the parameters of *dmrs-DownlinkForPDSCH-MappingTypeA-DCI-1-2* and *dmrs-DownlinkForPDSCH-MappingTypeB-DCI-1-2* instead of *dmrs-DownlinkForPDSCH-MappingTypeA* and *dmrs-DownlinkForPDSCH-MappingTypeB*.

When receiving PDSCH scheduled by DCI format 1_0 or receiving PDSCH before dedicated higher layer configuration of any of the parameters *dmrs-AdditionalPosition*, *maxLength* and *dmrs-Type,* the UE shall assume that the PDSCH is not present in any symbol carrying DM-RS except for PDSCH with allocation duration of 2 symbols with PDSCH mapping type B (described in clause 7.4.1.1.2 of [4, TS 38.211]), and a single symbol front-loaded DM-RS of configuration type 1 on DM-RS port 1000 is transmitted, and that all the remaining orthogonal antenna ports are not associated with transmission of PDSCH to another UE and in addition

- For PDSCH with mapping type A and type B, the UE shall assume *dmrs-AdditionalPosition*='pos2' and up to two additional single-symbol DM-RS present in a slot according to the PDSCH duration indicated in the DCI as defined in Clause 7.4.1.1 of [4, TS 38.211], and

- For PDSCH with allocation duration of 2 symbols with mapping type B, the UE shall assume that the PDSCH is present in the symbol carrying DM-RS.

When receiving PDSCH scheduled by DCI format 1_1 by PDCCH with CRC scrambled by C-RNTI, MCS-C-RNTI, or CS-RNTI,

- the UE may be configured with the higher layer parameter *dmrs-Type*, and the configured DM-RS configuration type is used for receiving PDSCH in as defined in Clause 7.4.1.1 of [4, TS 38.211].

- the UE may be configured with the maximum number of front-loaded DM-RS symbols for PDSCH by higher layer parameter *maxLength* given by *DMRS-DownlinkConfig*..

- if *maxLength* is set to 'len1', single-symbol DM-RS can be scheduled for the UE by DCI, and the UE can be configured with a number of additional DM-RS for PDSCH by higher layer parameter *dmrs-AdditionalPosition*, which can be set to 'pos0', 'pos1', 'pos2' or 'pos3'.

- if *maxLength* is set to 'len2', both single-symbol DM-RS and double symbol DM-RS can be scheduled for the UE by DCI, and the UE can be configured with a number of additional DM-RS for PDSCH by higher layer parameter *dmrs-AdditionalPosition*, which can be set to 'pos0' or 'pos1'.

- and the UE shall assume to receive additional DM-RS as specified in Table 7.4.1.1.2-3 and Table 7.4.1.1.2-4 as described in Clause 7.4.1.1.2 of [4, TS 38.211].

For the UE-specific reference signals generation as defined in Clause 7.4.1.1 of [4, TS 38.211], a UE can be configured by higher layers with one or two scrambling identity(s), $n_{ID}^{DMRS,i}$ $i = 0,1$ which are the same for both PDSCH mapping Type A and Type B.

A UE may be scheduled with a number of DM-RS ports by the antenna port index in DCI format 1_1 as described in Clause 7.3.1.2 of [5, TS 38.212].

For DM-RS configuration type 1,

- if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 9, 10, 11 or 30} in Table 7.3.1.2.2-1 and Table 7.3.1.2.2-2 of Clause 7.3.1.2 of [5, TS 38.212], or

- if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 9, 10, 11 or 12} in Table 7.3.1.2.2-1A and {2, 9, 10, 11, 30 or 31} in Table 7.3.1.2.2-2A of Clause 7.3.1.2 of [5, TS 38.212], or

- if a UE is scheduled with two codewords,

the UE may assume that all the remaining orthogonal antenna ports are not associated with transmission of PDSCH to another UE.

For DM-RS configuration type 2,

- if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 10 or 23} in Table 7.3.1.2.2-3 and Table 7.3.1.2.2-4 of Clause 7.3.1.2 of [5, TS38.212], or

- if a UE is scheduled with one codeword and assigned with the antenna port mapping with indices of {2, 10, 23 or 24} in Table 7.3.1.2.2-3A and {2, 10, 23 or 58} in Table 7.3.1.2.2-4A of Clause 7.3.1.2 of [5, TS 38.212], or

- if a UE is scheduled with two codewords,

the UE may assume that all the remaining orthogonal antenna ports are not associated with transmission of PDSCH to another UE.

If a UE receiving PDSCH scheduled by DCI format 1_2 is configured with the higher layer parameter *phaseTrackingRS* in *dmrs-DownlinkForPDSCH-MappingTypeA-DCI-1-2* or *dmrs-DownlinkForPDSCH-MappingTypeB-DCI-1-2* or a UE receiving PDSCH scheduled by DCI format 1_0 or DCI format 1_1 is configured with the higher layer parameter *phaseTrackingRS* in *dmrs-DownlinkForPDSCH-MappingTypeA* or *dmrs-DownlinkForPDSCH-MappingTypeB*, the UE may assume that the following configurations are not occurring simultaneously for the received PDSCH:

- any DM-RS ports among 1004-1007 or 1006-1011 for DM-RS configurations type 1 and type 2, respectively are scheduled for the UE and the other UE(s) sharing the DM-RS REs on the same CDM group(s), and

- PT-RS is transmitted to the UE.

The UE is not expected to simultaneously be configured with the maximum number of front-loaded DM-RS symbols for PDSCH by higher layer parameter *maxLength* being set equal to 'len2' and more than one additional DM-RS symbol as given by the higher layer parameter *dmrs-AdditionalPosition*.

The UE is not expected to assume co-scheduled UE(s) with different DM-RS configuration with respect to the actual number of front-loaded DM-RS symbol(s), the actual number of additional DM-RS, the DM-RS symbol location, and DM-RS configuration type as described in Clause 7.4.1.1 of [4, TS 38.211].

The UE does not expect the precoding of the potential co-scheduled UE(s) in other DM-RS ports of the same CDM group to be different in the PRG-level grid configured to this UE with PRG =2 or 4.

The UE does not expect the resource allocation of the potential co-scheduled UE(s) in other DM-RS ports of the same CDM group to be misaligned in the PRG-level grid to this UE with PRG=2 or 4.

When receiving PDSCH scheduled by DCI format 1_1, the UE shall assume that the CDM groups indicated in the configured index from Tables 7.3.1.2.2-1, 7.3.1.2.2-1A, 7.3.1.2.2-2, 7.3.1.2.2-2A, 7.3.1.2.2-3, 7.3.1.2.2-3A, 7.3.1.2.2-4, 7.3.1.2.2-4A of [5, TS. 38.212] contain potential co-scheduled downlink DM-RS and are not used for data transmission, where "1", "2" and "3" for the number of DM-RS CDM group(s) in Tables 7.3.1.2.2-1, 7.3.1.2.2-1A, 7.3.1.2.2-2, 7.3.1.2.2-3, 7.3.1.2.2-3A, 7.3.1.2.2-4, 7.3.1.2.2-4A of [5, TS. 38.212] correspond to CDM group 0, {0,1}, {0,1,2}, respectively.

When receiving PDSCH scheduled by DCI format 1_0, the UE shall assume the number of DM-RS CDM groups without data is 1 which corresponds to CDM group 0 for the case of PDSCH with allocation duration of 2 symbols, and the UE shall assume that the number of DM-RS CDM groups without data is 2 which corresponds to CDM group {0,1} for all other cases.

The UE is not expected to receive PDSCH scheduling DCI which indicates CDM group(s) with potential DM-RS ports which overlap with any configured CSI-RS resource(s) for that UE.

If the UE receives the DM-RS for PDSCH and an SS/PBCH block in the same OFDM symbol(s), then the UE may assume that the DM-RS and SS/PBCH block are quasi co-located with 'typeD', if 'typeD' is applicable. Furthermore, the UE shall not expect to receive DM-RS in resource elements that overlap with those of the SS/PBCH block, and the UE can expect that the same or different subcarrier spacing is configured for the DM-RS and SS/PBCH block in a CC except for the case of 240 kHz where only different subcarrier spacing is supported.

If at least one TCI codepoint indicates two TCI states and the UE receives the DM-RS for PDSCH and an SS/PBCH block in the same OFDM symbol(s), then the UE may assume that at least one DM-RS port for the PDSCH and SS/PBCH block are quasi co-located with 'QCL-TypeD', if 'QCL-TypeD' is applicable.

If the UE is configured by higher layer parameter PDCCH-Config that contains two different values of CORESETPoolIndex in different ControlResourceSets, and the UE receives the DM-RS for PDSCH(s) and an SS/PBCH block in the same OFDM symbol(s), then the UE may assume that at least one DM-RS port for the PDSCH(s) and SS/PBCH block are quasi co-located with 'QCL-TypeD', if 'QCL-TypeD' is applicable.

If a UE is configured by the higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet*, the UE may be scheduled with fully or partially overlapping PDSCHs in the time and frequency domain by multiple PDCCHs with the following restrictions,

- the UE is not expected to assume different DM-RS configuration with respect to the actual number of front-loaded DM-RS symbol(s), the actual number of additional DM-RS symbol(s), the actual DM-RS symbol location, and DM-RS configuration type.

- the UE is not expected to assume DM-RS ports in a CDM group indicated by two TCI states.

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)',*

- the first TCI state corresponds to the CDM group of the first antenna port indicated by the antenna port indication table, and the second TCI state corresponds to the other CDM group.

5.1.6.3 PT-RS reception procedure

The procedures on PT-RS reception described in this clause apply to a UE receiving PDSCH scheduled by DCI format 1_2 configured with the higher layer parameter *phaseTrackingRS* in *dmrs-DownlinkForPDSCH-MappingTypeA-DCI-1-2* or *dmrs-DownlinkForPDSCH-MappingTypeB-DCI-1-2* and to a UE receiving PDSCH scheduled by DCI format 1_0 or DCI format 1_1 configured with the higher layer parameter *phaseTrackingRS* in *dmrs-DownlinkForPDSCH-MappingTypeA* or *dmrs-DownlinkForPDSCH-MappingTypeB*.

A UE shall report the preferred MCS and bandwidth thresholds based on the UE capability at a given carrier frequency, for each subcarrier spacing applicable to data channel at this carrier frequency, assuming the MCS table with the maximum Modulation Order as it reported to support.

If a UE is configured with the higher layer parameter *phaseTrackingRS* in *DMRS-DownlinkConfig*,

- the higher layer parameters *timeDensity* and *frequencyDensity* in *PTRS-DownlinkConfig* indicate the threshold values *ptrs-MCS*$_i$, i=1,2,3 and $N_{RB,i}$, i=0,1, as shown in Table 5.1.6.3-1 and Table 5.1.6.3-2, respectively.
- if either or both of the additional higher layer parameters *timeDensity* and *frequencyDensity* are configured, and the RNTI equals MCS-C-RNTI, C-RNTI or CS-RNTI, the UE shall assume the PT-RS antenna port' presence and pattern is a function of the corresponding scheduled MCS of the corresponding codeword and scheduled bandwidth in corresponding bandwidth part as shown in Table 5.1.6.3-1 and Table 5.1.6.3-2,
  - if the higher layer parameter *timeDensity* given by *PTRS-DownlinkConfig* is not configured, the UE shall assume $L_{PT\text{-}RS}$ = 1.
  - if the higher layer parameter *frequencyDensity* given by *PTRS-DownlinkConfig* is not configured, the UE shall assume $K_{PT\text{-}RS}$ = 2.
- otherwise, if neither of the additional higher layer parameters *timeDensity* and *frequencyDensity* are configured and the RNTI equals MCS-C-RNTI, C-RNTI or CS-RNTI, the UE shall assume the PT-RS is present with $L_{PT\text{-}RS}$ = 1, $K_{PT\text{-}RS}$ = 2, and the UE shall assume PT-RS is not present when
  - the scheduled MCS from Table 5.1.3.1-1 is smaller than 10, or
  - the scheduled MCS from Table 5.1.3.1-2 is smaller than 5, or
  - the scheduled MCS from Table 5.1.3.1-3 is smaller than 15, or
  - the number of scheduled RBs is smaller than 3, or
- otherwise, if the RNTI equals RA-RNTI, [MSGB-RNTI], SI-RNTI, or P-RNTI, the UE shall assume PT-RS is not present

Table 5.1.6.3-1: Time density of PT-RS as a function of scheduled MCS

Scheduled MCS	Time density (L_{PT-RS})
I_{MCS} < ptrs-MCS$_1$	PT-RS is not present
ptrs-MCS1 $\leq$ I_{MCS} < ptrs-MCS2	4
ptrs-MCS2 $\leq$ I_{MCS} < ptrs-MCS3	2
ptrs-MCS3 $\leq$ I_{MCS} < ptrs-MCS4	1

Table 5.1.6.3-2: Frequency density of PT-RS as a function of scheduled bandwidth

Scheduled bandwidth	Frequency density (K_{PT-RS})
$N_{RB} < N_{RB0}$	PT-RS is not present
$N_{RB0} \leq N_{RB} < N_{RB1}$	2
$N_{RB1} \leq N_{RB}$	4

If a UE is not configured with the higher layer parameter *phaseTrackingRS* in *DMRS-DownlinkConfig*, the UE assumes PT-RS is not present.

The higher layer parameter *PTRS-DownlinkConfig* provides the parameters *ptrs-MCS*$_i$, i=1,2,3 and with values in range 0-29 when MCS Table 5.1.3.1-1 or MCS Table 5.1.3.1-3 is used and 0-28 when MCS Table 5.1.3.1-2 is used, respectively. *ptrs-MCS4* is not explicitly configured by higher layers but assumed 29 when MCS Table 5.1.3.1-1 or MCS Table 5.1.3.1-3 is used and 28 when MCS Table 5.1.3.1-2 is used, respectively. The higher layer parameter *frequencyDensity* in *PTRS-DownlinkConfig* provides the parameters N_{RBi} i=0,1 with values in range 1-276.

If the higher layer parameter *PTRS-DownlinkConfig* indicates that the time density thresholds *ptrs-MCS*$_i$ = *ptrs-MCS*$_{i+1}$, then the time density $L_{PT\text{-}RS}$ of the associated row where both these thresholds appear in Table 5.1.6.3-1 is disabled. If the higher layer parameter *PTRS-DownlinkConfig* indicates that the frequency density thresholds $N_{RBi} = N_{RBi+1}$, then the frequency density K_{PTRS} of the associated row where both these thresholds appear in Table 5.1.6.3-2 is disabled.

If either or both of the parameters PT-RS time density (L_{PT-RS}) and PT-RS frequency density (K_{PT-RS}), shown in Table 5.1.6.3-1 and Table 5.1.6.3-2, indicates that 'PT-RS not present', the UE shall assume that PT-RS is not present.

When the UE is receiving a PDSCH with allocation duration of 2 symbols as defined in Clause 7.4.1.1.2 of [4, TS 38.211] and if L_{PT-RS} is set to 2 or 4, the UE shall assume PT-RS is not transmitted.

When the UE is receiving a PDSCH with allocation duration of 4 symbols and if L_{PT-RS} is set to 4, the UE shall assume PT-RS is not transmitted.

When a UE is receiving PDSCH for retransmission, if the UE is scheduled with an MCS index greater than V, where V=28 for MCS Table 5.1.3.1-1 and Table 5.1.3.1-3, and V=27 for MCS Table 5.1.3.1-2 respectively, the MCS for the PT-RS time-density determination is obtained from the DCI received for the same transport block in the initial transmission, which is smaller than or equal to V.

The DL DM-RS port(s) associated with a PT-RS port are assumed to be quasi co-located with respect to 'typeA' and 'typeD'. If a UE is scheduled with one codeword, the PT-RS antenna port is associated with the lowest indexed DM-RS antenna port among the DM-RS antenna ports assigned for the PDSCH.

If a UE is scheduled with two codewords, the PT-RS antenna port is associated with the lowest indexed DM-RS antenna port among the DM-RS antenna ports assigned for the codeword with the higher MCS. If the MCS indices of the two codewords are the same, the PT-RS antenna port is associated with the lowest indexed DM-RS antenna port assigned for codeword 0.

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 if the UE is configured with the higher layer parameter *maxNrofPorts* equal to *n2*, and if the UE is indicated with two TCI states by the codepoints of the DCI field *'Transmission Configuration Indication'* and DM-RS port(s) within two CDM groups in the DCI field '*Antenna Port(s)'*, the UE shall receive two PT-RS ports which are associated to the lowest indexed DM-RS port among the DM-RS ports corresponding to the first/second indicated TCI state, respectively.

When a UE configured by the higher layer parameter *repetitionScheme* set to 'fdmSchemeA' or 'fdmSchemeB', and 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)*', the UE shall receive a single PT-RS port which is associated with the lowest indexed DM-RS antenna port among the DM-RS antenna ports assigned for the PDSCH, a PT-RS frequency density is determined by the number of PRBs associated to each TCI state, and a PT-RS resource element mapping is associated to the allocated PRBs for each TCI state.

5.1.6.4 SRS reception procedure for CLI

The SRS resources defined in Clause 6.4.1.4 of [4, TS 38.211] may be configured for SRS-RSRP measurement for CLI, as defined in Clause 5.1.19 of [7, TS 38.215]. The UE is not expected to measure SRS-RSRP with a subcarrier spacing other than the one configured for the active BWP confining the SRS resource. The UE is not expected to measure SRS-RSRP using the SRS-RSRP measurement resource which is not fully confined within the DL active BWP. The UE is not expected to measure more than 32 SRS resources, and the UE is not expected to receive more than 8 SRS resources in a slot.

5.1.6.5 PRS reception procedure

The UE can be configured with one or more DL PRS resource set configuration(s) as indicated by the higher layer parameters *NR-DL-PRS-ResourceSet* and *NR-DL-PRS-Resource* as defined by Clause 6.4.3 [17, TS 37.355]. Each DL PRS resource set consists of K≥1 DL PRS resource(s) where each has an associated spatial transmission filter. The UE can be configured with one or more DL PRS positioning frequency layer configuration(s) as indicated by the higher layer parameter *NR-DL-PRS-PositioningFrequencyLayer.* A DL PRS positioning frequency layer is defined as a collection of DL PRS resource sets which have common parameters configured by *NR-DL-PRS-PositioningFrequencyLayer*.

The UE assumes that the following parameters for each DL PRS resource(s) are configured via higher layer parameters *NR-DL-PRS-PositioningFrequencyLayer, NR-DL-PRS-ResourceSet* and *NR-DL-PRS-Resource*.

A positioning frequency layer is configured by *NR-DL-PRS-PositioningFrequencyLayer*, consists of one or more DL PRS resource sets and it is defined by:

- *dl-PRS-SubcarrierSpacing* defines the subcarrier spacing for the DL PRS resource. All DL PRS resources and DL PRS resource sets in the same DL PRS positioning frequency layer have the same value of *dl-PRS-SubcarrierSpacing*. The supported values of *dl-PRS-SubcarrierSpacing* are given in Table 4.2-1 of [4, TS38.211], excluding the value of 240kHz.

- *dl-PRS-CyclicPrefix* defines the cyclic prefix for the DL PRS resource. All DL PRS Resources and DL PRS Resource sets in the same DL PRS positioning frequency layer have the same value of *dl-PRS-CyclicPrefix*. The supported values of *dl-PRS-CyclicPrefix* are given in Table 4.2-1 of [4, TS38.211].

- *dl-PRS-PointA* defines the absolute frequency of the reference resource block. Its lowest subcarrier is also known as Point A. All DL PRS resources belonging to the same DL PRS resource set have common Point A and all DL PRS resources sets belonging to the same DL PRS positioning frequency layer have a common Point A.

The UE expects that it will be configured with *dl-PRS-ID* each of which is defined such that it is associated with multiple DL PRS resource sets. The UE expects that one of these *dl-PRS-ID* along with a *nr-DL-PRS-ResourceSetID* and a *nr-DL-PRS-ResourceID-r16* can be used to uniquely identify a DL PRS resource.

The UE may be configured by the network with *nr-PhysCellID*, *nr-CellGlobalID*, and *nr-ARFCN* [17, TS 37.355] associated with a *dl-PRS-ID*.

- If *nr-PhysCellID* or *nr-CellGlobalID* is provided, and if *nr-PhysCellID*, *nr-CellGlobalID* and *nr-ARFCN* associated with the *dl-PRS-ID*, if provided, are the same as the corresponding information of a serving cell, the UE may assume that the DL PRS is transmitted from the serving cell;

- Otherwise, the UE may assume that the DL PRS is not transmitted from a serving cell.

If the UE assumes that the DL PRS is transmitted from a serving cell, and if the serving cell is the same as the serving cell defined by the SS/PBCH block, the UE may assume that the DL PRS and the SS/PBCH block are transmitted from the same serving cell.

If the UE assumes that the DL PRS is not transmitted from a serving cell, and if *nr-PhysCellID* is provided, and is the same as physical cell ID of the SS/PBCH block from a non-serving cell of the same band as the DL PRS, the UE may assume that the DL PRS and the SS/PBCH block are transmitted from the same non-serving cell.

A DL PRS resource set is configured by *NR-DL-PRS-ResourceSet*, consists of one or more DL PRS resources and it is defined by:

- *nr-DL-PRS-ResourceSetID* defines the identity of the DL PRS resource set configuration.

- *dl-PRS-Periodicity-and-ResourceSetSlotOffset* defines the DL PRS resource periodicity and takes values $T_{\mathrm{per}}^{\mathrm{PRS}} \in 2^{\mu}\{4, 5, 8, 10, 16, 20, 32, 40, 64, 80, 160, 320, 640, 1280, 2560, 5120, 10240\}$ slots, where $\mu = 0, 1, 2, 3$ for *dl-PRS-SubcarrierSpacing*=15, 30, 60 and 120 kHz respectively and the slot offset for DL PRS resource set with respect to SFN0 slot 0. All the DL PRS resources within one DL PRS resource set are configured with the same DL PRS resource periodicity. The UE does not expect that the product of DL PRS resource periodicity $T_{\mathrm{per}}^{\mathrm{PRS}}$, the higher layer parameter *dl-prs-MutingBitRepetitionFactor* and the size of the bitmap of *dl-PRS-MutingOption1* exceeds $2^{\mu} \times 10240$, where $\mu = 0, 1, 2, 3$ for *dl-PRS-SubcarrierSpacing*=15, 30, 60 and 120 kHz respectively.

- *dl-PRS-ResourceRepetitionFactor* defines how many times each DL-PRS resource is repeated for a single instance of the DL-PRS resource set and takes values $T_{\mathrm{rep}}^{\mathrm{PRS}} \in \{1,2,4,6,8,16,32\}$. All the DL PRS resources within one resource set have the same resource repetition factor.

- *dl-PRS-ResourceTimeGap* defines the offset in number of slots between two repeated instances of a DL PRS resource with the same *nr-DL-PRS-ResourceSetId* within a single instance of the DL PRS resource set. The UE only expects to be configured with *dl-PRS-ResourceTimeGap* if *dl-PRS-ResourceRepetitionFactor* is configured with value greater than 1. The time duration spanned by one instance of a *nr-DL-PRS-ResourceSet* is not expected to exceed the configured value of DL PRS periodicity. All the DL PRS resources within one resource set have the same value of *dl-PRS-ResourceTimeGap*.

- *dl-PRS-MutingOption1* and *dl-PRS-MutingOption2* define the time locations where the DL PRS resource is expected to not be transmitted for a DL PRS resource set. If *dl-PRS-MutingOption1* is configured, each bit in the bitmap of *dl-PRS-MutingOption1* corresponds to a configurable number provided by higher layer parameter *dl-prs-MutingBitRepetitionFactor* of consecutive instances of a DL PRS resource set where all the DL PRS resources within the set are muted for the instance that is indicated to be muted. The length of the bitmap can be

{2, 4, 6, 8, 16, 32} bits. If *dl-PRS-MutingOption2* is configured each bit in the bitmap of *dl-PRS-MutingOption2* corresponds to a single repetition index for each of the DL PRS resources within each instance of a *nr-DL-PRS-ResourceSet* and the length of the bitmap is equal to the values of *dl-PRS-ResourceRepetitionFactor*. Both *dl-PRS-MutingOption1* and *dl-PRS-MutingOption2* may be configured at the same time in which case the logical AND operation is applied to the bit maps as described in Clause 7.4.1.7.4 of [4, TS 38.211].

- *NR-DL-PRS-SFN0-Offset* defines the time offset of the SFN0 slot 0 for the DL PRS resource set with respect to SFN0 slot 0 of reference provided by *nr-DL-PRS-ReferenceInfo*.
- *dl-PRS-ResourceList* determines the DL PRS resources that are contained within one DL PRS resource set.
- *dl-PRS-CombSizeN* defines the comb size of a DL PRS resource where the allowable values are given in Clause 7.4.1.7.3 of [TS38.211]. All DL PRS resource sets belonging to the same positioning frequency layer have the same value of *dl-PRS-CombSizeN*.
- *dl-PRS-ResourceBandwidth* defines the number of resource blocks configured for DL PRS transmission. The parameter has a granularity of 4 PRBs with a minimum of 24 PRBs and a maximum of 272 PRBs. All DL PRS resources sets within a positioning frequency layer have the same value of *dl-PRS-ResourceBandwidth*.
- *dl-PRS-StartPRB* defines the starting PRB index of the DL PRS resource with respect to reference Point A, where reference Point A is given by the higher-layer parameter *dl-PRS-PointA*. The starting PRB index has a granularity of one PRB with a minimum value of 0 and a maximum value of 2176 PRBs. All DL PRS resource sets belonging to the same positioning frequency layer have the same value of *dl-PRS-StartPRB*.
- *dl-PRS-NumSymbols* defines the number of symbols of the DL PRS resource within a slot where the allowable values are given in Clause 7.4.1.7.3 of [4, TS38.211].

A DL PRS resource is defined by:

- *nr-DL-PRS-ResourceID* determines the DL PRS resource configuration identity. All DL PRS resource IDs are locally defined within a DL PRS resource set.
- *dl-PRS-SequenceID* is used to initialize c_{init} value used in pseudo random generator as described in Clause 7.4.1.7.2 of [4, TS 38.211] for generation of DL PRS sequence for a given DL PRS resource.
- *dl-PRS-CombSizeN-AndReOffset* defines the starting RE offset of the first symbol within a DL PRS resource in frequency. The relative RE offsets of the remaining symbols within a DL PRS resource are defined based on the initial offset and the rule described in Clause 7.4.1.7.3 of [4, TS 38.211].
- *dl-PRS-ResourceSlotOffset* determines the starting slot of the DL PRS resource with respect to corresponding DL PRS resource set slot offset.
- *dl-PRS-ResourceSymbolOffset* determines the starting symbol of a slot configured with the DL PRS resource.
- *dl-PRS-QCL-Info* defines any quasi co-location information of the DL PRS resource with other reference signals. The DL PRS may be configured with QCL 'typeD' with a DL PRS associated with the same *dl-PRS-ID*, or with *rs-Type* set to 'typeC', 'typeD', or 'typeC-plus-typeD' with a SS/PBCH Block from a serving or non-serving cell.

The UE assumes constant EPRE is used for all REs of a given DL PRS resource.

The UE may be indicated by the network that DL PRS resource(s) can be used as the reference for the DL RSTD, DL PRS-RSRP, and UE Rx-Tx time difference measurements in a higher layer parameter *nr-DL-PRS-ReferenceInfo*. The reference indicated by the network to the UE can also be used by the UE to determine how to apply higher layer parameters *nr-DL-PRS-ExpectedRSTD* and *nr-DL-PRS-ExpectedRSTD-Uncerainty*. The UE expects the reference to be indicated whenever it is expected to receive the DL PRS. This reference provided by *nr-DL-PRS-ReferenceInfo* may include a *dl-PRS-ID*, a DL PRS resource set ID, and optionally a single DL PRS resource ID or a list of DL PRS resource IDs [17, TS 37.355]. The UE may use different DL PRS resources or a different DL PRS resource set to determine the reference for the RSTD measurement as long as the condition that the DL PRS resources used belong to a single DL PRS resource set is met. If the UE chooses to use a different reference than indicated by the network, then it is expected to report the *dl-PRS-ID*, the DL PRS resource ID(s) or the DL PRS resource set ID used to determine the reference.

The UE may be configured to report quality metrics *NR-TimingQuality* corresponding to the DL RSTD and UE Rx-Tx time difference measurements which include the following fields:

- *timingQualityValue* which provides the best estimate of the uncertainty of the measurement
- *timingQualityResolution* which specifies the resolution levels used in the *timingQualityValue* field.

The UE expects to be configured with higher layer parameter *nr-DL-PRS-ExpectedRSTD*, which defines the time difference with respect to the received DL subframe timing the UE is expected to receive DL PRS, and *nr-DL-PRS-ExpectedRSTD-Uncertainty*, which defines a search window around the *nr-DL-PRS-ExpectedRSTD*.

For DL UE positioning measurement reporting in higher layer parameters *NR-DL-TDOA-SignalMeasurementInformation* or *NR-Multi-RTT-SignalMeasurementInformation* the UE can be configured to report the DL PRS resource ID(s) or the DL PRS resource set ID(s) associated with the DL PRS resource(s) or the DL PRS resource set(s) which are used in determining the UE measurements DL RSTD, UE Rx-Tx time difference.

For the DL RSTD, DL PRS-RSRP, and UE Rx-Tx time difference measurements the UE can report an associated higher layer parameter *nr-TimeStamp*. The *nr-TimeStamp* can include the *dl-PRS-ID*, the SFN and the slot number for a subcarrier spacing. These values correspond to the reference which is provided by *nr-DL-PRS-ReferenceInfo*.

The UE is expected to measure the DL PRS resource outside the active DL BWP or with a numerology different from the numerology of the active DL BWP if the measurement is made during a configured measurement gap. When the UE is expected to measure the DL PRS resource, it may request a measurement gap via higher layer parameter *NR-PRS-MeasurementInfoList* [12, TS 38.331].

The UE assumes that the DL PRS from the serving cell is not mapped to any symbol that contains SS/PBCH block from the serving cell. If the time frequency location of the SS/PBCH block transmissions from non-serving cells are provided to the UE then the UE also assumes that the DL PRS from a non-serving cell is not mapped to any symbol that contains the SS/PBCH block of the same non-serving cell.

The UE may be configured to measure and report, subject to UE capability, up to 4 DL RSTD measurements per pair of *dl-PRS-ID* with each measurement between a different pair of DL PRS resources or DL PRS resource sets within the DL PRS configured for those *dl-PRS-ID*. The up to 4 measurements being performed on the same pair of *dl-PRS-ID* and all DL RSTD measurements in the same report use a single reference timing.

The UE may be configured to measure and report, subject to UE capability, up to 8 DL PRS-RSRP measurements on different DL PRS resources associated with the same *dl-PRS-ID*. When the UE reports DL PRS-RSRP measurements from one DL PRS resource set, the UE may indicate which DL PRS-RSRP measurements associated with the same higher layer parameter *nr-DL-PRS-RxBeamIndex* [17, TS 37.355] have been performed using the same spatial domain filter for reception if for each *nr-DL-PRS-RxBeamIndex* reported there are at least 2 DL PRS-RSRP measurements associated with it within the DL PRS resource set.

The UE may be configured to measure and report, subject to UE capability, up to 4 UE Rx-Tx time difference measurements corresponding to a single configured SRS resource or resource set for positioning. Each measurement corresponds to a single received DL PRS resource or resource set which can be in different positioning frequency layers.

The UE may be configured to measure and report, subject to UE capability, the timing and the quality metrics of up to 2 additional detected paths that are associated with each RSTD or UE Rx – Tx time difference. The timing of each additional path is reported relative to the path timing used for determining *nr-RSTD* or *nr-UE-RxTxTimeDiff*.

If the UE is configured with *DL-PRS-QCL-Info* and the QCL relation is between two DL PRS resources, then the UE assumes those DL PRS resources are associated with the same *dl-PRS-ID*. If *DL-PRS-QCL-Info* is configured to the UE with *qcl-Type* set to 'type-D' with a source DL PRS resource then the *nr-DL-PRS-ResourceSetId* and the *nr-DL-PRS-ResourceId* of the source DL PRS resource are expected to be indicated to the UE.

UE is not expected to process DL PRS without configuration of measurement gap.

Within a positioning frequency layer, the DL PRS resources are sorted in the decreasing order of priority for measurement to be performed by the UE, with the reference indicated by *nr-DL-PRS-ReferenceInfo* being the highest priority for measurement, and the following priority is assumed:

- Up to 64 *NR-SelectedDL-PRS-IndexPerTRP* of the frequency layer are sorted according to priority if *nr-SelectedDL-PRS-IndexListPerFreq* is provided, or up to 64 *NR-DL-PRS-AssistanceDataPerTRP* of the frequency layer are sorted according to priority otherwise;

- Up to 2 *DL-SelectedPRS-ResourceSetIndex* per *dl-PRS-ID* of the frequency layer are sorted according to priority if *dl-SelectedPRS-ResourceSetIndexList* is provided, or up to 2 *NR-DL-PRS-ResourceSet* per *dl-PRS-ID* of the frequency layer are sorted according to priority otherwise.

For the case when measurement gap is configured, the UE DL PRS processing capability is defined in [TS 37.355]. For the purpose of DL PRS processing capability, the duration *K* msec of DL PRS symbols within *P* msec window, is calculated by

- Type 1 duration calculation with UE symbol level buffering capability

$$K = \sum_{s \in S} K_s$$
$$K_s = T_s^{\text{end}} - T_s^{\text{start}}$$

- Type 2 duration calculation with UE slot level buffering capability

$$K = \frac{1}{2^\mu}|S|$$

- *S* is the set of slots based on the numerology of the DL PRS of a serving cell within the *P* msec window in the positioning frequency layer that contains potential DL PRS resources considering the actual *nr-DL-PRS-ExpectedRSTD, nr-DL-PRS-ExpectedRSTD-Uncertainty* provided for each pair of DL PRS Resource Sets.

- For Type 1, $[T_s^{\text{start}}, T_s^{\text{end}}]$ is the smallest interval in msec within slot s corresponding to an integer number of OFDM symbols based on the numerology of the DL PRS of a serving cell that covers the union of the potential PRS symbols and determines the PRS symbol occupancy within slot s, where the interval $[T_s^{\text{start}}, T_s^{\text{end}}]$ considers the actual *nr-DL-PRS-ExpectedRSTD, nr-DL-PRS-ExpectedRSTD-Uncertainty* provided for each pair of DL PRS resource sets (target and reference).

- For Type 2, μ is the numerology of the DL PRS, and $|S|$ is the cardinality of the set S.

5.1.7 Code block group based PDSCH transmission

5.1.7.1 UE procedure for grouping of code blocks to code block groups

If a UE is configured to receive code block group (CBG) based transmissions by receiving the higher layer parameter *codeBlockGroupTransmission* for PDSCH, the UE shall determine the number of CBGs for a transport block reception as

$$M = \min(N, C),$$

where *N* is the maximum number of CBGs per transport block as configured by *maxCodeBlockGroupsPerTransportBlock* for PDSCH, and *C* is the number of code blocks in the transport block according to the procedure defined in Clause 7.2.3 of [5, TS 38.212].

Define $M_1 = \mathrm{mod}(C, M)$, $K_1 = \left\lceil \frac{C}{M} \right\rceil$, and $K_2 = \left\lfloor \frac{C}{M} \right\rfloor$.

If $M_1 > 0$, CBG *m*, $m = 0,1,..., M_1 - 1$, consists of code blocks with indices $m \cdot K_1 + k, k = 0,1,..., K_1 - 1$. CBG *m*, $m = M_1, M_1 + 1,..., M - 1$, consists of code blocks with indices $M_1 \cdot K_1 + (m - M_1) \cdot K_2 + k, k = 0,1,..., K_2 - 1$.

5.1.7.2 UE procedure for receiving code block group based transmissions

If a UE is configured to receive code block group-based transmissions by receiving the higher layer parameter *codeBlockGroupTransmission* for PDSCH,

- The *'CBG transmission information'* (CBGTI) field of DCI format 1_1 is of length $N_{TB} \cdot N$ bits, where N_{TB} is the value of the higher layer parameter *maxNrofCodeWordsScheduledByDCI*. If $N_{TB} = 2$ the CBGTI field bits are mapped such that the first set of N bits starting from the MSB corresponds to the first TB while the second set of N bits corresponds to a second TB, if scheduled. The first *M* bits of each set of N bits in the CBGTI field have an in-order one-to-one mapping with the *M* CBGs of the TB, with the MSB mapped to CBG#0.

- For initial transmission of a TB as indicated by the '*New Data Indicator'* field of the scheduling DCI, the UE may assume that all the code block groups of the TB are present.

- For a retransmission of a TB as indicated by the '*New Data Indicator'* field of the scheduling DCI, the UE may assume that

  - The '*CBGTI'* field of the scheduling DCI indicates which CBGs of the TB are present in the transmission. A bit value of '0' in the *CBGTI* field indicates that the corresponding CBG is not transmitted and '1' indicates that it is transmitted.

  - If the *'CBG flushing out information' (CBGFI)* field of the scheduling DCI is present, '*CBGFI'* set to '0' indicates that the earlier received instances of the same CBGs being transmitted may be corrupted, and '*CBGFI'* set to '1' indicates that the CBGs being retransmitted are combinable with the earlier received instances of the same CBGs.

  - A CBG contains the same CBs as in the initial transmission of the TB.

5.2 UE procedure for reporting channel state information (CSI)

5.2.1 Channel state information framework

The procedures on aperiodic CSI reporting described in this clause assume that the CSI reporting is triggered by DCI format 0_1, but they equally apply to CSI reporting triggered by DCI format 0_2, by applying the higher layer parameter *reportTriggerSizeDCI-0-2* instead of *reportTriggerSize*.

The time and frequency resources that can be used by the UE to report CSI are controlled by the gNB. CSI may consist of Channel Quality Indicator (CQI), precoding matrix indicator (PMI), CSI-RS resource indicator (CRI), SS/PBCH Block Resource indicator (SSBRI), layer indicator (LI), rank indicator (RI), L1-RSRP or L1-SINR.

For CQI, PMI, CRI, SSBRI, LI, RI, L1-RSRP, L1-SINR a UE is configured by higher layers with $N\geq1$ *CSI-ReportConfig* Reporting Settings, $M\geq1$ *CSI-ResourceConfig* Resource Settings, and one or two list(s) of trigger states (given by the higher layer parameters *CSI-AperiodicTriggerStateList* and *CSI-SemiPersistentOnPUSCH-TriggerStateList*). Each trigger state in *CSI-AperiodicTriggerStateList* contains a list of associated *CSI-ReportConfigs* indicating the Resource Set IDs for channel and optionally for interference. Each trigger state in *CSI-SemiPersistentOnPUSCH-TriggerStateList* contains one associated *CSI-ReportConfig*.

5.2.1.1 Reporting settings

Each Reporting Setting *CSI-ReportConfig* is associated with a single downlink BWP (indicated by higher layer parameter *BWP-Id*) given in the associated *CSI-ResourceConfig* for channel measurement and contains the parameter(s) for one CSI reporting band: codebook configuration including codebook subset restriction, time-domain behavior, frequency granularity for CQI and PMI, measurement restriction configurations, and the CSI-related quantities to be reported by the UE such as the layer indicator (LI), L1-RSRP, L1-SINR, CRI, and SSBRI (SSB Resource Indicator).

The time domain behavior of the *CSI-ReportConfig* is indicated by the higher layer parameter *reportConfigType* and can be set to 'aperiodic', 'semiPersistentOnPUCCH', 'semiPersistentOnPUSCH', or 'periodic'. For 'periodic' and 'semiPersistentOnPUCCH'/'semiPersistentOnPUSCH' CSI reporting, the configured periodicity and slot offset applies in the numerology of the UL BWP in which the CSI report is configured to be transmitted on. The higher layer parameter *reportQuantity* indicates the CSI-related, L1-RSRP-related or L1-SINR-related quantities to report. The *reportFreqConfiguration* indicates the reporting granularity in the frequency domain, including the CSI reporting band and if PMI/CQI reporting is wideband or sub-band. The *timeRestrictionForChannelMeasurements* parameter in *CSI-ReportConfig* can be configured to enable time domain restriction for channel measurements and *timeRestrictionForInterferenceMeasurements* can be configured to enable time domain restriction for interference measurements. The *CSI-ReportConfig* can also contain *CodebookConfig*, which contains configuration parameters for Type-I, Type II or Enhanced Type II CSI including codebook subset restriction, and configurations of group-based reporting.

5.2.1.2 Resource settings

Each CSI Resource Setting *CSI-ResourceConfig* contains a configuration of a list of $S\geq1$ CSI Resource Sets (given by higher layer parameter *csi-RS-ResourceSetList*), where the list is comprised of references to either or both of NZP CSI-RS resource set(s) and SS/PBCH block set(s) or the list is comprised of references to CSI-IM resource set(s). Each CSI

Resource Setting is located in the DL BWP identified by the higher layer parameter *BWP-id*, and all CSI Resource Settings linked to a CSI Report Setting have the same DL BWP.

The time domain behavior of the CSI-RS resources within a CSI Resource Setting are indicated by the higher layer parameter *resourceType* and can be set to aperiodic, periodic, or semi-persistent. For periodic and semi-persistent CSI Resource Settings, the number of CSI-RS Resource Sets configured is limited to S=1. For periodic and semi-persistent CSI Resource Settings, the configured periodicity and slot offset is given in the numerology of its associated DL BWP, as given by *BWP-id*. When a UE is configured with multiple *CSI-ResourceConfigs* consisting the same NZP CSI-RS resource ID, the same time domain behavior shall be configured for the *CSI-ResourceConfigs*. When a UE is configured with multiple *CSI-ResourceConfigs* consisting the same CSI-IM resource ID, the same time-domain behavior shall be configured for the *CSI-ResourceConfigs*. All CSI Resource Settings linked to a CSI Report Setting shall have the same time domain behavior.

The following are configured via higher layer signaling for one or more CSI Resource Settings for channel and interference measurement:

- CSI-IM resource for interference measurement as described in Clause 5.2.2.4.
- NZP CSI-RS resource for interference measurement as described in Clause 5.2.2.3.1.
- NZP CSI-RS resource for channel measurement as described in Clause 5.2.2.3.1.

The UE may assume that the NZP CSI-RS resource(s) for channel measurement and the CSI-IM resource(s) for interference measurement configured for one CSI reporting are resource-wise QCLed with respect to 'typeD'. When NZP CSI-RS resource(s) is used for interference measurement, the UE may assume that the NZP CSI-RS resource for channel measurement and the CSI- IM resource or NZP CSI-RS resource(s) for interference measurement configured for one CSI reporting are QCLed with respect to 'typeD'.

For L1-SINR measurement:

- When one Resource Setting is configured, the Resource Setting (given by higher layer parameter *resourcesForChannelMeasurement*) is for channel and interference measurement on NZP CSI-RS for L1-SINR computation. UE may assume that same 1 port NZP CSI-RS resource(s) with density 3 REs/RB is used for both channel and interference measurements.
- When two Resource Settings are configured, the first one Resource Setting (given by higher layer parameter *resourcesForChannelMeasurement*) is for channel measurement on SSB or NZP CSI-RS and the second one (given by either higher layer parameter *csi-IM-ResourcesForInterference* or higher layer parameter *nzp-CSI-RS-ResourcesForInterference*) is for interference measurement performed on CSI-IM or on 1 port NZP CSI-RS with density 3 REs/RB, where each SSB or NZP CSI-RS resource for channel measurement is associated with one CSI-IM resource or one NZP CSI-RS resource for interference measurement by the ordering of the SSB or NZP CSI-RS resource for channel measurement and CSI-IM resource or NZP CSI-RS resource for interference measurement in the corresponding resource sets. The number of SSB(s) or CSI-RS resources for channel measurement equals to the number of CSI-IM resources or the number of NZP CSI-RS resource for interference measurement.
  - UE may apply the SSB, or 'typeD' RS configured with *qcl-Type* set to 'typeD' to the NZP CSI-RS resource for channel measurement, as the reference RS for determining 'typeD' assumption for the corresponding CSI-IM resource or the corresponding NZP CSI-RS resource for interference measurement configured for one CSI reporting.
  - UE may expect that the NZP CSI-RS resource set for channel measurement and the NZP-CSI-RS resource set for interference measurement, if any, are configured with the higher layer parameter *repetition*.

5.2.1.3 (void)

5.2.1.4 Reporting configurations

The UE shall calculate CSI parameters (if reported) assuming the following dependencies between CSI parameters (if reported)

- LI shall be calculated conditioned on the reported CQI, PMI, RI and CRI
- CQI shall be calculated conditioned on the reported PMI, RI and CRI

- PMI shall be calculated conditioned on the reported RI and CRI
- RI shall be calculated conditioned on the reported CRI.

The Reporting configuration for CSI can be aperiodic (using PUSCH), periodic (using PUCCH) or semi-persistent (using PUCCH, and DCI activated PUSCH). The CSI-RS Resources can be periodic, semi-persistent, or aperiodic. Table 5.2.1.4-1 shows the supported combinations of CSI Reporting configurations and CSI-RS Resource configurations and how the CSI Reporting is triggered for each CSI-RS Resource configuration. Periodic CSI-RS is configured by higher layers. Semi-persistent CSI-RS is activated and deactivated as described in Clause 5.2.1.5.2. Aperiodic CSI-RS is configured and triggered/activated as described in Clause 5.2.1.5.1.

Table 5.2.1.4-1: Triggering/Activation of CSI Reporting for the possible CSI-RS Configurations.

CSI-RS Configuration	Periodic CSI Reporting	Semi-Persistent CSI Reporting	Aperiodic CSI Reporting
Periodic CSI-RS	No dynamic triggering/activation	For reporting on PUCCH, the UE receives an activation command, as described in clause 6.1.3.16 of [10, TS 38.321]; for reporting on PUSCH, the UE receives triggering on DCI	Triggered by DCI; additionally, subselection indication as described in clause 6.1.3.13 of [10, TS 38.321] possible as defined in Clause 5.2.1.5.1.
Semi-Persistent CSI-RS	Not Supported	For reporting on PUCCH, the UE receives an activation command, as described in clause 6.1.3.16 of [10, TS 38.321]; for reporting on PUSCH, the UE receives triggering on DCI	Triggered by DCI; additionally, subselection indication as described in clause 6.1.3.13 of [10, TS 38.321] possible as defined in Clause 5.2.1.5.1.
Aperiodic CSI-RS	Not Supported	Not Supported	Triggered by DCI; additionally, subselection indication as described in clause 6.1.3.13 of [10, TS 38.321] possible as defined in Clause 5.2.1.5.1.

When the UE is configured with higher layer parameter *NZP-CSI-RS-ResourceSet* and when the higher layer parameter *repetition* is set to 'off', the UE shall determine a CRI from the supported set of CRI values as defined in Clause 6.3.1.1.2 of [5, TS 38.212] and report the number in each CRI report. When the higher layer parameter *repetition* is set to 'on', CRI is not reported. CRI reporting is not supported when the higher layer parameter *codebookType* is set to either 'typeII', 'typeII-PortSelection', 'typeII-r16' or to 'typeII-PortSelection-r16'.

For a periodic or semi-persistent CSI report on PUCCH, the periodicity T_{CSI} (measured in slots) and the slot offset T_{offset} are configured by the higher layer parameter *reportSlotConfig*. Unless specified otherwise, the UE shall transmit the CSI report in frames with SFN n_f and slot number within the frame $n_{s,f}^{\mu}$ satisfying

$$\left(N_{\text{slot}}^{\text{frame},\mu} n_f + n_{s,f}^{\mu} - T_{offset}\right) \bmod \mathrm{T}_{\text{CSI}} = 0$$

where μ is the SCS configuration of the UL BWP the CSI report is transmitted on.

For a semi-persistent CSI report on PUSCH, the periodicity T_{CSI} (measured in slots) is configured by the higher layer parameter *reportSlotConfig*. Unless specified otherwise, the UE shall transmit the CSI report in frames with SFN n_f and slot number within the frame $n_{s,f}^{\mu}$ satisfying

$$\left(N_{\text{slot}}^{\text{frame},\mu}\left(n_f - n_f^{start}\right) + n_{s,f}^{\mu} - n_{s,f}^{start}\right) \bmod \mathrm{T}_{\text{CSI}} = 0$$

where n_f^{start} and $n_{s,f}^{start}$ are the SFN and slot number within the frame respectively of the initial semi-persistent PUSCH transmission according to the activating DCI.

For a semi-persistent or aperiodic CSI report on PUSCH, the allowed slot offsets are configured by the following higher layer parameters:

- if triggered/activated by DCI format 0_2 and the higher layer parameter *reportSlotOffsetListDCI-0-2* is configured, the allowed slot offsets are configured by *reportSlotOffsetListDCI-0-2,* and

- if triggered/activated by DCI format 0_1 and the higher layer parameter *reportSlotOffsetListDCI-0-1* is configured, the allowed slot offsets are configured by *reportSlotOffsetListDCI-0-1,* and

- otherwise, the allowed slot offsets are configured by the higher layer parameter *reportSlotOffsetList*.

The offset is selected in the activating/triggering DCI.

For CSI reporting, a UE can be configured via higher layer signaling with one out of two possible subband sizes, where a subband is defined as $N_{\mathrm{PRB}}^{\mathrm{SB}}$ contiguous PRBs and depends on the total number of PRBs in the bandwidth part according to Table 5.2.1.4-2.

Table 5.2.1.4-2: Configurable subband sizes

Bandwidth part (PRBs)	Subband size (PRBs)
24 – 72	4, 8
73 – 144	8, 16
145 – 275	16, 32

The *reportFreqConfiguration* contained in a *CSI-ReportConfig* indicates the frequency granularity of the CSI Report. A CSI Reporting Setting configuration defines a CSI reporting band as a subset of subbands of the bandwidth part, where the *reportFreqConfiguration* indicates:

- the *csi-ReportingBand* as a contiguous or non-contiguous subset of subbands in the bandwidth part for which CSI shall be reported.
  - A UE is not expected to be configured with *csi-ReportingBand* which contains a subband where a CSI-RS resource linked to the CSI Report setting has the frequency density of each CSI-RS port per PRB in the subband less than the configured density of the CSI-RS resource.
  - If a CSI-IM resource is linked to the CSI Report Setting, a UE is not expected to be configured with *csi-ReportingBand* which contains a subband where not all PRBs in the subband have the CSI-IM REs present.
- wideband CQI or subband CQI reporting, as configured by the higher layer parameter *cqi-FormatIndicator*. When wideband CQI reporting is configured, a wideband CQI is reported for each codeword for the entire CSI reporting band. When subband CQI reporting is configured, one CQI for each codeword is reported for each subband in the CSI reporting band.
- wideband PMI or subband PMI reporting as configured by the higher layer parameter *pmi-FormatIndicator*. When wideband PMI reporting is configured, a wideband PMI is reported for the entire CSI reporting band. When subband PMI reporting is configured, except with 2 antenna ports, a single wideband indication (i_1 in Clause 5.2.2.2) is reported for the entire CSI reporting band and one subband indication (i_2 in clause 5.2.2.2) is reported for each subband in the CSI reporting band. When subband PMIs are configured with 2 antenna ports, a PMI is reported for each subband in the CSI reporting band.
  - a UE is not expected to be configured with *pmi-FormatIndicator* if *codebookType* is set to 'typeII-r16' or 'typeII-PortSelection-r16'.

A CSI Reporting Setting is said to have a wideband frequency-granularity if

- *reportQuantity* is set to 'cri-RI-PMI-CQI', or 'cri-RI-LI-PMI-CQI', *cqi-FormatIndicator* is set to 'widebandCQI' and *pmi-FormatIndicator* is set to 'widebandPMI', or
- *reportQuantity* is set to 'cri-RI-i1' or
- *reportQuantity* is set to 'cri-RI-CQI' or 'cri-RI-i1-CQI' and *cqi-FormatIndicator* is set to 'widebandCQI', or
- *reportQuantity* is set to 'cri-RSRP' or 'ssb-Index-RSRP' or 'cri-SINR', or 'ssb-Index-SINR'

otherwise, the CSI Reporting Setting is said to have a subband frequency-granularity.

If the UE is configured with a CSI Reporting Setting for a bandwidth part with fewer than 24 PRBs, the CSI reporting setting is expected to have a wideband frequency-granularity, and, if applicable, the higher layer parameter *codebookType* is set to 'typeI-SinglePanel'.

The first subband size is given by $N_{PRB}^{SB} - \left(N_{BWP,i}^{start} \bmod N_{PRB}^{SB}\right)$ and the last subband size given by $\left(N_{BWP,i}^{start} + N_{BWP,i}^{size}\right) \bmod N_{PRB}^{SB}$ if $\left(N_{BWP,i}^{start} + N_{BWP,i}^{size}\right) \bmod N_{PRB}^{SB} \neq 0$ and N_{PRB}^{SB} if $\left(N_{BWP,i}^{start} + N_{BWP,i}^{size}\right) \bmod N_{PRB}^{SB} = 0$

If a UE is configured with semi-persistent CSI reporting, the UE shall report CSI when both CSI-IM and NZP CSI-RS resources are configured as periodic or semi-persistent. If a UE is configured with aperiodic CSI reporting, the UE shall report CSI when both CSI-IM and NZP CSI-RS resources are configured as periodic, semi-persistent or aperiodic.

A UE configured with DCI format 0_1 or 0_2 does not expect to be triggered with multiple CSI reports with the same *CSI-ReportConfigId*.

5.2.1.4.1 Resource Setting configuration

For aperiodic CSI, each trigger state configured using the higher layer parameter *CSI-AperiodicTriggerState* is associated with one or multiple *CSI-ReportConfig* where each *CSI-ReportConfig* is linked to periodic, or semi-persistent, or aperiodic resource setting(s):

- When one Resource Setting is configured, the Resource Setting (given by higher layer parameter *resourcesForChannelMeasurement*) is for channel measurement for L1-RSRP or for channel and interference measurement for L1-SINR computation.

- When two Resource Settings are configured, the first one Resource Setting (given by higher layer parameter *resourcesForChannelMeasurement*) is for channel measurement and the second one (given by either higher layer parameter *csi-IM-ResourcesForInterference* or higher layer parameter *nzp-CSI-RS-ResourcesForInterference*) is for interference measurement performed on CSI-IM or on NZP CSI-RS.

- When three Resource Settings are configured, the first Resource Setting (higher layer parameter *resourcesForChannelMeasurement*) is for channel measurement, the second one (given by higher layer parameter *csi-IM-ResourcesForInterference*) is for CSI-IM based interference measurement and the third one (given by higher layer parameter *nzp-CSI-RS-ResourcesForInterference*) is for NZP CSI-RS based interference measurement.

For semi-persistent or periodic CSI, each *CSI-ReportConfig* is linked to periodic or semi-persistent Resource Setting(s):

- When one Resource Setting (given by higher layer parameter *resourcesForChannelMeasurement*) is configured, the Resource Setting is for channel measurement for L1-RSRP or for channel and interference measurement for L1-SINR computation.

- When two Resource Settings are configured, the first Resource Setting (given by higher layer parameter *resourcesForChannelMeasurement*) is for channel measurement and the second Resource Setting (given by higher layer parameter *csi-IM-ResourcesForInterference*) is used for interference measurement performed on CSI-IM. For L1-SINR computation, the second Resource Setting (given by higher layer parameter *csi-IM-ResourcesForInterference* or higher layer parameter *nzp-CSI-RS-ResourceForInterference*) is used for interference measurement performed on CSI-IM or on NZP CSI-RS.

A UE is not expected to be configured with more than one CSI-RS resource in resource set for channel measurement for a *CSI-ReportConfig* with the higher layer parameter *codebookType* set to either 'typeII', 'typeII-PortSelection', 'typeII-r16' or to 'typeII-PortSelection-r16'. A UE is not expected to be configured with more than 64 NZP CSI-RS resources and/or SS/PBCH block resources in resource setting for channel measurement for a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'none', 'cri-RI-CQI', 'cri-RSRP', 'ssb-Index-RSRP', 'cri-SINR' or 'ssb-Index-SINR'. If interference measurement is performed on CSI-IM, each CSI-RS resource for channel measurement is resource-wise associated with a CSI-IM resource by the ordering of the CSI-RS resource and CSI-IM resource in the corresponding resource sets. The number of CSI-RS resources for channel measurement equals to the number of CSI-IM resources.

Except for L1-SINR, if interference measurement is performed on NZP CSI-RS, a UE does not expect to be configured with more than one NZP CSI-RS resource in the associated resource set within the resource setting for channel measurement. Except for L1-SINR, the UE configured with the higher layer parameter *nzp-CSI-RS-ResourcesForInterference* may expect no more than 18 NZP CSI-RS ports configured in a NZP CSI-RS resource set.

For CSI measurement(s) other than L1-SINR, a UE assumes:

- each NZP CSI-RS port configured for interference measurement corresponds to an interference transmission layer.
- all interference transmission layers on NZP CSI-RS ports for interference measurement take into account the associated EPRE ratios configured in 5.2.2.3.1;
- other interference signal on REs of NZP CSI-RS resource for channel measurement, NZP CSI-RS resource for interference measurement, or CSI-IM resource for interference measurement.

For L1-SINR measurement with dedicated interference measurement resources, a UE assumes:

- the total received power on dedicated NZP CSI-RS resource for interference measurement or dedicated CSI-IM resource for interference measurement corresponds to interference and noise.

5.2.1.4.2 Report Quantity Configurations

A UE may be configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to either 'none', 'cri-RI-PMI-CQI ', 'cri-RI-i1', 'cri-RI-i1-CQI', 'cri-RI-CQI', 'cri-RSRP', 'cri-SINR', 'ssb-Index-RSRP', 'ssb-Index-SINR' or 'cri-RI-LI-PMI-CQI'.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'none', then the UE shall not report any quantity for the *CSI-ReportConfig*.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RI-PMI-CQI', or 'cri-RI-LI-PMI-CQI', the UE shall report a preferred precoder matrix for the entire reporting band, or a preferred precoder matrix per subband, according to Clause 5.2.2.2.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RI-i1',

- the UE expects, for that *CSI-ReportConfig,* to be configured with higher layer parameter *codebookType* set to 'typeI-SinglePanel' and *pmi-FormatIndicator* set to 'widebandPMI' and,
- the UE shall report a PMI consisting of a single wideband indication (i_1 in Clause 5.2.2.2.1) for the entire CSI reporting band.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RI-i1-CQI',

- the UE expects, for that *CSI-ReportConfig,* to be configured with higher layer parameter *codebookType* set to 'typeI-SinglePanel' and *pmi-FormatIndicator* set to 'widebandPMI' and,
- the UE shall report a PMI consisting of a single wideband indication (i_1 in Clause 5.2.2.2.1) for the entire CSI reporting band. The CQI is calculated conditioned on the reported i_1 assuming PDSCH transmission with $N_p \geq 1$ precoders (corresponding to the same i_1 but different i_2 in Clause 5.2.2.2.1), where the UE assumes that one precoder is randomly selected from the set of N_p precoders for each PRG on PDSCH, where the PRG size for CQI calculation is configured by the higher layer parameter *pdsch-BundleSizeForCSI*.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RI-CQI',

- if the UE is configured with higher layer parameter *non-PMI-PortIndication* contained in a *CSI-ReportConfig*, *r* ports are indicated in the order of layer ordering for rank *r* and each CSI-RS resource in the CSI resource setting is linked to the *CSI-ReportConfig* based on the order of the associated *NZP-CSI-RS-ResourceId* in the linked CSI resource setting for channel measurement given by higher layer parameter *resourcesForChannelMeasurement*. The configured higher layer parameter *non-PMI-PortIndication* contains a sequence $p_0^{(1)}, p_0^{(2)}, p_1^{(2)}, p_0^{(3)}, p_1^{(3)}, p_2^{(3)}, ..., p_0^{(R)}, p_1^{(R)}, ..., p_{R-1}^{(R)}$ of port indices, where $p_0^{(\nu)}, \ldots, p_{\nu-1}^{(\nu)}$ are the CSI-RS port indices associated with rank ν and $R \in \{1, 2, ..., P\}$ where $P \in \{1,2,4,8\}$ is the number of ports in the CSI-RS resource. The UE shall only report RI corresponding to the configured fields of *PortIndexFor8Ranks*.
- if the UE is not configured with higher layer parameter *non-PMI-PortIndication*, the UE assumes, for each CSI-RS resource in the CSI resource setting linked to the *CSI-ReportConfig*, that the CSI-RS port indices

$p_0^{(\nu)},\ldots,p_{\nu-1}^{(\nu)}=\{0,\ldots,\nu-1\}$ are associated with ranks $\nu=1,2,\ldots,P$ where $P\in\{1,2,4,8\}$ is the number of ports in the CSI-RS resource.

- When calculating the CQI for a rank, the UE shall use the ports indicated for that rank for the selected CSI-RS resource. The precoder for the indicated ports shall be assumed to be the identity matrix scaled by $\frac{1}{\sqrt{\nu}}$.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RSRP' or 'ssb-Index-RSRP',

- if the UE is configured with the higher layer parameter *groupBasedBeamReporting* set to 'disabled', the UE is not required to update measurements for more than 64 CSI-RS and/or SSB resources, and the UE shall report in a single report *nrofReportedRS* (higher layer configured) different CRI or SSBRI for each report setting.
- if the UE is configured with the higher layer parameter *groupBasedBeamReporting* set to 'enabled', the UE is not required to update measurements for more than 64 CSI-RS and/or SSB resources, and the UE shall report in a single reporting instance two different CRI or SSBRI for each report setting, where CSI-RS and/or SSB resources can be received simultaneously by the UE either with a single spatial domain receive filter, or with multiple simultaneous spatial domain receive filters.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-SINR' or 'ssb-Index-SINR',

- if the UE is configured with the higher layer parameter *groupBasedBeamReporting* set to 'disabled', the UE shall report in a single report *nrofReportedRS* (higher layer configured) different CRI or SSBRI for each report setting.
- if the UE is configured with the higher layer parameter *groupBasedBeamReporting* set to 'enabled', the UE shall report in a single reporting instance two different CRI or SSBRI for each report setting, where CSI-RS and/or SSB resources can be received simultaneously by the UE.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RSRP', 'cri-RI-PMI-CQI ', 'cri-RI-i1', 'cri-RI-i1-CQI', 'cri-RI-CQI', 'cri-RI-LI-PMI-CQI', or 'cri-SINR', and $K_s > 1$ resources are configured in the corresponding resource set for channel measurement, then the UE shall derive the CSI parameters other than CRI conditioned on the reported CRI, where CRI k ($k \geq 0$) corresponds to the configured (k+1)-th entry of associated *nzp-CSI-RS-Resources* in the corresponding *NZP-CSI-RS-ResourceSet* for channel measurement, and (k+1)-th entry of associated *csi-IM-Resource* in the corresponding *csi-IM-ResourceSet* (if configured) or (k+1)-th entry of associated *nzp-CSI-RS-Resources* in the corresponding *NZP-CSI-RS-ResourceSet* (if configured for *CSI-ReportConfig* with *reportQuantity* set to 'cri-SINR') for interference measurement. If $K_s = 2$ CSI-RS resources are configured, each resource shall contain at most 16 CSI-RS ports. If $2 < K_s \leq 8$ CSI-RS resources are configured, each resource shall contain at most 8 CSI-RS ports.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'ssb-Index-RSRP', the UE shall report SSBRI, where SSBRI k ($k \geq 0$) corresponds to the configured (k+1)-th entry of the associated *csi-SSB-ResourceList* in the corresponding *CSI-SSB-ResourceSet*.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'ssb-Index-SINR', the UE shall derive L1-SINR conditioned on the reported SSBRI, where SSBRI k ($k \geq 0$) corresponds to the configured (k+1)-th entry of the associated *csi-SSB-ResourceList* in the corresponding *CSI-SSB-ResourceSet* for channel measurement, and (k+1)-th entry of associated *csi-IM-Resource* in the corresponding *csi-IM-ResourceSet* (if configured) or (k+1)-th entry of associated *nzp-CSI-RS-Resources* in the corresponding *NZP-CSI-RS-ResourceSet* (if configured) for interference measurement.

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RI-PMI-CQI', ' cri-RI-i1', 'cri-RI-i1-CQI', 'cri-RI-CQI' or 'cri-RI-LI-PMI-CQI', then the UE is not expected to be configured with more than 8 CSI-RS resources in a CSI-RS resource set contained within a resource setting that is linked to the *CSI-ReportConfig*.

If the UE is configured with a *CSI-ReportConfig* with higher layer parameter *reportQuantity* set to 'cri-RSRP', 'cri-SINR' or 'none' and the *CSI-ReportConfig* is linked to a resource setting configured with the higher layer parameter *resourceType* set to 'aperiodic', then the UE is not expected to be configured with more than 16 CSI-RS resources in a CSI-RS resource set contained within the resource setting.

The LI indicates which column of the precoder matrix of the reported PMI corresponds to the strongest layer of the codeword corresponding to the largest reported wideband CQI. If two wideband CQIs are reported and have equal value, the LI corresponds to strongest layer of the first codeword.

For operation with shared spectrum channel access, if the UE is configured with a *CSI-ReportConfig* with higher layer parameter *reportQuantity* set to 'cri-RI-PMI-CQI ', 'cri-RI-i1', 'cri-RI-i1-CQI', 'cri-RI-CQI' or 'cri-RI-LI-PMI-CQI', the UE shall derive:

- the CSI parameters without averaging two or more instances of any periodic or semi-persistent *nzp-CSI-RS-Resources* in the corresponding *NZP-CSI-RS-ResourceSet* for channel measurement or for interference measurement located in different DL transmissions,
    - the instances of the *nzp-CSI-RS-Resources* are not in the same channel occupancy duration indicated by DCI format 2_0, if the UE is provided at least one of *SlotFormatIndicator* or co-*DurationList*; or
    - the instances of the *nzp-CSI-RS-Resources* occur within a set of consecutive symbols which are not all occupied by PDSCH(s) and/or aperiodic CSI-RS(s) indicated by DCI formats, if any, and the corresponding PDCCH(s), if the UE is neither provided with *CO-DurationPerCell* nor *SlotFormatIndicator*, but is provided with *csi-RS-ValidationWith-DCI*
- the interference measurements for computing CSI value based on periodic/semi-persistent CSI-IM measured only in OFDM symbol(s) that fulfill the same conditions under which the UE is expected to receive periodic/semi-persistent CSI-RS as described in Clause 11.1 and Clause 11.1.1 of [6, TS 38.213].

5.2.1.4.3 L1-RSRP Reporting

For L1-RSRP computation

- the UE may be configured with CSI-RS resources, SS/PBCH Block resources or both CSI-RS and SS/PBCH block resources, when resource-wise quasi co-located with 'type C' and 'typeD' when applicable.
- the UE may be configured with CSI-RS resource setting up to 16 CSI-RS resource sets having up to 64 resources within each set. The total number of different CSI-RS resources over all resource sets is no more than 128.

For L1-RSRP reporting, if the higher layer parameter *nrofReportedRS* in *CSI-ReportConfig* is configured to be one, the reported L1-RSRP value is defined by a 7-bit value in the range [-140, -44] dBm with 1dB step size, if the higher layer parameter *nrofReportedRS* is configured to be larger than one, or if the higher layer parameter *groupBasedBeamReporting* is configured as 'enabled', the UE shall use differential L1-RSRP based reporting, where the largest measured value of L1-RSRP is quantized to a 7-bit value in the range [-140, -44] dBm with 1dB step size, and the differential L1-RSRP is quantized to a 4-bit value. The differential L1-RSRP value is computed with 2 dB step size with a reference to the largest measured L1-RSRP value which is part of the same L1-RSRP reporting instance. The mapping between the reported L1-RSRP value and the measured quantity is described in [11, TS 38.133].

If the higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to "*notConfigured*", the UE shall derive the channel measurements for computing L1-RSRP value reported in uplink slot *n* based on only the SS/PBCH or NZP CSI-RS, no later than the CSI reference resource, (defined in TS 38.211[4]) associated with the CSI resource setting.

If the higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to "*Configured*", the UE shall derive the channel measurements for computing L1-RSRP reported in uplink slot *n* based on only the most recent, no later than the CSI reference resource, occasion of SS/PBCH or NZP CSI-RS (defined in [4, TS 38.211]) associated with the CSI resource setting.

5.2.1.4.4 L1-SINR Reporting

For L1-SINR computation, for channel measurement the UE may be configured with NZP CSI-RS resources and/or SS/PBCH Block resources, for interference measurement the UE may be configured with NZP CSI-RS or CSI-IM resources.

- for channel measurement, the UE may be configured with CSI-RS resource setting with up to 16 resource sets, with a total of up to 64 CSI-RS resources or up to 64 SS/PBCH Block resources.

For L1-SINR reporting, if the higher layer parameter *nrofReportedRS* in *CSI-ReportConfig* is configured to be one, the reported L1-SINR value is defined by a 7-bit value in the range [-23, 40] dB with 0.5 dB step size, and if the higher layer parameter *nrofReportedRS* is configured to be larger than one, or if the higher layer parameter *groupBasedBeamReporting* is configured as 'enabled', the UE shall use differential L1-SINR based reporting, where the largest measured value of L1-SINR is quantized to a 7-bit value in the range [-23, 40] dB with 0.5 dB step size, and the differential L1-SINR is quantized to a 4-bit value. The differential L1-SINR is computed with 1 dB step size with a reference to the largest measured L1-SINR value which is part of the same L1-SINR reporting instance. When NZP CSI-RS is configured for channel measurement and/or interference measurement, the reported L1-SINR values should not be compensated by the power offset(s) given by higher layer parameter *powerControOffsetSS* or *powerControlOffset*.

When one or two resource settings are configured for L1-SINR measurement

- If the higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to *'notConfigured'*, the UE shall derive the channel measurements for computing L1-SINR reported in uplink slot n based on only the SSB or NZP CSI-RS, no later than the CSI reference resource, (defined in TS 38.211[4]) associated with the CSI resource setting.

- If the higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to *'configured'*, the UE shall derive the channel measurements for computing L1-SINR reported in uplink slot n based on only the most recent, no later than the CSI reference resource, occasion of SSB or NZP CSI-RS (defined in [4, TS 38.211]) associated with the CSI resource setting.

- If the higher layer parameter *timeRestrictionForInterferenceMeasurements* in *CSI-ReportConfig* is set to *'notConfigured'*, the UE shall derive the interference measurements for computing L1-SINR reported in uplink slot n based on only the CSI-IM or NZP CSI-RS for interference measurement (defined in [4, TS 38.211]) or NZP CSI-RS for channel and interference measurement no later than the CSI reference resource associated with the CSI resource setting.

- If the higher layer parameter *timeRestrictionForInterferenceMeasurements* in *CSI-ReportConfig* is set to *'configured'*, the UE shall derive the interference measurements for computing the L1-SINR reported in uplink slot n based on the most recent, no later than the CSI reference resource, occasion of CSI-IM or NZP CSI-RS for interference measurement (defined in [4, TS 38.211]) or NZP CSI-RS for channel and interference measurement associated with the CSI resource setting.

5.2.1.5 Triggering/activation of CSI Reports and CSI-RS

5.2.1.5.1 Aperiodic CSI Reporting/Aperiodic CSI-RS when the triggering PDCCH and the CSI-RS have the same numerology

For CSI-RS resource sets associated with Resource Settings configured with the higher layer parameter *resourceType* set to 'aperiodic', 'periodic', or 'semi-persistent', trigger states for Reporting Setting(s) (configured with the higher layer parameter *reportConfigType* set to 'aperiodic') and/or Resource Setting for channel and/or interference measurement on one or more component carriers are configured using the higher layer parameter *CSI-AperiodicTriggerStateList*. For aperiodic CSI report triggering, a single set of CSI triggering states are higher layer configured, wherein the CSI triggering states can be associated with any candidate DL BWP. A UE is not expected to receive more than one DCI with non-zero *CSI request* field per slot per cell. A UE is not expected to receive DCI with non-zero *CSI request* field within a cell group in a slot overlapping with any slot receiving DCI with non-zero *CSI request* field in the same cell group. A UE is not expected to be configured with different *TCI-StateId*'s for the same aperiodic CSI-RS resource ID configured in multiple aperiodic CSI-RS resource sets with the same triggering offset in the same aperiodic trigger state. A UE is not expected to receive more than one aperiodic CSI report request for transmission in a given slot per cell. A UE is not expected to receive an aperiodic CSI report request for transmission in a slot overlapping with any slot having an aperiodic CSI report transmission in the same cell group. If a UE does not indicate its capability of *CSItriggerStateContainingNonactiveBWP* the UE is not expected to be triggered with a CSI report for a non-active DL BWP. Otherwise, when a UE is triggered with a CSI report for a DL BWP that is non-active when expecting to receive the most recent occasion, no later than the CSI reference resource, of the associated NZP CSI-RS, the UE is not expected to report the CSI for the non-active DL BWP and the CSI report associated with that BWP is omitted. When a UE is triggered with aperiodic NZP CSI-RS in a DL BWP that is non-active when expecting to receive the NZP CSI-RS, the UE is not expected to measure the aperiodic CSI-RS. In the carrier of the serving cell expecting to receive that associated NZP CSI-RS, if the active DL BWP when receiving the NZP CSI-RS is different from the active DL BWP when receiving the triggering DCI,

- the last symbol of the PDCCH span of the DCI carrying the BWP switching shall be no later than the last symbol of the PDCCH span of the DCI carrying the CSI trigger, irrespective of whether they are in the same carrier of a serving cell or not and irrespective of whether they are in the same SCS or not;

- the UE is not expected to have any other BWP switching in that carrier after the last symbol of the PDCCH span covering the DCI carrying the CSI trigger and before the first symbol of the triggered NZP CSI-RS or CSI-IM.

A trigger state is initiated using the *CSI request* field in DCI.

- When all the bits of *CSI request* field in DCI are set to zero, no CSI is requested.
- When the number of configured CSI triggering states in *CSI-AperiodicTriggerStateList* is greater than $2^{N_{\mathrm{TS}}}-1$, where N_{TS} is the number of bits in the DCI *CSI request* field, the UE receives a subselection indication, as described in clause 6.1.3.13 of [10, TS 38.321], used to map up to $2^{N_{\mathrm{TS}}}-1$ trigger states to the codepoints of the *CSI request* field in DCI. N_{TS} is configured by the higher layer parameter *reportTriggerSize* where $N_{TS} \in \{0,1,2,3,4,5,6\}$. When the UE would transmit a PUCCH with HARQ-ACK information in slot *n* corresponding to the PDSCH carrying the subselection indication, the corresponding action in [10, TS 38.321] and UE assumption on the mapping of the selected CSI trigger state(s) to the codepoint(s) of DCI CSI request field shall be applied starting from the first slot that is after slot $n+3N_{slot}^{subframe,\mu}$ where μ is the SCS configuration for the PUCCH.
- When the number of CSI triggering states in *CSI-AperiodicTriggerStateList* is less than or equal to $2^{N_{\mathrm{TS}}}-1$, the *CSI request* field in DCI directly indicates the triggering state.
- For each aperiodic CSI-RS resource in a CSI-RS resource set associated with each CSI triggering state, the UE is indicated the quasi co-location configuration of quasi co-location RS source(s) and quasi co-location type(s), as described in Clause 5.1.5, through higher layer signaling of *qcl-info* which contains a list of references to *TCI-State's* for the aperiodic CSI-RS resources associated with the CSI triggering state. If a *State* referred to in the list is configured with a reference to an RS configured with *qcl-Type* set to 'typeD', that RS may be an SS/PBCH block located in the same or different CC/DL BWP or a CSI-RS resource configured as periodic or semi-persistent located in the same or different CC/DL BWP.
  - If the scheduling offset between the last symbol of the PDCCH carrying the triggering DCI and the first symbol of the aperiodic CSI-RS resources in a *NZP-CSI-RS-ResourceSet* configured without higher layer parameter *trs-Info* is smaller than the UE reported threshold *beamSwitchTiming*, as defined in [13, TS 38.306], when the reported value is one of the values of {14, 28, 48} and *enableBeamSwitchTiming* is not provided, or is smaller than 48 when the UE provides *beamSwitchTiming-r16, enableBeamSwitchTiming* is provided and the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *repetition* set to 'off' or configured without the higher layer parameter *repetition*, or is smaller than the UE reported threshold *beamSwitchTiming-r16*, when *enableBeamSwitchTiming* is provided and the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *repetition* set to 'on'.
    - If a UE is configured with *enableDefaultTCI-StatePerCoresetPoolIndex* and the UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet*
      - if there is any other DL signal with an indicated TCI state in the same symbols as the CSI-RS, the UE applies the QCL assumption of the other DL signal also when receiving the aperiodic CSI-RS. The other DL signal refers to PDSCH scheduled by a PDCCH associated with the same *coresetPoolIndex* as the PDCCH triggering the aperiodic CSI-RS and scheduled with offset larger than or equal to the threshold *timeDurationForQCL*, as defined in [13, TS 38.306], aperiodic CSI-RS triggered by a PDCCH associated with the same *coresetPoolIndex* as the PDCCH triggering the aperiodic CSI-RS and scheduled with offset larger than or equal to the UE reported threshold *beamSwitchTiming* when the reported value is one of the values {14,28,48} and *enableBeamSwitchTiming* is not provided, aperiodic CSI-RS triggered by a PDCCH associated with the same *coresetPoolIndex* as the PDCCH triggering the aperiodic CSI-RS and scheduled with offset larger than or equal to 48 when the reported value of *beamSwitchTiming-r16* is one of the values {224, 336} and *enableBeamSwitchTiming* is provided, periodic CSI-RS, semi-persistent CSI-RS;
      - else, the UE applies the QCL parameter(s) of the CORESET associated with a monitored search space with the lowest *controlResourceSetId* among CORESETs, which are configured with the same value of *coresetPoolIndex* as the PDCCH triggering that aperiodic CSI-RS, in the latest slot in which one or more CORESETs are associated with the same value of *coresetPoolIndex* as the PDCCH triggering that aperiodic CSI-RS

- else if a UE is configured with *enableTwoDefaultTCI-States* and at least one TCI codepoint is mapped to two TCI states
  - if there is any other DL signal with an indicated TCI state in the same symbols as the CSI-RS, the UE applies the QCL assumption of the other DL signal also when receiving the aperiodic CSI-RS. The other DL signal refers to PDSCH scheduled with offset larger than or equal to the threshold *timeDurationForQCL,* as defined in [13, TS 38.306], aperiodic CSI-RS scheduled with offset larger than or equal to the UE reported threshold *beamSwitchTiming* when the reported value is one of the values {14,28,48} and *enableBeamSwitchTiming* is not provided, aperiodic CSI-RS scheduled with offset larger than or equal to 48 when the reported value of *beamSwitchTiming-r16* is one of the values {224, 336} and *enableBeamSwitchTiming* is provided, periodic CSI-RS, semi-persistent CSI-RS. If there is a PDSCH indicated with two TCI states in the same symbols as the CSI-RS, the UE applies the first TCI state of the two TCI states when receiving the aperiodic CSI-RS.
  - else, the UE applies the first one of two TCI states corresponding to the lowest TCI codepoint among those mapped to two TCI states and applicable to the PDSCH within the active BWP of the cell in which the CSI-RS is to be received when receiving the aperiodic CSI-RS.
- else if there is any other DL signal with an indicated TCI state in the same symbols as the CSI-RS, the UE applies the QCL assumption of the other DL signal also when receiving the aperiodic CSI-RS. The other DL signal refers to PDSCH scheduled with offset larger than or equal to the threshold *timeDurationForQCL,* as defined in [13, TS 38.306], periodic CSI-RS, semi-persistent CSI-RS, aperiodic CSI-RS in a *NZP-CSI-RS-ResourceSet* scheduled with offset larger than or equal to the UE reported threshold *beamSwitchTiming* when the reported value is one of the values {14,28,48} and when *enableBeamSwitchTiming* is not provided or the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *trs-Info* , aperiodic CSI-RS in a *NZP-CSI-RS-ResourceSet* configured with the higher layer parameter *repetition* set to 'off' or configured without the higher layer parameters *repetition* and *trs-Info* scheduled with offset larger than or equal to 48 when the UE provides *beamSwitchTiming-r16* and *enableBeamSwitchTiming* is provided, aperiodic CSI-RS in a *NZP-CSI-RS-ResourceSet* configured with the higher layer parameter *repetition* set to 'on' scheduled with offset larger than or equal to the UE reported threshold *beamSwitchTiming-r16* and *enableBeamSwitchTiming* is provided;
- else if at least one CORESET is configured for the BWP in which the aperiodic CSI-RS is received, when receiving the aperiodic CSI-RS, the UE applies the QCL assumption used for the CORESET associated with a monitored search space with the lowest *controlResourceSetId* in the latest slot in which one or more CORESETs within the active BWP of the serving cell are monitored;
- else if the UE is configured with *enableDefaultBeamForCCS* and when receiving the aperiodic CSI-RS, the UE applies the QCL assumption of the lowest-ID activated TCI state applicable to the PDSCH within the active BWP of the cell in which the CSI-RS is to be received.

- If the scheduling offset between the last symbol of the PDCCH carrying the triggering DCI and the first symbol of the aperiodic CSI-RS resources in a *NZP-CSI-RS-ResourceSet* is equal to or greater than the UE reported threshold *beamSwitchTiming* when the reported value is one of the values of {14,28,48} and *enableBeamSwitchTiming* is not provided and the *NZP-CSI-RS-ResourceSet* is not configured with higher layer parameter *trs-Info,* or is equal to or greater than the UE reported threshold *beamSwitchTiming* when the reported value is one of the values of {14,28,48} and the *NZP-CSI-RS-ResourceSet* is configured with higher layer parameter *trs-Info*, or is equal to or greater than 48 when the UE provides *beamSwitchTiming-r16* and *enableBeamSwitchTiming* is provided and the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *repetition* set to 'off' or configured without the higher layer parameters *repetition* and *trs-Info*, or is equal to or greater than the UE reported threshold *beamSwitchTiming-r16,* when *enableBeamSwitchTiming* is provided and the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *repetition* set to 'on', the UE is expected to apply the QCL assumptions in the indicated TCI states for the aperiodic CSI-RS resources in the CSI triggering state indicated by the CSI trigger field in DCI.
- The UE is not expected to receive aperiodic CSI-RS and PDSCH/aperiodic CSI-RS associated with different values of *coresetPoolIndex* in overlapped symbol(s). The UE is not expected to receive aperiodic CSI-RS and semi-persistent/periodic CSI-RS with different 'QCL-type D' in overlapped symbol(s).

- A non-zero codepoint of the CSI request field in the DCI is mapped to a CSI triggering state according to the order of the associated positions of the up to $2^{N_{TS}} - 1$ trigger states in *CSI-AperiodicTriggerStateList* with codepoint '1' mapped to the triggering state in the first position.

For a UE configured with the higher layer parameter *CSI-AperiodicTriggerStateList*, if a Resource Setting linked to a *CSI-ReportConfig* has multiple aperiodic resource sets, only one of the aperiodic CSI-RS resource sets from the Resource Setting is associated with the trigger state, and the UE is higher layer configured per trigger state per Resource Setting to select the one CSI-IM/NZP CSI-RS resource set from the Resource Setting.

When aperiodic CSI-RS is used with aperiodic reporting, the CSI-RS offset is configured per resource set by the higher layer parameter *aperiodicTriggeringOffset* or *aperiodicTriggeringOffset-r16*. The CSI-RS triggering offset has the values of {0, 1, 2, 3, 4, 5, 6, …, 15, 16, 24} slots. If the UE is not configured with *minimumSchedulingOffsetK0* for any DL BWP and *minimumSchedulingOffsetK2* for any UL BWP and if all the associated trigger states do not have the higher layer parameter *qcl-Type* set to 'typeD' in the corresponding TCI states, the CSI-RS triggering offset is fixed to zero. The aperiodic triggering offset of the CSI-IM follows offset of the associated NZP CSI-RS for channel measurement. The aperiodic CSI-RS is transmitted in a slot K_s , $K_s = n + X + \left\lfloor \left(\frac{N_{slot,offset,PDCCH}^{CA}}{2^{\mu_{offset,PDCCH}}} - \frac{N_{slot,offset,CSIRS}^{CA}}{2^{\mu_{offset,CSIRS}}} \right) \cdot 2^{\mu_{CSIRS}} \right\rfloor$, if UE is configured with *ca-SlotOffset* for at least one of the triggered and triggering cell, and in slot $K_s = n + X$, otherwise, and where

- n is the slot containing the triggering DCI, X is the CSI-RS triggering offset according to the higher layer parameter *aperiodicTriggeringOffset* or *aperiodicTriggeringOffset-r16*,
- $N_{\text{slot, offset, PDCCH}}^{\text{CA}}$ and $\mu_{\text{offset,PDCCH}}$ are the $N_{\text{slot, offset}}^{\text{CA}}$ and the μ_{offset} which are determined by higher-layer configured *ca-SlotOffset* for the cell receiving the PDCCH, $N_{\text{slot, offset, CSIRS}}^{\text{CA}}$ and $\mu_{\text{offset,CSIRS}}$ are the $N_{\text{slot, offset}}^{\text{CA}}$ and the μ_{offset} which are determined by higher-layer configured *ca-SlotOffset* for the cell transmitting the CSI-RS respectively, as defined in [4, TS 38.211] clause 4.5.

The UE does not expect that aperiodic CSI-RS is transmitted before the OFDM symbol(s) carrying its triggering DCI. When the minimum scheduling offset restriction is applied, UE is not expected to be triggered by CSI triggering state indicated by the CSI request field in DCI in which CSI-RS triggering offset is smaller than the currently applicable minimum scheduling offset restriction $K_{0\text{min}}$.

If interference measurement is performed on aperiodic NZP CSI-RS, a UE is not expected to be configured with a different aperiodic triggering offset of the NZP CSI-RS for interference measurement from the associated NZP CSI-RS for channel measurement.

If the UE is configured with a single carrier for uplink, the UE is not expected to transmit more than one aperiodic CSI report triggered by different DCIs on overlapping OFDM symbols.

5.2.1.5.1a Aperiodic CSI Reporting/Aperiodic CSI-RS when the triggering PDCCH and the CSI-RS have different numerologies

When the triggering PDCCH and the triggered aperiodic CSI-RS are of different numerologies, the behavior defined in 5.2.1.5.1 for the case where the numerologies are the same applies with the following exceptions:

Beam switch timing:

- If the scheduling offset between the last symbol of the PDCCH carrying the triggering DCI and the first symbol of the aperiodic CSI-RS resources in a *NZP-CSI-RS-ResourceSet* configured without higher layer parameter *trs-Info* is smaller than *beamSwitchTiming* + $d \cdot 2^{\mu_{CSIRS}} / 2^{\mu_{PDCCH}}$ in CSI-RS symbols, as defined in [13, TS 38.306], when the reported value is one of the values of {14, 28, 48} and *enableBeamSwitchTiming* is not provided, or is smaller than 48+ $d \cdot 2^{\mu_{CSIRS}} / 2^{\mu_{PDCCH}}$ in CSI-RS symbols when the UE provides *beamSwitchTiming-r16* and *enableBeamSwitchTiming* is provided and the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *repetition* set to 'off' or configured without the higher layer parameter *repetition*, or is smaller than *beamSwitchTiming-r16* + $d \cdot 2^{\mu_{CSIRS}} / 2^{\mu_{PDCCH}}$ in CSI-RS symbols, when *enableBeamSwitchTiming* is provided and the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *repetition* set to 'on', where if the $\mu_{\text{PDCCH}} < \mu_{\text{CSIRS}}$, the beam switching timing delay d is defined in Table 5.2.1.5.1a-1, else d is zero
  - if one of the associated trigger states has the higher layer parameter *qcl-Type* set to 'typeD',
    - if there is any other DL signal with an indicated TCI state in the same symbols as the CSI-RS, the UE applies the QCL assumption of the other DL signal also when receiving the aperiodic CSI-RS. The other DL signal refers to PDSCH scheduled with offset larger than or equal to the threshold *timeDurationForQCL*, as defined in [13, TS 38.306], periodic CSI-RS, semi-persistent CSI-RS, aperiodic

CSI-RS scheduled with offset larger than or equal to *beamSwitchTiming* + $d \cdot 2^{\mu_{CSIRS}}/2^{\mu_{PDCCH}}$ in CSI-RS symbols when the reported value is one of the values {14,28,48} and when *enableBeamSwitchTiming* is not provided or the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *trs-Info*, aperiodic CSI-RS in a *NZP-CSI-RS-ResourceSet* configured with the higher layer parameter *repetition* set to 'off' or configured without the higher layer parameters *repetition* and *trs-Info* scheduled with offset larger than or equal to 48+ $d \cdot 2^{\mu_{CSIRS}}/2^{\mu_{PDCCH}}$ in CSI-RS symbols when the UE provides *beamSwitchTiming-r16* and *enableBeamSwitchTiming* is provided, aperiodic CSI-RS in a *NZP-CSI-RS-ResourceSet* configured with the higher layer parameter *repetition* set to 'on' and scheduled with offset larger than or equal to *beamSwitchTiming-r16* + $d \cdot 2^{\mu_{CSIRS}}/2^{\mu_{PDCCH}}$ in CSI-RS symbols when *enableBeamSwitchTiming* is provided;

- else,
  - if at least one CORESET is configured for the BWP in which the aperiodic CSI-RS is to be received, when receiving the aperiodic CSI-RS, the UE applies the QCL assumption used for the CORESET associated with a monitored search space with the lowest *controlResourceSetId* in the latest slot in which one or more CORESETs within the active BWP of the serving cell are monitored.
  - else if the UE is configured with *enableDefaultBeamForCCS*, when receiving the aperiodic CSI-RS, the UE applies the QCL assumption of the lowest-ID activated TCI state applicable to the PDSCH within the active BWP of the cell in which the CSI-RS is to be received.

- If the scheduling offset between the last symbol of the PDCCH carrying the triggering DCI and the first symbol of the aperiodic CSI-RS resources in a *NZP-CSI-RS-ResourceSet* is equal to or greater than *beamSwitchTiming* + $d \cdot 2^{\mu_{CSIRS}}/2^{\mu_{PDCCH}}$ in CSI-RS symbols, when the reported value is one of the values of {14,28,48} and *enableBeamSwitchTiming* is not provided and the *NZP-CSI-RS-ResourceSet* is not configured with higher layer parameter *trs-Info*, or is equal to or greater than *beamSwitchTiming* + $d \cdot 2^{\mu_{CSIRS}}/2^{\mu_{PDCCH}}$ in CSI-RS symbols when the reported value is one of the values of {14,28,48} and the *NZP-CSI-RS-ResourceSet* is configured with higher layer parameter *trs-Info*, or is equal to or greater than 48+$d \cdot 2^{\mu_{CSIRS}}/2^{\mu_{PDCCH}}$ in CSI-RS symbols when the UE provides *beamSwitchTiming-r16* and *enableBeamSwitchTiming* is provided and the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *repetition* set to 'off' or configured without the higher layer parameters *repetition* and *trs-Info*, or is equal to or greater than *beamSwitchTiming-r16* + *d* $2^{\mu_{CSIRS}}/2^{\mu_{PDCCH}}$ in CSI-RS symbols when *enableBeamSwitchTiming* is provided and the *NZP-CSI-RS-ResourceSet* is configured with the higher layer parameter *repetition* set to 'on', where if the $\mu_{PDCCH} < \mu_{CSIRS}$, the beam switching timing delay *d* is defined in Table 5.2.1.5.1a-1, else *d* is zero, the UE is expected to apply the QCL assumptions in the indicated TCI states for the aperiodic CSI-RS resources in the CSI triggering state indicated by the CSI trigger field in DCI.

Table 5.2.1.5.1a-1: Additional beam switching timing delay *d*

μ_{PDCCH}	*d* [PDCCH symbols]
0	8
1	8
2	14

Aperiodic CSI-RS timing:

- When the aperiodic CSI-RS is used with aperiodic CSI reporting, the CSI-RS triggering offset *X* is configured per resource set by the higher layer parameter *aperiodicTriggeringOffset* or *aperiodicTriggeringOffset-r16*, including the case that the UE is not configured with *minimumSchedulingOffsetK0* for any DL BWP or *minimumSchedulingOffsetK2* for any UL BWP and all the associated trigger states do not have the higher layer parameter *qcl-Type* set to 'typeD' in the corresponding TCI states. The CSI-RS triggering offset has the values of {0, 1, …, 31} slots when the $\mu_{PDCCH} < \mu_{CSIRS}$ and {0, 1, 2, 3, 4, 5, 6, …, 15, 16, 24} when the $\mu_{PDCCH} > \mu_{CSIRS}$.. The aperiodic CSI-RS is transmitted in a slot $\left\lfloor n \cdot \frac{2^{\mu_{CSIRS}}}{2^{\mu_{PDCCH}}} \right\rfloor + X + \left\lfloor \left(\frac{N_{slot,offset,PDCCH}^{CA}}{2^{\mu_{offset,PDCCH}}} - \frac{N_{slot,offset,CSIRS}^{CA}}{2^{\mu_{offset,CSIRS}}} \right) \cdot 2^{\mu_{CSIRS}} \right\rfloor$, if UE is configured with *ca-SlotOffset* for at least one of the triggered and triggering cell, and $K_s = \left\lfloor n \cdot \frac{2^{\mu_{CSIRS}}}{2^{\mu_{PDCCH}}} \right\rfloor + X$, otherwise, and where

  - n is the slot containing the triggering DCI, X is the CSI-RS triggering offset in the numerology of CSI-RS according to the higher layer parameter *aperiodicTriggeringOffset* or *aperiodicTriggeringOffset-r16*,

  - μ_{CSIRS} and μ_{PDCCH} are the subcarrier spacing configurations for CSI-RS and PDCCH, respectively,

  - $N_{\text{slot, offset, PDCCH}}^{\text{CA}}$ and $\mu_{\text{offset, PDCCH}}$ are the $N_{\text{slot, offset}}^{\text{CA}}$ and the μ_{offset}, respectively, which are determined by higher-layer configured *ca-SlotOffset* for the cell receiving the PDCCH respectively, $N_{\text{slot, offset, CSIRS}}^{\text{CA}}$ and $\mu_{\text{offset, CSIRS}}$ are the $N_{\text{slot, offset}}^{\text{CA}}$ and the μ_{offset}, respectively, which are determined by higher-layer configured *ca-SlotOffset* for the cell transmitting the CSI-RS respectively, as defined in [4, TS 38.211] clause 4.5

- If the $\mu_{PDCCH} < \mu_{CSIRS}$, the UE is expected to be able to measure the aperiodic CSI RS, if the CSI-RS starts no earlier than the first symbol of the CSI-RS carrier's slot that starts at least *Ncsirs* PDCCH symbols after the end of the PDCCH triggering the aperiodic CSI-RS.

- If the $\mu_{PDCCH} > \mu_{CSIRS}$, the UE is expected to be able to measure the aperiodic CSI RS, if the CSI-RS starts no earlier than at least *Ncsirs* PDCCH symbols after the end of the PDCCH triggering the aperiodic CSI-RS.

Table 5.2.1.5.1a: N_{csirs} as a function of the subcarrier spacing of the triggering PDCCH

μ_{PDCCH}	N_{csirs} [symbols]
0	4
1	5
2	10
3	14

When the triggering PDCCH and the triggered aperiodic CSI-RS are of different numerologies, the CSI request constraint and CSI reporting constraint defined in 5.2.1.5.1 for the case where the numerologies are the same applies with the following additions:

- CSI request constraints:

  - A UE is not expected to receive more than one CSI request per reference slot length across all CCs in a cell group, where the SCS of the reference slot is the minimum of SCS of the PDCCH with which the DCI was transmitted, the SCS of the PUSCH with which the CSI report is to be transmitted, and the SCS of the minimum SCS of the CSI-RS associated to the CSI reports triggered by the DCI. The beginning of a slot length is defined according the PDCCH cell with which the DCI carrying the CSI request is transmitted.

- CSI reporting constraints:

  - A UE is not expected to receive more than one CSI request for transmission in a given reference slot length across all CCs in a cell group, where the SCS of the reference slot is the minimum of SCS of the PDCCH with which the DCI was transmitted, the SCS of the PUSCH with which the CSI report is to be transmitted, and the SCS of the minimum SCS of the CSI-RS associated to the CSI reports triggered by the DCI. The beginning of a slot length is defined according the PUSCH cell with which the CSI report is transmitted.

5.2.1.5.2 Semi-persistent CSI/Semi-persistent CSI-RS

For semi-persistent reporting on PUSCH, a set of trigger states are higher layer configured by *CSI-SemiPersistentOnPUSCH-TriggerStateList*, where the CSI request field in DCI scrambled with SP-CSI-RNTI activates one of the trigger states. A UE is not expected to receive a DCI scrambled with SP-CSI-RNTI activating one semi-persistent CSI report with the same *CSI-ReportConfigId* as in a semi-persistent CSI report which is activated by a previously received DCI scrambled with SP-CSI-RNTI.

For semi-persistent reporting on PUCCH, the PUCCH resource used for transmitting the CSI report are configured by *reportConfigType*. Semi-persistent reporting on PUCCH is activated by an activation command as described in clause 6.1.3.16 of [10, TS 38.321], which selects one of the semi-persistent Reporting Settings for use by the UE on the PUCCH. When the UE would transmit a PUCCH with HARQ-ACK information in slot n corresponding to the PDSCH carrying the activation command, the indicated semi-persistent Reporting Setting should be applied starting from the first slot that is after slot $n+3N_{slot}^{subframe,\mu}$ where μ is the SCS configuration for the PUCCH.

For a UE configured with CSI resource setting(s) where the higher layer parameter *resourceType* set to 'semiPersistent'.

- when a UE receives an activation command, as described in clause 6.1.3.12 of [10, TS 38.321], for CSI-RS resource set(s) for channel measurement and CSI-IM/NZP CSI-RS resource set(s) for interference measurement associated with configured CSI resource setting(s), and when the UE would transmit a PUCCH with HARQ-ACK information in slot *n* corresponding to the PDSCH carrying the selection command, the corresponding actions in [10, TS 38.321] and the UE assumptions (including QCL assumptions provided by a list of reference to *TCI-State's*, one per activated resource) on CSI-RS/CSI-IM transmission corresponding to the configured CSI-RS/CSI-IM resource configuration(s) shall be applied starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$ where μ is the SCS configuration for the PUCCH. If a *TCI-State* referred to in the list is configured with a reference to an RS configured with *qcl-Type* set to '*typeD*', that RS can be an SS/PBCH block, periodic or semi-persistent CSI-RS located in same or different CC/DL BWP.

- when a UE receives a deactivation command, as described in clause 6.1.3.12 of [10, TS 38.321], for activated CSI-RS/CSI-IM resource set(s) associated with configured CSI resource setting(s), and when the UE would transmit a PUCCH with HARQ-ACK information in slot *n* corresponding to the PDSCH carrying the deactivation command, the corresponding actions in [10, TS 38.321] and UE assumption on cessation of CSI-RS/CSI-IM transmission corresponding to the deactivated CSI-RS/CSI-IM resource set(s) shall apply starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$ where μ is the SCS configuration for the PUCCH.

A codepoint of the CSI request field in the DCI is mapped to a SP-CSI triggering state according to the order of the positions of the configured trigger states in *CSI-SemiPersistentOnPUSCH-TriggerStateList*, with codepoint '0' mapped to the triggering state in the first position. A UE validates, for semi-persistent CSI activation or release, a DL semi-persistent assignment PDCCH on a DCI only if the following conditions are met:

- the CRC parity bits of the DCI format are scrambled with a SP-CSI-RNTI provided by higher layer parameter *sp-CSI-RNTI*

- Special fields for the DCI format are set according to Table 5.2.1.5.2-1 or Table 5.2.1.5.2-2.

If validation is achieved, the UE considers the information in the DCI format as a valid activation or valid release of semi-persistent CSI transmission on PUSCH, and the UE activates or deactivates a CSI Reporting Setting indicated by CSI request field in the DCI. If validation is not achieved, the UE considers the DCI format as having been detected with a non-matching CRC.

Table 5.2.1.5.2-1: Special fields for semi-persistent CSI activation PDCCH validation

	DCI format 0_1/0_2
HARQ process number	set to all '0's
Redundancy version	set to all '0's

Table 5.2.1.5.2-2: Special fields for semi-persistent CSI deactivation PDCCH validation

	DCI format 0_1/0_2
HARQ process number	set to all '0's
Modulation and coding scheme	set to all '1's
Resource block assignment	If higher layer configures RA type 0 only, set to all '0's; If higher layer configures RA type 1 only, set to all '1's; If higher layer configures dynamic switch between RA type 0 and 1, then if MSB is'0', set to all '0's; else, set to all '1's For DCI 0_1, if higher layer configures RA type 2, set to all '1's if μ = 0; set to all '0's if μ = 1
Redundancy version	set to all '0's

If the UE has an active semi-persistent CSI-RS/CSI-IM resource configuration, or an active semi-persistent ZP CSI-RS resource set configuration, and has not received a deactivation command, the activated semi-persistent CSI-RS/CSI-IM resource set or the activated semi-persistent ZP CSI-RS resource set configurations are considered to be active when the corresponding DL BWP is active, otherwise they are considered suspended.

If the UE is configured with carrier deactivation, the following configurations in the carrier in activated state would also be deactivated and need re-activation configuration(s): semi-persistent CSI-RS/CSI- IM resource, semi-persistent CSI reporting on PUCCH, semi-persistent SRS, semi-persistent ZP CSI-RS resource set.

5.2.1.6 CSI processing criteria

The UE indicates the number of supported simultaneous CSI calculations N_{CPU} with parameter *simultaneousCSI-ReportsPerCC* in a component carrier, and *simultaneousCSI-ReportsAllCC* across all component carriers. If a UE supports N_{CPU} simultaneous CSI calculations it is said to have N_{CPU} CSI processing units for processing CSI reports. If L CPUs are occupied for calculation of CSI reports in a given OFDM symbol, the UE has $N_{CPU}-L$ unoccupied CPUs. If N CSI reports start occupying their respective CPUs on the same OFDM symbol on which $N_{CPU}-L$ CPUs are unoccupied, where each CSI report $n=0,\ldots,N-1$ corresponds to $O_{CPU}^{(n)}$, the UE is not required to update the $N-M$ requested CSI reports with lowest priority (according to Clause 5.2.5), where $0 \le M \le N$ is the largest value such that $\sum_{n=0}^{M-1} O_{CPU}^{(n)} \le N_{CPU}-L$ holds.

A UE is not expected to be configured with an aperiodic CSI trigger state containing more than N_{CPU} Reporting Settings. Processing of a CSI report occupies a number of CPUs for a number of symbols as follows:

- $O_{CPU}=0$ for a CSI report with CSI-ReportConfig with higher layer parameter *reportQuantity* set to 'none' and *CSI-RS-ResourceSet* with higher layer parameter *trs-Info* configured

- $O_{CPU}=1$ for a CSI report with *CSI-ReportConfig* with higher layer parameter *reportQuantity* set to 'cri-RSRP', 'ssb-Index-RSRP', 'cri-SINR', 'ssb-Index-SINR' or 'none' (and *CSI-RS-ResourceSet* with higher layer parameter *trs-Info* not configured)

- for a CSI report with *CSI-ReportConfig* with higher layer parameter *reportQuantity* set to 'cri-RI-PMI-CQI', 'cri-RI-i1', 'cri-RI-i1-CQI', 'cri-RI-CQI', or 'cri-RI-LI-PMI-CQI',

  - if a CSI report is aperiodically triggered without transmitting a PUSCH with either transport block or HARQ-ACK or both when L = 0 CPUs are occupied, where the CSI corresponds to a single CSI with wideband frequency-granularity and to at most 4 CSI-RS ports in a single resource without CRI report and where *codebookType* is set to 'typeI-SinglePanel' or where *reportQuantity* is set to 'cri-RI-CQI', $O_{CPU}=N_{CPU}$,

  - otherwise, $O_{CPU}=K_s$, where K_s is the number of CSI-RS resources in the CSI-RS resource set for channel measurement.

For a CSI report with *CSI-ReportConfig* with higher layer parameter *reportQuantity* not set to 'none', the CPU(s) are occupied for a number of OFDM symbols as follows:

- A periodic or semi-persistent CSI report (excluding an initial semi-persistent CSI report on PUSCH after the PDCCH triggering the report) occupies CPU(s) from the first symbol of the earliest one of each CSI-RS/CSI-IM/SSB resource for channel or interference measurement, respective latest CSI-RS/CSI-IM/SSB occasion no later than the corresponding CSI reference resource, until the last symbol of the configured PUSCH/PUCCH carrying the report.

- An aperiodic CSI report occupies CPU(s) from the first symbol after the PDCCH triggering the CSI report until the last symbol of the scheduled PUSCH carrying the report.

- An initial semi-persistent CSI report on PUSCH after the PDCCH trigger occupies CPU(s) from the first symbol after the PDCCH until the last symbol of the scheduled PUSCH carrying the report.

For a CSI report with *CSI-ReportConfig* with higher layer parameter *reportQuantity* set to 'none' and *CSI-RS-ResourceSet* with higher layer parameter *trs-Info* not configured, the CPU(s) are occupied for a number of OFDM symbols as follows:

- A semi-persistent CSI report (excluding an initial semi-persistent CSI report on PUSCH after the PDCCH triggering the report) occupies CPU(s) from the first symbol of the earliest one of each transmission occasion of periodic or semi-persistent CSI-RS/SSB resource for channel measurement for L1-RSRP computation, until Z'_3 symbols after the last symbol of the latest one of the CSI-RS/SSB resource for channel measurement for L1-RSRP computation in each transmission occasion.

- An aperiodic CSI report occupies CPU(s) from the first symbol after the PDCCH triggering the CSI report until the last symbol between Z_3 symbols after the first symbol after the PDCCH triggering the CSI report and Z'_3 symbols after the last symbol of the latest one of each CSI-RS/SSB resource for channel measurement for L1-RSRP computation.

where (Z_3, Z'_3) are defined in the table 5.4-2.

In any slot, the UE is not expected to have more active CSI-RS ports or active CSI-RS resources in active BWPs than reported as capability. NZP CSI-RS resource is active in a duration of time defined as follows. For aperiodic CSI-RS, starting from the end of the PDCCH containing the request and ending at the end of the scheduled PUSCH containing the report associated with this aperiodic CSI-RS. For semi-persistent CSI-RS, starting from the end of when the activation command is applied, and ending at the end of when the deactivation command is applied. For periodic CSI-RS, starting when the periodic CSI-RS is configured by higher layer signalling, and ending when the periodic CSI-RS configuration is released. If a CSI-RS resource is referred *N* times by one or more CSI Reporting Settings, the CSI-RS resource and the CSI-RS ports within the CSI-RS resource are counted *N* times.

5.2.2 Channel state information

5.2.2.1 Channel quality indicator (CQI)

The CQI indices and their interpretations are given in Table 5.2.2.1-2 or Table 5.2.2.1-4 for reporting CQI based on QPSK, 16QAM and 64QAM. The CQI indices and their interpretations are given in Table 5.2.2.1-3 for reporting CQI based on QPSK, 16QAM, 64QAM and 256QAM.

Based on an unrestricted observation interval in time unless specified otherwise in this Clause, and an unrestricted observation interval in frequency, the UE shall derive for each CQI value reported in uplink slot *n* the highest CQI index which satisfies the following condition:

- A single PDSCH transport block with a combination of modulation scheme, target code rate and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding:
  - 0.1, if the higher layer parameter *cqi-Table* in *CSI-ReportConfig* configures 'table1' (corresponding to Table 5.2.2.1-2), or 'table2' (corresponding to Table 5.2.2.1-3), or
  - 0.00001, if the higher layer parameter *cqi-Table* in *CSI-ReportConfig* configures 'table3' (corresponding to Table 5.2.2.1-4).

If the higher layer parameter *timeRestrictionForChannelMeasurements* is set to "*notConfigured*", the UE shall derive the channel measurements for computing CSI value reported in uplink slot *n* based on only the NZP CSI-RS, no later than the CSI reference resource, (defined in TS 38.211[4]) associated with the CSI resource setting.

If the higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to "*Configured*", the UE shall derive the channel measurements for computing CSI reported in uplink slot *n* based on only the most recent, no later than the CSI reference resource, occasion of NZP CSI-RS (defined in [4, TS 38.211]) associated with the CSI resource setting.

If the higher layer parameter *timeRestrictionForInterferenceMeasurements* is set to "*notConfigured*", the UE shall derive the interference measurements for computing CSI value reported in uplink slot *n* based on only the CSI-IM and/or NZP CSI-RS for interference measurement no later than the CSI reference resource associated with the CSI resource setting.

If the higher layer parameter *timeRestrictionForInterferenceMeasurements* in *CSI-ReportConfig* is set to "*Configured*", the UE shall derive the interference measurements for computing the CSI value reported in uplink slot *n* based on the most recent, no later than the CSI reference resource, occasion of CSI-IM and/or NZP CSI-RS for interference measurement (defined in [4, TS 38.211]) associated with the CSI resource setting.

For each sub-band index *s*, a 2-bit sub-band differential CQI is defined as:

- Sub-band Offset level (*s*) = sub-band CQI index (*s*) - wideband CQI index.

The mapping from the 2-bit sub-band differential CQI values to the offset level is shown in Table 5.2.2.1-1

Table 5.2.2.1-1: Mapping sub-band differential CQI value to offset level

Sub-band differential CQI value	Offset level
0	0
1	1
2	≥ 2
3	≤-1

A combination of modulation scheme and transport block size corresponds to a CQI index if:

- the combination could be signaled for transmission on the PDSCH in the CSI reference resource according to the Transport Block Size determination described in Clause 5.1.3.2, and
- the modulation scheme is indicated by the CQI index, and
- the combination of transport block size and modulation scheme when applied to the reference resource results in the effective channel code rate which is the closest possible to the code rate indicated by the CQI index. If more than one combination of transport block size and modulation scheme results in an effective channel code rate equally close to the code rate indicated by the CQI index, only the combination with the smallest of such transport block sizes is relevant.

Table 5.2.2.1-2: 4-bit CQI Table

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

Table 5.2.2.1-3: 4-bit CQI Table 2

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	193	0.3770
3	QPSK	449	0.8770
4	16QAM	378	1.4766
5	16QAM	490	1.9141
6	16QAM	616	2.4063
7	64QAM	466	2.7305
8	64QAM	567	3.3223
9	64QAM	666	3.9023
10	64QAM	772	4.5234
11	64QAM	873	5.1152
12	256QAM	711	5.5547
13	256QAM	797	6.2266
14	256QAM	885	6.9141
15	256QAM	948	7.4063

Table 5.2.2.1-4: 4-bit CQI Table 3

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	30	0.0586
2	QPSK	50	0.0977
3	QPSK	78	0.1523
4	QPSK	120	0.2344
5	QPSK	193	0.3770
6	QPSK	308	0.6016
7	QPSK	449	0.8770
8	QPSK	602	1.1758
9	16QAM	378	1.4766
10	16QAM	490	1.9141
11	16QAM	616	2.4063
12	64QAM	466	2.7305
13	64QAM	567	3.3223
14	64QAM	666	3.9023
15	64QAM	772	4.5234

5.2.2.1.1 (void)

5.2.2.2 Precoding matrix indicator (PMI)

5.2.2.2.1 Type I Single-Panel Codebook

For 2 antenna ports {3000, 3001} and the UE configured with higher layer parameter *codebookType* set to 'typeI-SinglePanel' each PMI value corresponds to a codebook index given in Table 5.2.2.2.1-1. The UE is configured with the higher layer parameter *twoTX-CodebookSubsetRestriction*. The bitmap parameter *twoTX-CodebookSubsetRestriction* forms the bit sequence $a_5,...,a_1,a_0$ where a_0 is the LSB and a_5 is the MSB and where a bit value of zero indicates that PMI reporting is not allowed to correspond to the precoder associated with the bit. Bits 0 to 3 are associated respectively with the codebook indices 0 to 3 for $\upsilon=1$ layer, and bits 4 and 5 are associated respectively with the codebook indices 0 and 1 for $\upsilon=2$ layers.

Table 5.2.2.2.1-1: Codebooks for 1-layer and 2-layer CSI reporting using antenna ports 3000 to 3001

Codebook index	Number of layers υ	
	1	2
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\j & -j\end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	-
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	-

For 4 antenna ports {3000, 3001, 3002, 3003}, 8 antenna ports {3000, 3001, …, 3007}, 12 antenna ports {3000, 3001, …, 3011}, 16 antenna ports {3000, 3001, …, 3015}, 24 antenna ports {3000, 3001, …, 3023}, and 32 antenna ports {3000, 3001, …, 3031}, and the UE configured with higher layer parameter *codebookType* set to 'typeI-SinglePanel', except when the number of layers $\upsilon\in\{2,3,4\}$ (where υ is the associated RI value), each PMI value corresponds to three codebook indices $i_{1,1}, i_{1,2}, i_2$. When the number of layers $\upsilon\in\{2,3,4\}$, each PMI value corresponds to four codebook indices $i_{1,1}, i_{1,2}, i_{1,3}, i_2$. The composite codebook index i_1 is defined by

$$i_1 = \begin{cases} \begin{bmatrix} i_{1,1} & i_{1,2} \end{bmatrix} & \upsilon \notin \{2,3,4\} \\ \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,3} \end{bmatrix} & \upsilon \in \{2,3,4\} \end{cases}$$

The codebooks for 1-8 layers are given respectively in Tables 5.2.2.2.1-5, 5.2.2.2.1-6, 5.2.2.2.1-7, 5.2.2.2.1-8, 5.2.2.2.1-9, 5.2.2.2.1-10, 5.2.2.2.1-11, and 5.2.2.2.1-12. The mapping from $i_{1,3}$ to k_1 and k_2 for 2-layer reporting is given in Table 5.2.2.2.1-3. The mapping from $i_{1,3}$ to k_1 and k_2 for 3-layer and 4-layer reporting when $P_{\text{CSI-RS}} < 16$ is given in Table 5.2.2.2.1-4. The quantities φ_n, θ_p, u_m, $v_{l,m}$, and $\tilde{v}_{l,m}$ are given by

$$\varphi_n = e^{j\pi n/2}$$
$$\theta_p = e^{j\pi p/4}$$
$$u_m = \begin{cases} \begin{bmatrix} 1 & e^{j\frac{2\pi m}{O_2 N_2}} & \cdots & e^{j\frac{2\pi m(N_2-1)}{O_2 N_2}} \end{bmatrix} & N_2 > 1 \\ 1 & N_2 = 1 \end{cases}$$
$$v_{l,m} = \begin{bmatrix} u_m & e^{j\frac{2\pi l}{O_1 N_1}} u_m & \cdots & e^{j\frac{2\pi l(N_1-1)}{O_1 N_1}} u_m \end{bmatrix}^T$$
$$\tilde{v}_{l,m} = \begin{bmatrix} u_m & e^{j\frac{4\pi l}{O_1 N_1}} u_m & \cdots & e^{j\frac{4\pi l(N_1/2-1)}{O_1 N_1}} u_m \end{bmatrix}^T$$

- The values of N_1 and N_2 are configured with the higher layer parameter *n1-n2*, respectively. The supported configurations of (N_1, N_2) for a given number of CSI-RS ports and the corresponding values of (O_1, O_2) are given in Table 5.2.2.2.1-2. The number of CSI-RS ports, $P_{\text{CSI-RS}}$, is $2N_1N_2$.
- UE shall only use $i_{1,2} = 0$ and shall not report $i_{1,2}$ if the value of N_2 is 1.

The bitmap parameter *n1-n2* forms the bit sequence $a_{A_c-1},...,a_1,a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that PMI reporting is not allowed to correspond to any precoder associated with the bit. The number of bits is given by $A_c = N_1O_1N_2O_2$. Except when the number of layers $\upsilon \in \{3,4\}$ and the number of antenna ports is 16, 24, or 32, bit $a_{N_2O_2l+m}$ is associated with all precoders based on the quantity $v_{l,m}$, $l = 0,\ldots,N_1O_1-1$, $m = 0,\ldots,N_2O_2-1$. When the number of layers $\upsilon \in \{3,4\}$ and the number of antenna ports is 16, 24, or 32,

- bits $a_{(N_2O_2(2l-1)+m) \bmod N_1O_1N_2O_2}$, $a_{N_2O_2(2l)+m}$, and $a_{N_2O_2(2l+1)+m}$ are each associated with all precoders based on the quantity $\tilde{v}_{l,m}$, $l = 0,\ldots,N_1O_1/2-1$, $m = 0,\ldots,N_2O_2-1$;
- if one or more of the associated bits is zero, then PMI reporting is not allowed to correspond to any precoder based on $\tilde{v}_{l,m}$.

For UE configured with higher layer parameter *codebookType* set to 'typeI-SinglePanel', the bitmap parameter *typeI-SinglePanel-ri-Restriction* forms the bit sequence $r_7,...,r_1,r_0$ where r_0 is the LSB and r_7 is the MSB. When r_i is zero, $i \in \{0,1,\ldots,7\}$, PMI and RI reporting are not allowed to correspond to any precoder associated with $\upsilon = i+1$ layers.

For UE configured with higher layer parameter *reportQuantity* set to 'cri-RI-i1-CQI', the bitmap parameter *typeI-SinglePanel-codebookSubsetRestriction-i2* forms the bit sequence $b_{15},...,b_1,b_0$ where b_0 is the LSB and b_{15} is the MSB. The bit b_i is associated with precoders corresponding to codebook index $i_2 = i$. When b_i is zero, the randomly selected precoder for CQI calculation is not allowed to correspond to any precoder associated with the bit b_i.

Table 5.2.2.2.1-2: Supported configurations of (N_1, N_2) and (O_1, O_2)

Number of CSI-RS antenna ports, $P_{\text{CSI-RS}}$	(N_1, N_2)	(O_1, O_2)
4	(2,1)	(4,1)
8	(2,2)	(4,4)
	(4,1)	(4,1)
12	(3,2)	(4,4)
	(6,1)	(4,1)
16	(4,2)	(4,4)
	(8,1)	(4,1)
24	(4,3)	(4,4)
	(6,2)	(4,4)
	(12,1)	(4,1)
32	(4,4)	(4,4)
	(8,2)	(4,4)
	(16,1)	(4,1)

Table 5.2.2.2.1-3: Mapping of $i_{1,3}$ to k_1 and k_2 for 2-layer CSI reporting

$i_{1,3}$	$N_1 > N_2 > 1$		$N_1 = N_2$		$N_1 = 2, N_2 = 1$		$N_1 > 2, N_2 = 1$	
	k_1	k_2	k_1	k_2	k_1	k_2	k_1	k_2
0	0	0	0	0	0	0	0	0
1	O_1	0	O_1	0	O_1	0	O_1	0
2	0	O_2	0	O_2			$2O_1$	0
3	$2O_1$	0	O_1	O_2			$3O_1$	0

Table 5.2.2.2.1-4: Mapping of $i_{1,3}$ to k_1 and k_2 for 3-layer and 4-layer CSI reporting when $P_{\text{CSI-RS}} < 16$

$i_{1,3}$	$N_1 = 2, N_2 = 1$		$N_1 = 4, N_2 = 1$		$N_1 = 6, N_2 = 1$		$N_1 = 2, N_2 = 2$		$N_1 = 3, N_2 = 2$	
	k_1	k_2	k_1	k_2	k_1	k_2	k_1	k_2	k_1	k_2
0	O_1	0	O_1	0	O_1	0	O_1	0	O_1	0
1			$2O_1$	0	$2O_1$	0	0	O_2	0	O_2
2			$3O_1$	0	$3O_1$	0	O_1	O_2	O_1	O_2
3					$4O_1$	0			$2O_1$	0

Table 5.2.2.2.1-5: Codebook for 1-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

codebookMode = 1			
$i_{1,1}$	$i_{1,2}$	i_2	
$0,1,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1,2,3$	$W^{(1)}_{i_{1,1},i_{1,2},i_2}$
where $W^{(1)}_{l,m,n} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \end{bmatrix}$.			

***codebookMode* = 2**, $N_2>1$					
$i_{1,1}$	$i_{1,2}$	i_2			
		0	**1**	**2**	**3**
$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1},2i_{1,2},0}$	$W^{(1)}_{2i_{1,1},2i_{1,2},1}$	$W^{(1)}_{2i_{1,1},2i_{1,2},2}$	$W^{(1)}_{2i_{1,1},2i_{1,2},3}$
$i_{1,1}$	$i_{1,2}$	i_2			
		4	**5**	**6**	**7**
$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},0}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},1}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},2}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2},3}$
$i_{1,1}$	$i_{1,2}$	i_2			
		8	**9**	**10**	**11**
$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,0}$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,1}$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,2}$	$W^{(1)}_{2i_{1,1},2i_{1,2}+1,3}$
$i_{1,1}$	$i_{1,2}$	i_2			
		12	**13**	**14**	**15**
$0,1,...,\frac{N_1O_1}{2}-1$	$0,1,...,\frac{N_2O_2}{2}-1$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,0}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,1}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,2}$	$W^{(1)}_{2i_{1,1}+1,2i_{1,2}+1,3}$
where $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m}\end{bmatrix}$.					

***codebookMode* = 2**, $N_2=1$					
$i_{1,1}$	$i_{1,2}$	i_2			
		0	**1**	**2**	**3**
$0,1,...,\frac{N_1O_1}{2}-1$	0	$W^{(1)}_{2i_{1,1},0,0}$	$W^{(1)}_{2i_{1,1},0,1}$	$W^{(1)}_{2i_{1,1},0,2}$	$W^{(1)}_{2i_{1,1},0,3}$
$i_{1,1}$	$i_{1,2}$	i_2			
		4	**5**	**6**	**7**
$0,1,...,\frac{N_1O_1}{2}-1$	0	$W^{(1)}_{2i_{1,1}+1,0,0}$	$W^{(1)}_{2i_{1,1}+1,0,1}$	$W^{(1)}_{2i_{1,1}+1,0,2}$	$W^{(1)}_{2i_{1,1}+1,0,3}$
$i_{1,1}$	$i_{1,2}$	i_2			
		8	**9**	**10**	**11**
$0,1,...,\frac{N_1O_1}{2}-1$	0	$W^{(1)}_{2i_{1,1}+2,0,0}$	$W^{(1)}_{2i_{1,1}+2,0,1}$	$W^{(1)}_{2i_{1,1}+2,0,2}$	$W^{(1)}_{2i_{1,1}+2,0,3}$
$i_{1,1}$	$i_{1,2}$	i_2			
		12	**13**	**14**	**15**
$0,1,...,\frac{N_1O_1}{2}-1$	0	$W^{(1)}_{2i_{1,1}+3,0,0}$	$W^{(1)}_{2i_{1,1}+3,0,1}$	$W^{(1)}_{2i_{1,1}+3,0,2}$	$W^{(1)}_{2i_{1,1}+3,0,3}$
where $W^{(1)}_{l,m,n}=\frac{1}{\sqrt{P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m}\end{bmatrix}$.					

Table 5.2.2.2.1-6: Codebook for 2-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

***codebookMode* = 1**			
$i_{1,1}$	$i_{1,2}$	i_2	
$0,1,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	0,1	$W^{(2)}_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_2}$
where $W^{(2)}_{l,l',m,m',n}=\frac{1}{\sqrt{2P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'}\end{bmatrix}$. and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.1-3.			

***codebookMode* = 2,** $N_2 > 1$			
$i_{1,1}$	$i_{1,2}$	i_2	
		0	**1**
$0,\ldots,\frac{N_1O_1}{2}-1$	$0,\ldots,\frac{N_2O_2}{2}-1$	$W^{(2)}_{2i_{1,1},2i_{1,1}+k_1,2i_{1,2},2i_{1,2}+k_2,0}$	$W^{(2)}_{2i_{1,1},2i_{1,1}+k_1,2i_{1,2},2i_{1,2}+k_2,1}$
$i_{1,1}$	$i_{1,2}$	i_2	
		2	**3**
$0,\ldots,\frac{N_1O_1}{2}-1$	$0,\ldots,\frac{N_2O_2}{2}-1$	$W^{(2)}_{2i_{1,1}+1,2i_{1,1}+1+k_1,2i_{1,2},2i_{1,2}+k_2,0}$	$W^{(2)}_{2i_{1,1}+1,2i_{1,1}+1+k_1,2i_{1,2},2i_{1,2}+k_2,1}$
$i_{1,1}$	$i_{1,2}$	i_2	
		4	**5**
$0,\ldots,\frac{N_1O_1}{2}-1$	$0,\ldots,\frac{N_2O_2}{2}-1$	$W^{(2)}_{2i_{1,1},2i_{1,1}+k_1,2i_{1,2}+1,2i_{1,2}+1+k_2,0}$	$W^{(2)}_{2i_{1,1},2i_{1,1}+k_1,2i_{1,2}+1,2i_{1,2}+1+k_2,1}$
$i_{1,1}$	$i_{1,2}$	i_2	
		6	**7**
$0,\ldots,\frac{N_1O_1}{2}-1$	$0,\ldots,\frac{N_2O_2}{2}-1$	$W^{(2)}_{2i_{1,1}+1,2i_{1,1}+1+k_1,2i_{1,2}+1,2i_{1,2}+1+k_2,0}$	$W^{(2)}_{2i_{1,1}+1,2i_{1,1}+1+k_1,2i_{1,2}+1,2i_{1,2}+1+k_2,1}$
where $W^{(2)}_{l,l',m,m',n} = \frac{1}{\sqrt{2P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$. and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.1-3.			

***codebookMode* = 2,** $N_2 = 1$					
$i_{1,1}$	$i_{1,2}$	i_2			
		0	**1**	**2**	**3**
$0,\ldots,\frac{N_1O_1}{2}-1$	0	$W^{(2)}_{2i_{1,1},2i_{1,1}+k_1,0,0,0}$	$W^{(2)}_{2i_{1,1},2i_{1,1}+k_1,0,0,1}$	$W^{(2)}_{2i_{1,1}+1,2i_{1,1}+1+k_1,0,0,0}$	$W^{(2)}_{2i_{1,1}+1,2i_{1,1}+1+k_1,0,0,1}$
$i_{1,1}$	$i_{1,2}$	i_2			
		4	**5**	**6**	**7**
$0,\ldots,\frac{N_1O_1}{2}-1$	0	$W^{(2)}_{2i_{1,1}+2,2i_{1,1}+2+k_1,0,0,0}$	$W^{(2)}_{2i_{1,1}+2,2i_{1,1}+2+k_1,0,0,1}$	$W^{(2)}_{2i_{1,1}+3,2i_{1,1}+3+k_1,0,0,0}$	$W^{(2)}_{2i_{1,1}+3,2i_{1,1}+3+k_1,0,0,1}$
where $W^{(2)}_{l,l',m,m',n} = \frac{1}{\sqrt{2P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$. and the mapping from $i_{1,3}$ to k_1 is given in Table 5.2.2.2.1-3.					

Table 5.2.2.2.1-7: Codebook for 3-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

***codebookMode* = 1-2,** $P_{\text{CSI-RS}} < 16$			
$i_{1,1}$	$i_{1,2}$	i_2	
$0,\ldots,N_1O_1-1$	$0,1,\ldots,N_2O_2-1$	$0,1$	$W^{(3)}_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_2}$
where $W^{(3)}_{l,l',m,m',n} = \frac{1}{\sqrt{3P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l,m} \\ \varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l,m} \end{bmatrix}$. and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.1-4.			

***codebookMode* = 1-2**, $P_{\text{CSI-RS}} \geq 16$				
$i_{1,1}$	$i_{1,2}$	$i_{1,3}$	i_2	
$0,\ldots,\frac{N_1 O_1}{2}-1$	$0,\ldots,N_2 O_2-1$	$0,1,2,3$	$0,1$	$W^{(3)}_{i_{1,1},i_{1,2},i_{1,3},i_2}$
where $W^{(3)}_{l,m,p,n} = \frac{1}{\sqrt{3P_{\text{CSI-RS}}}} \begin{bmatrix} \tilde{v}_{l,m} & \tilde{v}_{l,m} & \tilde{v}_{l,m} \\ \theta_p \tilde{v}_{l,m} & -\theta_p \tilde{v}_{l,m} & \theta_p \tilde{v}_{l,m} \\ \varphi_n \tilde{v}_{l,m} & \varphi_n \tilde{v}_{l,m} & -\varphi_n \tilde{v}_{l,m} \\ \varphi_n \theta_p \tilde{v}_{l,m} & -\varphi_n \theta_p \tilde{v}_{l,m} & -\varphi_n \theta_p \tilde{v}_{l,m} \end{bmatrix}$.				

Table 5.2.2.2.1-8: Codebook for 4-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

***codebookMode* = 1-2**, $P_{\text{CSI-RS}} < 16$			
$i_{1,1}$	$i_{1,2}$	i_2	
$0,\ldots,N_1 O_1-1$	$0,1,\ldots,N_2 O_2-1$	$0,1$	$W^{(4)}_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_2}$
where $W^{(4)}_{l,l',m,m',n} = \frac{1}{\sqrt{4P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} & v_{l',m'} & v_{l,m} & v_{l',m'} \\ \varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l,m} & -\varphi_n v_{l',m'} \end{bmatrix}$. and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.1-4.			

***codebookMode* = 1-2**, $P_{\text{CSI-RS}} \geq 16$				
$i_{1,1}$	$i_{1,2}$	$i_{1,3}$	i_2	
$0,\ldots,\frac{N_1 O_1}{2}-1$	$0,\ldots,N_2 O_2-1$	$0,1,2,3$	$0,1$	$W^{(4)}_{i_{1,1},i_{1,2},i_{1,3},i_2}$
where $W^{(4)}_{l,m,p,n} = \frac{1}{\sqrt{4P_{\text{CSI-RS}}}} \begin{bmatrix} \tilde{v}_{l,m} & \tilde{v}_{l,m} & \tilde{v}_{l,m} & \tilde{v}_{l,m} \\ \theta_p \tilde{v}_{l,m} & -\theta_p \tilde{v}_{l,m} & \theta_p \tilde{v}_{l,m} & -\theta_p \tilde{v}_{l,m} \\ \varphi_n \tilde{v}_{l,m} & \varphi_n \tilde{v}_{l,m} & -\varphi_n \tilde{v}_{l,m} & -\varphi_n \tilde{v}_{l,m} \\ \varphi_n \theta_p \tilde{v}_{l,m} & -\varphi_n \theta_p \tilde{v}_{l,m} & -\varphi_n \theta_p \tilde{v}_{l,m} & \varphi_n \theta_p \tilde{v}_{l,m} \end{bmatrix}$.				

Table 5.2.2.2.1-9: Codebook for 5-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

***codebookMode* = 1-2**				
	$i_{1,1}$	$i_{1,2}$	i_2	
$N_2 > 1$	$0,\ldots,N_1 O_1-1$	$0,\ldots,N_2 O_2-1$	$0,1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 1$	$0,\ldots,N_1 O_1-1$	0	$0,1$	$W^{(5)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,0,0,0,i_2}$
where $W^{(5)}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{5P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & v_{l',m'} & -v_{l',m'} & v_{l'',m''} \end{bmatrix}$.				

Table 5.2.2.2.1-10: Codebook for 6-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

***codebookMode* = 1-2**				
	$i_{1,1}$	$i_{1,2}$	i_2	
$N_2 > 1$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 1$	$0,\ldots,N_1O_1-1$	0	$0,1$	$W^{(6)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,0,0,0,i_2}$
where $W^{(6)}_{l,l',l'',m,m'.m'',n} = \frac{1}{\sqrt{6P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} \end{bmatrix}$.				

Table 5.2.2.2.1-11: Codebook for 7-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

***codebookMode* = 1-2**				
	$i_{1,1}$	$i_{1,2}$	i_2	
$N_1 = 4, N_2 = 1$	$0,\ldots,\frac{N_1O_1}{2}-1$	0	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 > 4, N_2 = 1$	$0,\ldots,N_1O_1-1$	0	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 = 2, N_2 = 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,\frac{N_2O_2}{2}-1$	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 > 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(7)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
where $W^{(7)}_{l,l',l'',l''',m,m',m'',m''',n} = \frac{1}{\sqrt{7P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$.				

Table 5.2.2.2.1-12: Codebook for 8-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

***codebookMode* = 1-2**				
	$i_{1,1}$	$i_{1,2}$	i_2	
$N_1 = 4, N_2 = 1$	$0,\ldots,\frac{N_1O_1}{2}-1$	0	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 > 4, N_2 = 1$	$0,\ldots,N_1O_1-1$	0	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1}+2O_1,i_{1,1}+3O_1,0,0,0,0,i_2}$
$N_1 = 2, N_2 = 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 = 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,\frac{N_2O_2}{2}-1$	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
$N_1 > 2, N_2 > 2$	$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1$	$W^{(8)}_{i_{1,1},i_{1,1}+O_1,i_{1,1},i_{1,1}+O_1,i_{1,2},i_{1,2},i_{1,2}+O_2,i_{1,2}+O_2,i_2}$
where $W^{(8)}_{l,l',l'',l''',m,m'.m'',m''',n} = \frac{1}{\sqrt{8P_{\text{CSI-RS}}}}\begin{bmatrix} v_{l,m} & v_{l,m} & v_{l',m'} & v_{l',m'} & v_{l'',m''} & v_{l'',m''} & v_{l''',m'''} & v_{l''',m'''} \\ \varphi_n v_{l,m} & -\varphi_n v_{l,m} & \varphi_n v_{l',m'} & -\varphi_n v_{l',m'} & v_{l'',m''} & -v_{l'',m''} & v_{l''',m'''} & -v_{l''',m'''} \end{bmatrix}$.				

5.2.2.2.2 Type I Multi-Panel Codebook

For 8 antenna ports {3000, 3001, …, 3007}, 16 antenna ports {3000, 3001, …, 3015}, and 32 antenna ports {3000, 3001, …, 3031}, and the UE configured with higher layer parameter *codebookType* set to 'typeI-MultiPanel',

- The values of N_g, N_1 and N_2 are configured with the higher layer parameters *ng-n1-n2*. The supported configurations of $\left(N_g, N_1, N_2\right)$ for a given number of CSI-RS ports and the corresponding values of (O_1, O_2) are given in Table 5.2.2.2.2-1. The number of CSI-RS ports, $P_{\text{CSI-RS}}$, is $2N_g N_1 N_2$.

- When $N_g = 2$, *codebookMode* shall be set to either '1' or '2'. When $N_g = 4$, *codebookMode* shall be set to '1'.

The bitmap parameter *ng-n1-n2* forms the bit sequence $a_{A_c-1},...,a_1,a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that PMI reporting is not allowed to correspond to any precoder associated with the bit. The number of bits is given by $A_c = N_1 O_1 N_2 O_2$. Bit $a_{N_2 O_2 l+m}$ is associated with all precoders based on the quantity $v_{l,m}$, $l = 0,\ldots,N_1 O_1 - 1$, $m = 0,\ldots,N_2 O_2 - 1$, as defined below. The bitmap parameter *ri-Restriction* forms the bit sequence $r_3,...,r_1,r_0$ where r_0 is the LSB and r_3 is the MSB. When r_i is zero, $i \in \{0,1,\ldots,3\}$, PMI and RI reporting are not allowed to correspond to any precoder associated with $\upsilon = i+1$ layers.

Table 5.2.2.2.2-1: Supported configurations of $\left(N_g, N_1, N_2\right)$ and (O_1, O_2)

Number of CSI-RS antenna ports, $P_{\text{CSI-RS}}$	$\left(N_g, N_1, N_2\right)$	(O_1, O_2)
8	(2,2,1)	(4,1)
16	(2,4,1)	(4,1)
	(4,2,1)	(4,1)
	(2,2,2)	(4,4)
32	(2,8,1)	(4,1)
	(4,4,1)	(4,1)
	(2,4,2)	(4,4)
	(4,2,2)	(4,4)

Each PMI value corresponds to the codebook indices i_1 and i_2, where i_1 is the vector

$$i_1 = \begin{cases} \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,4} \end{bmatrix} & \upsilon = 1 \\ \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,3} & i_{1,4} \end{bmatrix} & \upsilon \in \{2,3,4\} \end{cases}$$

and υ is the associated RI value. When *codebookMode* is set to '1', $i_{1,4}$ is

$$i_{1,4} = \begin{cases} i_{1,4,1} & N_g = 2 \\ \begin{bmatrix} i_{1,4,1} & i_{1,4,2} & i_{1,4,3} \end{bmatrix} & N_g = 4 \end{cases}.$$

When *codebookMode* is set to '2', $i_{1,4}$ and i_2 are

$$\begin{aligned} i_{1,4} &= \begin{bmatrix} i_{1,4,1} & i_{1,4,2} \end{bmatrix} \\ i_2 &= \begin{bmatrix} i_{2,0} & i_{2,1} & i_{2,2} \end{bmatrix} \end{aligned}.$$

The mapping from $i_{1,3}$ to k_1 and k_2 for 2-layer reporting is given in Table 5.2.2.2.1-3. The mapping from $i_{1,3}$ to k_1 and k_2 for 3-layer and 4-layer reporting is given in Table 5.2.2.2.2-2.

- UE shall only use $i_{1,2} = 0$ and shall not report $i_{1,2}$ if the value of N_2 is 1.

Table 5.2.2.2.2-2: Mapping of $i_{1,3}$ to k_1 and k_2 for 3-layer and 4-layer CSI reporting

$i_{1,3}$	$N_1=2, N_2=1$		$N_1=4, N_2=1$		$N_1=8, N_2=1$		$N_1=2, N_2=2$		$N_1=4, N_2=2$	
	k_1	k_2	k_1	k_2	k_1	k_2	k_1	k_2	k_1	k_2
0	O_1	0	O_1	0	O_1	0	O_1	0	O_1	0
1			$2O_1$	0	$2O_1$	0	0	O_2	0	O_2
2			$3O_1$	0	$3O_1$	0	O_1	O_2	O_1	O_2
3					$4O_1$	0			$2O_1$	0

Several quantities are used to define the codebook elements. The quantities φ_n, a_p, b_n, u_m, and $v_{l,m}$ are given by

$$\begin{aligned}
\varphi_n &= e^{j\pi n/2} \\
a_p &= e^{j\pi/4} e^{j\pi p/2} \\
b_n &= e^{-j\pi/4} e^{j\pi n/2} \\
u_m &= \begin{cases} \begin{bmatrix} 1 & e^{j\frac{2\pi m}{O_2 N_2}} & \cdots & e^{j\frac{2\pi m(N_2-1)}{O_2 N_2}} \end{bmatrix} & N_2 > 1 \\ 1 & N_2 = 1 \end{cases} \\
v_{l,m} &= \begin{bmatrix} u_m & e^{j\frac{2\pi l}{O_1 N_1}} u_m & \cdots & e^{j\frac{2\pi l(N_1-1)}{O_1 N_1}} u_m \end{bmatrix}^T
\end{aligned}$$

Furthermore, the quantities $W_{l,m,p,n}^{1,N_g,1}$ and $W_{l,m,p,n}^{2,N_g,1}$ ($N_g \in \{2,4\}$) are given by

$$W_{l,m,p,n}^{1,2,1} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \\ \varphi_{p_1} v_{l,m} \\ \varphi_n \varphi_{p_1} v_{l,m} \end{bmatrix} \quad W_{l,m,p,n}^{2,2,1} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ -\varphi_n v_{l,m} \\ \varphi_{p_1} v_{l,m} \\ -\varphi_n \varphi_{p_1} v_{l,m} \end{bmatrix}$$

$$W_{l,m,p,n}^{1,4,1} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ \varphi_n v_{l,m} \\ \varphi_{p_1} v_{l,m} \\ \varphi_n \varphi_{p_1} v_{l,m} \\ \varphi_{p_2} v_{l,m} \\ \varphi_n \varphi_{p_2} v_{l,m} \\ \varphi_{p_3} v_{l,m} \\ \varphi_n \varphi_{p_3} v_{l,m} \end{bmatrix} \quad W_{l,m,p,n}^{2,4,1} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ -\varphi_n v_{l,m} \\ \varphi_{p_1} v_{l,m} \\ -\varphi_n \varphi_{p_1} v_{l,m} \\ \varphi_{p_2} v_{l,m} \\ -\varphi_n \varphi_{p_2} v_{l,m} \\ \varphi_{p_3} v_{l,m} \\ -\varphi_n \varphi_{p_3} v_{l,m} \end{bmatrix}$$

where

$$p = \begin{cases} p_1 & N_g = 2 \\ \begin{bmatrix} p_1 & p_2 & p_3 \end{bmatrix} & N_g = 4 \end{cases},$$

and the quantities $W_{l,m,p,n}^{1,N_g,2}$ and $W_{l,m,p,n}^{2,N_g,2}$ ($N_g = 2$) are given by

$$W_{l,m,p,n}^{1,2,2} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ \varphi_{n_0} v_{l,m} \\ a_{p_1} b_{n_1} v_{l,m} \\ a_{p_2} b_{n_2} v_{l,m} \end{bmatrix} \quad W_{l,m,p,n}^{2,2,2} = \frac{1}{\sqrt{P_{\text{CSI-RS}}}} \begin{bmatrix} v_{l,m} \\ -\varphi_{n_0} v_{l,m} \\ a_{p_1} b_{n_1} v_{l,m} \\ -a_{p_2} b_{n_2} v_{l,m} \end{bmatrix}$$

where

$$p = \begin{bmatrix} p_1 & p_2 \end{bmatrix}$$
$$n = \begin{bmatrix} n_0 & n_1 & n_2 \end{bmatrix}.$$

The codebooks for 1-4 layers are given respectively in Tables 5.2.2.2.2-3, 5.2.2.2.2-4, 5.2.2.2.2-5, and 5.2.2.2.2-6.

Table 5.2.2.2.2-3: Codebook for 1-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

***codebookMode* = 1**, $N_g \in \{2,4\}$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,\ldots,N_g - 1$	i_2	
$0,\ldots,N_1O_1 - 1$	$0,\ldots,N_2O_2 - 1$	$0,1,2,3$	$0,1,2,3$	$W_{i_{1,1},i_{1,2},i_{1,4},i_2}^{(1)}$
where $W_{l,m,p,n}^{(1)} = W_{l,m,p,n}^{1,N_g,1}$.				

***codebookMode* = 2**, $N_g = 2$					
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,2$	$i_{2,0}$	$i_{2,q}$, $q = 1,2$	
$0,\ldots,N_1O_1 - 1$	$0,\ldots,N_2O_2 - 1$	$0,1,2,3$	$0,1,2,3$	$0,1$	$W_{i_{1,1},i_{1,2},i_{1,4},i_2}^{(1)}$
where $W_{l,m,p,n}^{(1)} = W_{l,m,p,n}^{1,N_g,2}$.					

Table 5.2.2.2.2-4: Codebook for 2-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

***codebookMode* = 1**, $N_g \in \{2,4\}$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,\ldots,N_g - 1$	i_2	
$0,\ldots,N_1O_1 - 1$	$0,\ldots,N_2O_2 - 1$	$0,1,2,3$	$0,1$	$W_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_{1,4},i_2}^{(2)}$
where $W_{l,l',m,m',p,n}^{(2)} = \frac{1}{\sqrt{2}} \begin{bmatrix} W_{l,m,p,n}^{1,N_g,1} & W_{l',m',p,n}^{2,N_g,1} \end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.1-3.				

***codebookMode* = 2**, $N_g = 2$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q = 1,2$	$i_{2,q}$, $q = 0,1,2$	
$0,\ldots,N_1O_1 - 1$	$0,\ldots,N_2O_2 - 1$	$0,1,2,3$	$0,1$	$W_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_{1,4},i_2}^{(2)}$
where $W_{l,l',m,m',p,n}^{(2)} = \frac{1}{\sqrt{2}} \begin{bmatrix} W_{l,m,p,n}^{1,N_g,2} & W_{l',m',p,n}^{2,N_g,2} \end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.1-3.				

Table 5.2.2.2.2-5: Codebook for 3-layer CSI reporting using antenna ports 3000 to 2999+P_{CSI-RS}

***codebookMode* = 1**, $N_g \in \{2,4\}$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q=1,\ldots,N_g-1$	i_2	
$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1,2,3$	$0,1$	$W^{(3)}_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_{1,4},i_2}$
where $W^{(3)}_{l,l',m,m',p,n}=\frac{1}{\sqrt{3}}\begin{bmatrix}W^{1,N_g,1}_{l,m,p,n} & W^{1,N_g,1}_{l',m',p,n} & W^{2,N_g,1}_{l,m,p,n}\end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.2-2.				

***codebookMode* = 2**, $N_g = 2$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q=1,2$	$i_{2,q}$, $q=0,1,2$	
$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1,2,3$	$0,1$	$W^{(3)}_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_{1,4},i_2}$
where $W^{(3)}_{l,l',m,m',p,n}=\frac{1}{\sqrt{3}}\begin{bmatrix}W^{1,N_g,2}_{l,m,p,n} & W^{1,N_g,2}_{l',m',p,n} & W^{2,N_g,2}_{l,m,p,n}\end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.2-2.				

Table 5.2.2.2.2-6: Codebook for 4-layer CSI reporting using antenna ports 3000 to 2999+P_{CSI-RS}

***codebookMode* = 1**, $N_g \in \{2,4\}$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q=1,\ldots,N_g-1$	i_2	
$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1,2,3$	$0,1$	$W^{(4)}_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_{1,4},i_2}$
where $W^{(4)}_{l,l',m,m',p,n}=\frac{1}{\sqrt{4}}\begin{bmatrix}W^{1,N_g,1}_{l,m,p,n} & W^{1,N_g,1}_{l',m',p,n} & W^{2,N_g,1}_{l,m,p,n} & W^{2,N_g,1}_{l',m',p,n}\end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.2-2.				

***codebookMode* = 2**, $N_g = 2$				
$i_{1,1}$	$i_{1,2}$	$i_{1,4,q}$, $q=1,2$	$i_{2,q}$, $q=0,1,2$	
$0,\ldots,N_1O_1-1$	$0,\ldots,N_2O_2-1$	$0,1,2,3$	$0,1$	$W^{(4)}_{i_{1,1},i_{1,1}+k_1,i_{1,2},i_{1,2}+k_2,i_{1,4},i_2}$
where $W^{(4)}_{l,l',m,m',p,n}=\frac{1}{\sqrt{4}}\begin{bmatrix}W^{1,N_g,2}_{l,m,p,n} & W^{1,N_g,2}_{l',m',p,n} & W^{2,N_g,2}_{l,m,p,n} & W^{2,N_g,2}_{l',m',p,n}\end{bmatrix}$ and the mapping from $i_{1,3}$ to k_1 and k_2 is given in Table 5.2.2.2.2-2.				

5.2.2.2.3 Type II Codebook

For 4 antenna ports {3000, 3001, …, 3003}, 8 antenna ports {3000, 3001, …, 3007}, 12 antenna ports {3000, 3001, …, 3011}, 16 antenna ports {3000, 3001, …, 3015}, 24 antenna ports {3000, 3001, …, 3023}, and 32 antenna ports {3000, 3001, …, 3031}, and the UE configured with higher layer parameter *codebookType* set to 'typeII'

- The values of N_1 and N_2 are configured with the higher layer parameter *n1-n2-codebookSubsetRestriction*. The supported configurations of (N_1,N_2) for a given number of CSI-RS ports and the corresponding values of (O_1,O_2) are given in Table 5.2.2.2.1-2. The number of CSI-RS ports, $P_{\text{CSI-RS}}$, is $2N_1N_2$.

- The value of L is configured with the higher layer parameter *numberOfBeams*, where $L=2$ when $P_{\text{CSI-RS}}=4$ and $L\in\{2,3,4\}$ when $P_{\text{CSI-RS}}>4$.

- The value of N_{PSK} is configured with the higher layer parameter *phaseAlphabetSize*, where $N_{\text{PSK}}\in\{4,8\}$.

- The UE is configured with the higher layer parameter *subbandAmplitude* set to 'true' or 'false'.
- The UE shall not report RI > 2.

When $\upsilon \le 2$, where υ is the associated RI value, each PMI value corresponds to the codebook indices i_1 and i_2 where

$$i_1 = \begin{cases} \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,3,1} & i_{1,4,1} \end{bmatrix} & \upsilon = 1 \\ \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,3,1} & i_{1,4,1} & i_{1,3,2} & i_{1,4,2} \end{bmatrix} & \upsilon = 2 \end{cases}$$

$$i_2 = \begin{cases} \begin{bmatrix} i_{2,1,1} \end{bmatrix} & subbandAmplitude = \text{'false'},\ \upsilon = 1 \\ \begin{bmatrix} i_{2,1,1} & i_{2,1,2} \end{bmatrix} & subbandAmplitude = \text{'false'},\ \upsilon = 2 \\ \begin{bmatrix} i_{2,1,1} & i_{2,2,1} \end{bmatrix} & subbandAmplitude = \text{'true'},\ \upsilon = 1 \\ \begin{bmatrix} i_{2,1,1} & i_{2,2,1} & i_{2,1,2} & i_{2,2,2} \end{bmatrix} & subbandAmplitude = \text{'true'},\ \upsilon = 2 \end{cases}..$$

The L vectors combined by the codebook are identified by the indices $i_{1,1}$ and $i_{1,2}$, where

$$\begin{aligned} i_{1,1} &= \begin{bmatrix} q_1 & q_2 \end{bmatrix} \\ q_1 &\in \{0,1,\ldots,O_1 - 1\} \\ q_2 &\in \{0,1,\ldots,O_2 - 1\} \end{aligned}$$

$$i_{1,2} \in \left\{ 0,1,\ldots,\binom{N_1 N_2}{L} - 1 \right\}.$$

Let

$$\begin{aligned} n_1 &= \left[n_1^{(0)},\ldots,n_1^{(L-1)} \right] \\ n_2 &= \left[n_2^{(0)},\ldots,n_2^{(L-1)} \right] \\ n_1^{(i)} &\in \{0,1,\ldots,N_1 - 1\} \\ n_2^{(i)} &\in \{0,1,\ldots,N_2 - 1\} \end{aligned}$$

and

$$C(x,y) = \begin{cases} \binom{x}{y} & x \ge y \\ 0 & x < y \end{cases}.$$

where the values of $C(x,y)$ are given in Table 5.2.2.2.3-1.

Then the elements of n_1 and n_2 are found from $i_{1,2}$ using the algorithm:

$s_{-1} = 0$

for $i = 0,\ldots,L-1$

Find the largest $x^* \in \{L-1-i,\ldots,N_1 N_2 - 1 - i\}$ in Table 5.2.2.2.3-1 such that $i_{1,2} - s_{i-1} \ge C\left(x^*, L-i\right)$

$e_i = C\left(x^*, L-i\right)$

$s_i = s_{i-1} + e_i$

$n^{(i)} = N_1 N_2 - 1 - x^*$

$n_1^{(i)} = n^{(i)} \bmod N_1$

$$n_2^{(i)} = \frac{\left(n^{(i)} - n_1^{(i)}\right)}{N_1}$$

When n_1 and n_2 are known, $i_{1,2}$ is found using:

$n^{(i)} = N_1 n_2^{(i)} + n_1^{(i)}$ where the indices $i = 0,1,\ldots,L-1$ are assigned such that $n^{(i)}$ increases as i increases

$i_{1,2} = \sum_{i=0}^{L-1} C\left(N_1 N_2 - 1 - n^{(i)}, L - i\right)$, where $C(x,y)$ is given in Table 5.2.2.2.3-1.

- If $N_2 = 1$, $q_2 = 0$ and $n_2^{(i)} = 0$ for $i = 0,1,\ldots,L-1$, and q_2 is not reported.
- When $(N_1, N_2) = (2,1)$, $n_1 = [0,1]$ and $n_2 = [0,0]$, and $i_{1,2}$ is not reported.
- When $(N_1, N_2) = (4,1)$ and $L = 4$, $n_1 = [0,1,2,3]$ and $n_2 = [0,0,0,0]$, and $i_{1,2}$ is not reported.
- When $(N_1, N_2) = (2,2)$ and $L = 4$, $n_1 = [0,1,0,1]$ and $n_2 = [0,0,1,1]$, and $i_{1,2}$ is not reported.

Table 5.2.2.2.3-1: Combinatorial coefficients $C(x,y)$

x \ y	1	2	3	4
0	0	0	0	0
1	1	0	0	0
2	2	1	0	0
3	3	3	1	0
4	4	6	4	1
5	5	10	10	5
6	6	15	20	15
7	7	21	35	35
8	8	28	56	70
9	9	36	84	126
10	10	45	120	210
11	11	55	165	330
12	12	66	220	495
13	13	78	286	715
14	14	91	364	1001
15	15	105	455	1365

The strongest coefficient on layer $l, l = 1,\ldots,\upsilon$ is identified by $i_{1,3,l} \in \{0,1,\ldots,2L-1\}$.

The amplitude coefficient indicators $i_{1,4,l}$ and $i_{2,2,l}$ are

$$i_{1,4,l} = \left[k_{l,0}^{(1)}, k_{l,1}^{(1)}, \ldots, k_{l,2L-1}^{(1)}\right]$$
$$i_{2,2,l} = \left[k_{l,0}^{(2)}, k_{l,1}^{(2)}, \ldots, k_{l,2L-1}^{(2)}\right]$$
$$k_{l,i}^{(1)} \in \{0,1,\ldots,7\}$$
$$k_{l,i}^{(2)} \in \{0,1\}$$

for $l=1,\ldots,\upsilon$. The mapping from $k_{l,i}^{(1)}$ to the amplitude coefficient $p_{l,i}^{(1)}$ is given in Table 5.2.2.2.3-2 and the mapping from $k_{l,i}^{(2)}$ to the amplitude coefficient $p_{l,i}^{(2)}$ is given in Table 5.2.2.2.3-3. The amplitude coefficients are represented by

$$p_l^{(1)} = \left[p_{l,0}^{(1)}, p_{l,1}^{(1)}, \ldots, p_{l,2L-1}^{(1)} \right]$$
$$p_l^{(2)} = \left[p_{l,0}^{(2)}, p_{l,1}^{(2)}, \ldots, p_{l,2L-1}^{(2)} \right]$$

for $l=1,\ldots,\upsilon$.

Table 5.2.2.2.3-2: Mapping of elements of $i_{1,4,l}$: $k_{l,i}^{(1)}$ to $p_{l,i}^{(1)}$

$k_{l,i}^{(1)}$	$p_{l,i}^{(1)}$
0	0
1	$\sqrt{1/64}$
2	$\sqrt{1/32}$
3	$\sqrt{1/16}$
4	$\sqrt{1/8}$
5	$\sqrt{1/4}$
6	$\sqrt{1/2}$
7	1

Table 5.2.2.2.3-3: Mapping of elements of $i_{2,2,l}$: $k_{l,i}^{(2)}$ to $p_{l,i}^{(2)}$

$k_{l,i}^{(2)}$	$p_{l,i}^{(2)}$
0	$\sqrt{1/2}$
1	1

The phase coefficient indicators are

$$i_{2,1,l} = \left[c_{l,0}, c_{l,1}, \ldots, c_{l,2L-1} \right]$$

for $l=1,\ldots,\upsilon$.

The amplitude and phase coefficient indicators are reported as follows:

- The indicators $k_{l,i_{1,3,l}}^{(1)}=7$, $k_{l,i_{1,3,l}}^{(2)}=1$, and $c_{l,i_{1,3,l}}=0$ ($l=1,\ldots,\upsilon$). $k_{l,i_{1,3,l}}^{(1)}$, $k_{l,i_{1,3,l}}^{(2)}$, and $c_{l,i_{1,3,l}}$ are not reported for $l=1,\ldots,\upsilon$.
- The remaining $2L-1$ elements of $i_{1,4,l}$ ($l=1,\ldots,\upsilon$) are reported, where $k_{l,i}^{(1)} \in \{0,1,\ldots,7\}$. Let M_l ($l=1,\ldots,\upsilon$) be the number of elements of $i_{1,4,l}$ that satisfy $k_{l,i}^{(1)} > 0$.
- The remaining $2L-1$ elements of $i_{2,1,l}$ and $i_{2,2,l}$ ($l=1,\ldots,\upsilon$) are reported as follows:

- When *subbandAmplitude* is set to 'false',
  - $k_{l,i}^{(2)}=1$ for $l=1,\ldots,\upsilon$, and $i=0,1,\ldots,2L-1$. $i_{2,2,l}$ is not reported for $l=1,\ldots,\upsilon$.
  - For $l=1,\ldots,\upsilon$, the elements of $i_{2,1,l}$ corresponding to the coefficients that satisfy $k_{l,i}^{(1)}>0$, $i \neq i_{1,3,l}$, as determined by the reported elements of $i_{1,4,l}$, are reported, where $c_{l,i} \in \{0,1,\ldots,N_{\text{PSK}}-1\}$ and the remaining $2L-M_l$ elements of $i_{2,1,l}$ are not reported and are set to $c_{l,i}=0$.
- When *subbandAmplitude* is set to 'true',
  - For $l=1,\ldots,\upsilon$, the elements of $i_{2,2,l}$ and $i_{2,1,l}$ corresponding to the $\min\left(M_l,K^{(2)}\right)-1$ strongest coefficients (excluding the strongest coefficient indicated by $i_{1,3,l}$), as determined by the corresponding reported elements of $i_{1,4,l}$, are reported, where $k_{l,i}^{(2)} \in \{0,1\}$ and $c_{l,i} \in \{0,1,\ldots,N_{\text{PSK}}-1\}$. The values of $K^{(2)}$ are given in Table 5.2.2.2.3-4. The remaining $2L-\min\left(M_l,K^{(2)}\right)$ elements of $i_{2,2,l}$ are not reported and are set to $k_{l,i}^{(2)}=1$. The elements of $i_{2,1,l}$ corresponding to the $M_l-\min\left(M_l,K^{(2)}\right)$ weakest non-zero coefficients are reported, where $c_{l,i} \in \{0,1,2,3\}$. The remaining $2L-M_l$ elements of $i_{2,1,l}$ are not reported and are set to $c_{l,i}=0$.
  - When two elements, $k_{l,x}^{(1)}$ and $k_{l,y}^{(1)}$, of the reported elements of $i_{1,4,l}$ are identical ($k_{l,x}^{(1)}=k_{l,y}^{(1)}$), then element $\min(x,y)$ is prioritized to be included in the set of the $\min\left(M_l,K^{(2)}\right)-1$ strongest coefficients for $i_{2,1,l}$ and $i_{2,2,l}$ ($l=1,\ldots,\upsilon$) reporting.

Table 5.2.2.2.3-4: Full resolution subband coefficients when *subbandAmplitude* is set to 'true'

L	$K^{(2)}$
2	4
3	4
4	6

The codebooks for 1-2 layers are given in Table 5.2.2.2.3-5, where the indices $m_1^{(i)}$ and $m_2^{(i)}$ are given by

$$m_1^{(i)}=O_1 n_1^{(i)}+q_1$$
$$m_2^{(i)}=O_2 n_2^{(i)}+q_2$$

for $i=0,1,\ldots,L-1$, and the quantities $\varphi_{l,i}$, u_m, and $v_{l,m}$ are given by

$$\varphi_{l,i} = \begin{cases} e^{j2\pi c_{l,i}/N_{\mathrm{PSK}}} & \textit{subbandAmplitude} = \text{'false'} \\ e^{j2\pi c_{l,i}/N_{\mathrm{PSK}}} & \textit{subbandAmplitude} = \text{'true'},\ \min\left(M_l, K^{(2)}\right) \text{ strongest coefficients (including } i_{1,3,l}\text{) with } k_{l,i}^{(1)} > 0 \\ e^{j2\pi c_{l,i}/4} & \textit{subbandAmplitude} = \text{'true'},\ M_l - \min\left(M_l, K^{(2)}\right) \text{ weakest coefficients with } k_{l,i}^{(1)} > 0 \\ 1 & \textit{subbandAmplitude} = \text{'true'},\ 2L - M_l \text{ coefficients with } k_{l,i}^{(1)} = 0 \end{cases}$$

$$u_m = \begin{cases} \begin{bmatrix} 1 & e^{j\frac{2\pi m}{O_2 N_2}} & \cdots & e^{j\frac{2\pi m(N_2-1)}{O_2 N_2}} \end{bmatrix} & N_2 > 1 \\ 1 & N_2 = 1 \end{cases} .$$

$$v_{l,m} = \begin{bmatrix} u_m & e^{j\frac{2\pi l}{O_1 N_1}} u_m & \cdots & e^{j\frac{2\pi l(N_1-1)}{O_1 N_1}} u_m \end{bmatrix}^T$$

Table 5.2.2.2.3-5: Codebook for 1-layer and 2-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

Layers	
$\upsilon = 1$	$W^{(1)}_{q_1,q_2,n_1,n_2,p_1^{(1)},p_1^{(2)},i_{2,1,1}} = W^{1}_{q_1,q_2,n_1,n_2,p_1^{(1)},p_1^{(2)},i_{2,1,1}}$
$\upsilon = 2$	$W^{(2)}_{q_1,q_2,n_1,n_2,p_1^{(1)},p_1^{(2)},i_{2,1,1},p_2^{(1)},p_2^{(2)},i_{2,1,2}} = \frac{1}{\sqrt{2}}\begin{bmatrix} W^{1}_{q_1,q_2,n_1,n_2,p_1^{(1)},p_1^{(2)},i_{2,1,1}} & W^{2}_{q_1,q_2,n_1,n_2,p_2^{(1)},p_2^{(2)},i_{2,1,2}} \end{bmatrix}$
where $W^{l}_{q_1,q_2,n_1,n_2,p_l^{(1)},p_l^{(2)},c_l} = \frac{1}{\sqrt{N_1 N_2 \sum_{i=0}^{2L-1}\left(p_{l,i}^{(1)} p_{l,i}^{(2)}\right)^2}} \begin{bmatrix} \sum_{i=0}^{L-1} v_{m_1^{(i)},m_2^{(i)}}\, p_{l,i}^{(1)} p_{l,i}^{(2)} \varphi_{l,i} \\ \sum_{i=0}^{L-1} v_{m_1^{(i)},m_2^{(i)}}\, p_{l,i+L}^{(1)} p_{l,i+L}^{(2)} \varphi_{l,i+L} \end{bmatrix},\ l = 1,2$, and the mappings from i_1 to q_1, q_2, n_1, n_2, $p_1^{(1)}$, and $p_2^{(1)}$, and from i_2 to $i_{2,1,1}$, $i_{2,1,2}$, $p_1^{(2)}$ and $p_2^{(2)}$ are as described above, including the ranges of the constituent indices of i_1 and i_2.	

When the UE is configured with higher layer parameter *codebookType* set to 'typeII', thebitmap parameter *typeII-RI-Restriction* forms the bit sequence r_1, r_0 where r_0 is the LSB and r_1 is the MSB. When r_i is zero, $i \in \{0,1\}$, PMI and RI reporting are not allowed to correspond to any precoder associated with $\upsilon = i+1$ layers. The bitmap parameter *n1-n2-codebookSubsetRestriction* forms the bit sequence $B = B_1 B_2$ where bit sequences B_1, and B_2 are concatenated to form B. To define B_1 and B_2, first define the $O_1 O_2$ vector groups $G(r_1, r_2)$ as

$$G(r_1,r_2) = \left\{ v_{N_1 r_1 + x_1, N_2 r_2 + x_2} : x_1 = 0,1,\ldots,N_1-1; x_2 = 0,1,\ldots,N_2-1 \right\}$$

for

$$\begin{aligned} r_1 &\in \{0,1,\ldots,O_1-1\} \\ r_2 &\in \{0,1,\ldots,O_2-1\} \end{aligned}.$$

The UE shall be configured with restrictions for 4 vector groups indicated by $\left(r_1^{(k)}, r_2^{(k)}\right)$ for $k = 0,1,2,3$ and identified by the group indices

$$g^{(k)} = O_1 r_2^{(k)} + r_1^{(k)}$$

for $k=0,1,\ldots,3$, where the indices are assigned such that $g^{(k)}$ increases as k increases. The remaining vector groups are not restricted.

- If $N_2=1$, $g^{(k)}=k$ for $k=0,1,\ldots,3$, and B_1 is empty.

- If $N_2>1$, $B_1=b_1^{(10)}\cdots b_1^{(0)}$ is the binary representation of the integer β_1 where $b_1^{(10)}$ is the MSB and $b_1^{(0)}$ is the LSB. β_1 is found using:

$$\beta_1=\sum_{k=0}^{3}C\left(O_1O_2-1-g^{(k)},4-k\right),$$

where $C(x,y)$ is defined in Table 5.2.2.2.3-1. The group indices $g^{(k)}$ and indicators $\left(r_1^{(k)},r_2^{(k)}\right)$ for $k=0,1,2,3$ may be found from β_1 using the algorithm:

$s_{-1}=0$

for $k=0,\ldots,3$

Find the largest $x^*\in\{3-k,\ldots,O_1O_2-1-k\}$ such that $\beta_1-s_{k-1}\geq C\left(x^*,4-k\right)$

$e_k=C\left(x^*,4-k\right)$

$s_k=s_{k-1}+e_k$

$g^{(k)}=O_1O_2-1-x^*$

$r_1^{(k)}=g^{(k)}\bmod O_1$

$r_2^{(k)}=\dfrac{\left(g^{(k)}-r_1^{(k)}\right)}{O_1}$

The bit sequence $B_2=B_2^{(0)}B_2^{(1)}B_2^{(2)}B_2^{(3)}$ is the concatenation of the bit sequences $B_2^{(k)}$ for $k=0,1,\ldots,3$, corresponding to the group indices $g^{(k)}$. The bit sequence $B_2^{(k)}$ is defined as

$$B_2^{(k)}=b_2^{(k,2N_1N_2-1)}\cdots b_2^{(k,0)}$$

Bits $b_2^{(k,2(N_1x_2+x_1)+1)}b_2^{(k,2(N_1x_2+x_1))}$ indicate the maximum allowed amplitude coefficient $p_{l,i}^{(1)}$ for the vector in group $g^{(k)}$ indexed by x_1,x_2, where the maximum amplitude coefficients are given in Table 5.2.2.2.3-6. A UE that does not report parameter *amplitudeSubsetRestriction* = 'supported' in its capability signaling is not expected to be configured with $b_2^{(k,2(N_1x_2+x_1)+1)}b_2^{(k,2(N_1x_2+x_1))}$ = 01 or 10.

Table 5.2.2.2.3-6: Maximum allowed amplitude coefficients for restricted vectors

Bits $b_2^{(k,2(N_1x_2+x_1)+1)}b_2^{(k,2(N_1x_2+x_1))}$	Maximum Amplitude Coefficient $p_{l,i}^{(1)}$
00	0
01	$\sqrt{1/4}$
10	$\sqrt{1/2}$
11	1

5.2.2.2.4 Type II Port Selection Codebook

For 4 antenna ports {3000, 3001, …, 3003}, 8 antenna ports {3000, 3001, …, 3007}, 12 antenna ports {3000, 3001, …, 3011}, 16 antenna ports {3000, 3001, …, 3015}, 24 antenna ports {3000, 3001, …, 3023}, and 32 antenna ports {3000, 3001, …, 3031}, and the UE configured with higher layer parameter *codebookType* set to 'typeII-PortSelection'

- The number of CSI-RS ports is given by $P_{\text{CSI-RS}} \in \{4,8,12,16,24,32\}$ as configured by higher layer parameter *nrofPorts*.
- The value of L is configured with the higher layer parameter *numberOfBeams* , where $L=2$ when $P_{\text{CSI-RS}}=4$ and $L \in \{2,3,4\}$ when $P_{\text{CSI-RS}}>4$.
- The value of d is configured with the higher layer parameter *portSelectionSamplingSize*, where $d \in \{1,2,3,4\}$ and $d \le \min\left(\frac{P_{\text{CSI-RS}}}{2}, L\right)$.
- The value of N_{PSK} is configured with the higher layer parameter *phaseAlphabetSize*, where $N_{\text{PSK}} \in \{4,8\}$.
- The UE is configured with the higher layer parameter *subbandAmplitude* set to 'true' or 'false'.
- The UE shall not report RI > 2.

The UE is also configured with the higher layer parameter *typeII-PortSelectionRI-Restriction*. The bitmap parameter *typeII-PortSelectionRI-Restriction* forms the bit sequence r_1, r_0 where r_0 is the LSB and r_1 is the MSB. When r_i is zero, $i \in \{0,1\}$, PMI and RI reporting are not allowed to correspond to any precoder associated with $\upsilon = i+1$ layers.

When $\upsilon \le 2$, where υ is the associated RI value, each PMI value corresponds to the codebook indices i_1 and i_2 where

$$i_1 = \begin{cases} \begin{bmatrix} i_{1,1} & i_{1,3,1} & i_{1,4,1} \end{bmatrix} & \upsilon = 1 \\ \begin{bmatrix} i_{1,1} & i_{1,3,1} & i_{1,4,1} & i_{1,3,2} & i_{1,4,2} \end{bmatrix} & \upsilon = 2 \end{cases}$$

$$i_2 = \begin{cases} \begin{bmatrix} i_{2,1,1} \end{bmatrix} & subbandAmplitude = \text{'false'},\ \upsilon = 1 \\ \begin{bmatrix} i_{2,1,1} & i_{2,1,2} \end{bmatrix} & subbandAmplitude = \text{'false'},\ \upsilon = 2 \\ \begin{bmatrix} i_{2,1,1} & i_{2,2,1} \end{bmatrix} & subbandAmplitude = \text{'true'},\ \upsilon = 1 \\ \begin{bmatrix} i_{2,1,1} & i_{2,2,1} & i_{2,1,2} & i_{2,2,2} \end{bmatrix} & subbandAmplitude = \text{'true'},\ \upsilon = 2 \end{cases}.$$

The L antenna ports per polarization are selected by the index $i_{1,1}$, where

$$i_{1,1} \in \left\{0,1,\ldots,\left\lceil \frac{P_{\text{CSI-RS}}}{2d} \right\rceil - 1\right\}.$$

The strongest coefficient on layer $l, l=1,\ldots,\upsilon$ is identified by $i_{1,3,l} \in \{0,1,\ldots,2L-1\}$.

The amplitude coefficient indicators $i_{1,4,l}$ and $i_{2,2,l}$ are

$$\begin{aligned} i_{1,4,l} &= \left[k_{l,0}^{(1)}, k_{l,1}^{(1)}, \ldots, k_{l,2L-1}^{(1)}\right] \\ i_{2,2,l} &= \left[k_{l,0}^{(2)}, k_{l,1}^{(2)}, \ldots, k_{l,2L-1}^{(2)}\right] \\ k_{l,i}^{(1)} &\in \{0,1,\ldots,7\} \\ k_{l,i}^{(2)} &\in \{0,1\} \end{aligned}$$

for $l=1,\ldots,\upsilon$. The mapping from $k_{l,i}^{(1)}$ to the amplitude coefficient $p_{l,i}^{(1)}$ is given in Table 5.2.2.2.3-2 and the mapping from $k_{l,i}^{(2)}$ to the amplitude coefficient $p_{l,i}^{(2)}$ is given in Table 5.2.2.2.3-3. The amplitude coefficients are represented by

$$p_l^{(1)}=\left[\,p_{l,0}^{(1)},p_{l,1}^{(1)},\ldots,p_{l,2L-1}^{(1)}\right]$$
$$p_l^{(2)}=\left[\,p_{l,0}^{(2)},p_{l,1}^{(2)},\ldots,p_{l,2L-1}^{(2)}\right]$$

for $l=1,\ldots,\upsilon$.

The phase coefficient indicators are

$$i_{2,1,l}=\left[c_{l,0},c_{l,1},\ldots,c_{l,2L-1}\right]$$

for $l=1,\ldots,\upsilon$.

The amplitude and phase coefficient indicators are reported as follows:

- The indicators $k_{l,i_{1,3,l}}^{(1)}=7$, $k_{l,i_{1,3,l}}^{(2)}=1$, and $c_{l,i_{1,3,l}}=0$ ($l=1,\ldots,\upsilon$). $k_{l,i_{1,3,l}}^{(1)}$, $k_{l,i_{1,3,l}}^{(2)}$, and $c_{l,i_{1,3,l}}$ are not reported for $l=1,\ldots,\upsilon$.
- The remaining $2L-1$ elements of $i_{1,4,l}$ ($l=1,\ldots,\upsilon$) are reported, where $k_{l,i}^{(1)}\in\{0,1,\ldots,7\}$. Let M_l ($l=1,\ldots,\upsilon$) be the number of elements of $i_{1,4,l}$ that satisfy $k_{l,i}^{(1)}>0$.
- The remaining $2L-1$ elements of $i_{2,1,l}$ and $i_{2,2,l}$ ($l=1,\ldots,\upsilon$) are reported as follows:
  - When *subbandAmplitude* is set to 'false',
    - $k_{l,i}^{(2)}=1$ for $l=1,\ldots,\upsilon$, and $i=0,1,\ldots,2L-1$. $i_{2,2,l}$ is not reported for $l=1,\ldots,\upsilon$.
    - For $l=1,\ldots,\upsilon$, the M_l-1 elements of $i_{2,1,l}$ corresponding to the coefficients that satisfy $k_{l,i}^{(1)}>0$, $i\neq i_{1,3,l}$, as determined by the reported elements of $i_{1,4,l}$, are reported, where $c_{l,i}\in\{0,1,\ldots,N_{\mathrm{PSK}}-1\}$ and the remaining $2L-M_l$ elements of $i_{2,1,l}$ are not reported and are set to $c_{l,i}=0$.
  - When *subbandAmplitude* is set to 'true',
    - For $l=1,\ldots,\upsilon$, the elements of $i_{2,2,l}$ and $i_{2,1,l}$ corresponding to the $\min\left(M_l,K^{(2)}\right)-1$ strongest coefficients (excluding the strongest coefficient indicated by $i_{1,3,l}$), as determined by the corresponding reported elements of $i_{1,4,l}$, are reported, where $k_{l,i}^{(2)}\in\{0,1\}$ and $c_{l,i}\in\{0,1,\ldots,N_{\mathrm{PSK}}-1\}$. The values of $K^{(2)}$ are given in Table 5.2.2.2.3-4. The remaining $2L-\min\left(M_l,K^{(2)}\right)$ elements of $i_{2,2,l}$ are not reported and are set to $k_{l,i}^{(2)}=1$. The elements of $i_{2,1,l}$ corresponding to the $M_l-\min\left(M_l,K^{(2)}\right)$ weakest non-zero coefficients are reported, where $c_{l,i}\in\{0,1,2,3\}$. The remaining $2L-M_l$ elements of $i_{2,1,l}$ are not reported and are set to $c_{l,i}=0$.
    - When two elements, $k_{l,x}^{(1)}$ and $k_{l,y}^{(1)}$, of the reported elements of $i_{1,4,l}$ are identical ($k_{l,x}^{(1)}=k_{l,y}^{(1)}$), then element $\min(x,y)$ is prioritized to be included in the set of the $\min\left(M_l,K^{(2)}\right)-1$ strongest coefficients for $i_{2,1,l}$ and $i_{2,2,l}$ ($l=1,\ldots,\upsilon$) reporting.

The codebooks for 1-2 layers are given in Table 5.2.2.2.4-1, where the quantity $\varphi_{l,i}$ is given by

$$\varphi_{l,i}=\begin{cases} e^{j2\pi c_{l,i}/N_{\text{PSK}}} & \textit{subbandAmplitude} = \text{'false'} \\ e^{j2\pi c_{l,i}/N_{\text{PSK}}} & \textit{subbandAmplitude} = \text{'true', } \min\left(M_l, K^{(2)}\right) \text{ strongest coefficients (including } i_{1,3,l}\text{) with } k_{l,i}^{(1)}>0 \\ e^{j2\pi c_{l,i}/4} & \textit{subbandAmplitude} = \text{'true', } M_l-\min\left(M_l, K^{(2)}\right) \text{ weakest coefficients with } k_{l,i}^{(1)}>0 \\ 1 & \textit{subbandAmplitude} = \text{'true', } 2L-M_l \text{ coefficients with } k_{l,i}^{(1)}=0 \end{cases}$$

and v_m is a $P_{\text{CSI-RS}}/2$ -element column vector containing a value of 1 in element $(m \bmod P_{\text{CSI-RS}}/2)$ and zeros elsewhere (where the first element is element 0).

Table 5.2.2.2.4-1: Codebook for 1-layer and 2-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

Layers	
$\upsilon=1$	$W^{(1)}_{i_{1,1},p_1^{(1)},p_1^{(2)},i_{2,1,1}}=W^{1}_{i_{1,1},p_1^{(1)},p_1^{(2)},i_{2,1,1}}$
$\upsilon=2$	$W^{(2)}_{i_{1,1},p_1^{(1)},p_1^{(2)},i_{2,1,1},p_2^{(1)},p_2^{(2)},i_{2,1,2}}=\frac{1}{\sqrt{2}}\begin{bmatrix}W^{1}_{i_{1,1},p_1^{(1)},p_1^{(2)},i_{2,1,1}} & W^{2}_{i_{1,1},p_2^{(1)},p_2^{(2)},i_{2,1,2}}\end{bmatrix}$
where $W^{l}_{i_{1,1},p_l^{(1)},p_l^{(2)},i_{2,1,l}}=\frac{1}{\sqrt{\sum_{i=0}^{2L-1}\left(p_{l,i}^{(1)}p_{l,i}^{(2)}\right)^2}}\begin{bmatrix}\sum_{i=0}^{L-1}v_{i_{1,1}d+i}\,p_{l,i}^{(1)}p_{l,i}^{(2)}\varphi_{l,i} \\ \sum_{i=0}^{L-1}v_{i_{1,1}d+i}\,p_{l,i+L}^{(1)}p_{l,i+L}^{(2)}\varphi_{l,i+L}\end{bmatrix}$, $l=1,2$, and the mappings from i_1 to $i_{1,1}$, $p_1^{(1)}$, and $p_2^{(1)}$ and from i_2 to $i_{2,1,1}$, $i_{2,1,2}$, $p_1^{(2)}$, and $p_2^{(2)}$ are as described above, including the ranges of the constituent indices of i_1 and i_2.	

5.2.2.2.5 Enhanced Type II Codebook

For 4 antenna ports {3000, 3001, …, 3003}, 8 antenna ports {3000, 3001, …, 3007}, 12 antenna ports {3000, 3001, …, 3011}, 16 antenna ports {3000, 3001, …, 3015}, 24 antenna ports {3000, 3001, …, 3023}, and 32 antenna ports {3000, 3001, …, 3031}, and UE configured with higher layer parameter *codebookType* set to ' typeII-r16'

- The values of N_1 and N_2 are configured with the higher layer parameter *n1-n2-codebookSubsetRestriction-r16*. The supported configurations of (N_1, N_2) for a given number of CSI-RS ports and the corresponding values of (O_1, O_2) are given in Table 5.2.2.2.1-2. The number of CSI-RS ports, $P_{\text{CSI-RS}}$, is $2N_1N_2$.
- The values of L, β and p_υ are determined by the higher layer parameter *paramCombination-r16*, where the mapping is given in Table 5.2.2.2.5-1.
  - The UE is not expected to be configured with *paramCombination-r16* equal to
    - 3, 4, 5, 6, 7, or 8 when $P_{\text{CSI-RS}}=4$,
    - 7 or 8 when $P_{\text{CSI-RS}}<32$
    - 7 or 8 when higher layer parameter t*ypeII-RI-Restriction-r16* is configured with $r_i=1$ for any $i>1$.
    - 7 or 8 when $R=2$.
- The parameter R is configured with the higher-layer parameter *numberOfPMI-SubbandsPerCQI-Subband*. This parameter controls the total number of precoding matrices N_3 indicated by the PMI as a function of the number of configured subbands in *csi-ReportingBand*, the subband size configured by the higher-level parameter *subbandSize* and of the total number of PRBs in the bandwidth part according to Table 5.2.1.4-2, as follows:
  - When $R=1$:
    - One precoding matrix is indicated by the PMI for each subband in *csi-ReportingBand*.

- When $R = 2$:
  - For each subband in *csi-ReportingBand* that is not the first or last subband of a BWP, two precoding matrices are indicated by the PMI: the first precoding matrix corresponds to the first $N_{PRB}^{SB}/2$ PRBs of the subband and the second precoding matrix corresponds to the last $N_{PRB}^{SB}/2$ PRBs of the subband.
  - For each subband in *csi-ReportingBand* that is the first or last subband of a BWP
    - If $\left(N_{BWP,i}^{start} \bmod N_{PRB}^{SB}\right) \geq \frac{N_{PRB}^{SB}}{2}$, one precoding matrix is indicated by the PMI corresponding to the first subband. If $\left(N_{BWP,i}^{start} \bmod N_{PRB}^{SB}\right) < \frac{N_{PRB}^{SB}}{2}$, two precoding matrices are indicated by the PMI corresponding to the first subband: the first precoding matrix corresponds to the first $\frac{N_{PRB}^{SB}}{2} - \left(N_{BWP,i}^{start} \bmod N_{PRB}^{SB}\right)$ PRBs of the first subband and the second precoding matrix corresponds to the last $\frac{N_{PRB}^{SB}}{2}$ PRBs of the first subband.
    - If $1 + \left(N_{BWP,i}^{start} + N_{BWP,i}^{size} - 1\right) \bmod N_{PRB}^{SB} \leq \frac{N_{PRB}^{SB}}{2}$, one precoding matrix is indicated by the PMI corresponding to the last subband. If $1 + \left(N_{BWP,i}^{start} + N_{BWP,i}^{size} - 1\right) \bmod N_{PRB}^{SB} > \frac{N_{PRB}^{SB}}{2}$, two precoding matrices are indicated by the PMI corresponding to the last subband: the first precoding matrix corresponds to the first $\frac{N_{PRB}^{SB}}{2}$ PRBs of the last subband and the second precoding matrix corresponds to the last $1 + \left(N_{BWP,i}^{start} + N_{BWP,i}^{size} - 1\right) \bmod N_{PRB}^{SB} - \frac{N_{PRB}^{SB}}{2}$ PRBs of the last subband.

Table 5.2.2.2.5-1: Codebook parameter configurations for L, β and p_υ

paramCombination-r16	L	p_υ		β
		$\upsilon \in \{1,2\}$	$\upsilon \in \{3,4\}$	
1	2	¼	1/8	¼
2	2	¼	1/8	½
3	4	¼	1/8	¼
4	4	¼	1/8	½
5	4	¼	¼	¾
6	4	½	¼	½
7	6	¼	-	½
8	6	¼	-	¾

- The UE shall report the RI value υ according to the configured higher layer parameter *typeII-RI-Restriction-r16*. The UE shall not report $\upsilon > 4$.

The PMI value corresponds to the codebook indices of i_1 and i_2 where

$$i_1 = \begin{cases} \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,5} & i_{1,6,1} & i_{1,7,1} & i_{1,8,1} \end{bmatrix} \\ \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,5} & i_{1,6,1} & i_{1,7,1} & i_{1,8,1} & i_{1,6,2} & i_{1,7,2} & i_{1,8,2} \end{bmatrix} \\ \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,5} & i_{1,6,1} & i_{1,7,1} & i_{1,8,1} & i_{1,6,2} & i_{1,7,2} & i_{1,8,2} & i_{1,6,3} & i_{1,7,3} & i_{1,8,3} \end{bmatrix} \\ \begin{bmatrix} i_{1,1} & i_{1,2} & i_{1,5} & i_{1,6,1} & i_{1,7,1} & i_{1,8,1} & i_{1,6,2} & i_{1,7,2} & i_{1,8,2} & i_{1,6,3} & i_{1,7,3} & i_{1,8,3} & i_{1,6,4} & i_{1,7,4} & i_{1,8,4} \end{bmatrix} \end{cases}$$

$$i_2 = \begin{cases} \begin{bmatrix} i_{2,3,1} & i_{2,4,1} & i_{2,5,1} \end{bmatrix} \\ \begin{bmatrix} i_{2,3,1} & i_{2,4,1} & i_{2,5,1} & i_{2,3,2} & i_{2,4,2} & i_{2,5,2} \end{bmatrix} \\ \begin{bmatrix} i_{2,3,1} & i_{2,4,1} & i_{2,5,1} & i_{2,3,2} & i_{2,4,2} & i_{2,5,2} & i_{2,3,3} & i_{2,4,3} & i_{2,5,3} \end{bmatrix} \\ \begin{bmatrix} i_{2,3,1} & i_{2,4,1} & i_{2,5,1} & i_{2,3,2} & i_{2,4,2} & i_{2,5,2} & i_{2,3,3} & i_{2,4,3} & i_{2,5,3} & i_{2,3,4} & i_{2,4,4} & i_{2,5,4} \end{bmatrix} \end{cases}$$

The precoding matrices indicated by the PMI are determined from $L + M_\upsilon$ vectors.

L vectors, $v_{m_1^{(i)},m_2^{(i)}}, i = 0,1,\ldots,L-1$, are indentified by the indices q_1, q_2, n_1, n_2, indicated by $i_{1,1}$, $i_{1,2}$, obtained as in 5.2.2.2.3, where the values of $C(x,y)$ are given in Table 5.2.2.2.5-4.

$M_\upsilon = \left\lceil p_\upsilon \frac{N_3}{R} \right\rceil$ vectors, $\left[y_{0,l}^{(f)}, y_{1,l}^{(f)}, \ldots, y_{N_3-1,l}^{(f)}\right]^T$, $f = 0,1,\ldots,M_\upsilon - 1$, are identified by $M_{initial}$ (for $N_3 > 19$) and $n_{3,l}$ $(l = 1,\ldots,\upsilon)$ where

$$M_{initial} \in \{-2M_\upsilon + 1, -2M_\upsilon + 2, \ldots, 0\}$$

$$n_{3,l} = \left[n_{3,l}^{(0)}, \ldots, n_{3,l}^{(M_\upsilon - 1)}\right]$$

$$n_{3,l}^{(f)} \in \{0,1,\ldots,N_3 - 1\}$$

which are indicated by means of the indices $i_{1,5}$ (for $N_3 > 19$) and $i_{1,6,l}$ (for $M_\upsilon > 1$ and $l = 1,\ldots,\upsilon$), where

$$i_{1,5} \in \{0,1,\ldots,2M_\upsilon - 1\}$$

$$i_{1,6,l} \in \begin{cases} \left\{0,1,\ldots,\binom{N_3 - 1}{M_\upsilon - 1} - 1\right\} & N_3 \leq 19 \\ \left\{0,1,\ldots,\binom{2M_\upsilon - 1}{M_\upsilon - 1} - 1\right\} & N_3 > 19 \end{cases}$$

The amplitude coefficient indicators $i_{2,3,l}$ and $i_{2,4,l}$ are

$$i_{2,3,l} = \left[k_{l,0}^{(1)} \quad k_{l,1}^{(1)}\right]$$

$$i_{2,4,l} = \left[k_{l,0}^{(2)} \ldots k_{l,M_\upsilon - 1}^{(2)}\right]$$

$$k_{l,f}^{(2)} = \left[k_{l,0,f}^{(2)} \ldots k_{l,2L-1,f}^{(2)}\right]$$

$$k_{l,p}^{(1)} \in \{1,\ldots,15\}$$

$$k_{l,i,f}^{(2)} \in \{0,\ldots,7\}$$

for $l = 1,\ldots,\upsilon$.

The phase coefficient indicator $i_{2,5,l}$ is

$$i_{2,5,l} = \left[c_{l,0} \ldots c_{l,M_\upsilon - 1}\right]$$

$$c_{l,f} = \left[c_{l,0,f} \ldots c_{l,2L-1,f}\right]$$

$$c_{l,i,f} \in \{0,\ldots,15\}$$

for $l = 1,\ldots,\upsilon$.

Let $K_0 = \lceil \beta 2LM_1 \rceil$. The bitmap whose nonzero bits identify which coefficients in $i_{2,4,l}$ and $i_{2,5,l}$ are reported, is indicated by $i_{1,7,l}$

$$i_{1,7,l} = \left[k_{l,0}^{(3)} \ldots k_{l,M_\upsilon - 1}^{(3)}\right]$$

$$k_{l,f}^{(3)} = \left[k_{l,0,f}^{(3)} \ldots k_{l,2L-1,f}^{(3)}\right]$$

$$k_{l,i,f}^{(3)} \in \{0,1\}$$

for $l = 1,\ldots,\upsilon$, such that $K_l^{NZ} = \sum_{i=0}^{2L-1} \sum_{f=0}^{M_\upsilon - 1} k_{l,i,f}^{(3)} \leq K_0$ is the number of nonzero coefficients for layer $l = 1,\ldots,\upsilon$ and $K^{NZ} = \sum_{l=1}^{\upsilon} K_l^{NZ} \leq 2K_0$ is the total number of nonzero coefficients.

The indices of $i_{2,4,l}$, $i_{2,5,l}$ and $i_{1,7,l}$ are associated to the M_υ codebook indices in $n_{3,l}$.

The mapping from $k_{l,p}^{(1)}$ to the amplitude coefficient $p_{l,p}^{(1)}$ is given in Table 5.2.2.2.5-2 and the mapping from $k_{l,i,f}^{(2)}$ to the amplitude coefficient $p_{l,i,f}^{(2)}$ is given in Table 5.2.2.2.5-3. The amplitude coefficients are represented by

$$p_l^{(1)} = \left[p_{l,0}^{(1)} \quad p_{l,1}^{(1)}\right]$$

$$p_l^{(2)} = \left[p_{l,0}^{(2)} \dots p_{l,M_\upsilon-1}^{(2)}\right]$$

$$p_{l,f}^{(2)} = \left[p_{l,0,f}^{(2)} \dots p_{l,2L-1,f}^{(2)}\right]$$

for $l = 1, \dots, \upsilon$.

Let $f_l^* \in \{0,1,\dots,M_\upsilon - 1\}$ be the index of $i_{2,4,l}$ and $i_l^* \in \{0,1,\dots,2L-1\}$ be the index of $k_{l,f_l^*}^{(2)}$ which identify the strongest coefficient of layer l, i.e., the element $k_{l,i_l^*,f_l^*}^{(2)}$ of $i_{2,4,l}$, for $l = 1, \dots, \upsilon$. The codebook indices of $n_{3,l}$ are remapped with respect to $n_{3,l}^{(f_l^*)}$ as $n_{3,l}^{(f)} = \left(n_{3,l}^{(f)} - n_{3,l}^{(f_l^*)}\right) \bmod N_3$, such that $n_{3,l}^{(f_l^*)} = 0$, after remapping. The index f is remapped with respect to f_l^* as $f = (f - f_l^*) \bmod M_\upsilon$, such that the index of the strongest coefficient is $f_l^* = 0$ ($l = 1, \dots, \upsilon$), after remapping. The indices of $i_{2,4,l}$, $i_{2,5,l}$ and $i_{1,7,l}$ indicate amplitude coefficients, phase coefficients and bitmap after remapping.

The strongest coefficient of layer l is identified by $i_{1,8,l} \in \{0,1,\dots,2L-1\}$, which is obtained as follows

$$i_{1,8,l} = \begin{cases} \sum_{i=0}^{i_1^*} k_{1,i,0}^{(3)} - 1 & \upsilon = 1 \\ i_l^* & 1 < \upsilon \le 4 \end{cases}$$

for $l = 1, \dots, \upsilon$.

Table 5.2.2.2.5-2: Mapping of elements of $i_{2,3,l}$: $k_{l,p}^{(1)}$ to $p_{l,p}^{(1)}$

$k_{l,p}^{(1)}$	$p_{l,p}^{(1)}$	$k_{l,p}^{(1)}$	$p_{l,p}^{(1)}$	$k_{l,p}^{(1)}$	$p_{l,p}^{(1)}$	$k_{l,p}^{(1)}$	$p_{l,p}^{(1)}$
0	Reserved	4	$\left(\frac{1}{2048}\right)^{1/4}$	8	$\left(\frac{1}{128}\right)^{1/4}$	12	$\left(\frac{1}{8}\right)^{1/4}$
1	$\frac{1}{\sqrt{128}}$	5	$\frac{1}{2\sqrt{8}}$	9	$\frac{1}{\sqrt{8}}$	13	$\frac{1}{\sqrt{2}}$
2	$\left(\frac{1}{8192}\right)^{1/4}$	6	$\left(\frac{1}{512}\right)^{1/4}$	10	$\left(\frac{1}{32}\right)^{1/4}$	14	$\left(\frac{1}{2}\right)^{1/4}$
3	$\frac{1}{8}$	7	$\frac{1}{4}$	11	$\frac{1}{2}$	15	1

The amplitude and phase coefficient indicators are reported as follows:

- $k_{l,\left\lfloor\frac{i_l^*}{L}\right\rfloor}^{(1)} = 15$, $k_{l,i_l^*,0}^{(2)} = 7$, $k_{l,i_l^*,0}^{(3)} = 1$ and $c_{l,i_l^*,0} = 0$ $(l = 1, \dots, \upsilon)$. The indicators $k_{l,\left\lfloor\frac{i_l^*}{L}\right\rfloor}^{(1)}$, $k_{l,i_l^*,0}^{(2)}$ and $c_{l,i_l^*,0}$ are not reported for $l = 1, \dots, \upsilon$.
- The indicator $k_{l,\left(\left\lfloor\frac{i_l^*}{L}\right\rfloor+1\right) \bmod 2}^{(1)}$ is reported for $l = 1, \dots, \upsilon$.
- The $K^{NZ} - \upsilon$ indicators $k_{l,i,f}^{(2)}$ for which $k_{l,i,f}^{(3)} = 1$, $i \ne i_l^*, f \ne 0$ are reported.
- The $K^{NZ} - \upsilon$ indicators $c_{l,i,f}$ for which $k_{l,i,f}^{(3)} = 1$, $i \ne i_l^*, f \ne 0$ are reported.
- The remaining $2L \cdot M_\nu \cdot \nu - K^{NZ}$ indicators $k_{l,i,f}^{(2)}$ are not reported.

- The remaining $2L \cdot M_v \cdot v - K^{NZ}$ indicators $c_{l,i,f}$ are not reported.

Table 5.2.2.2.5-3: Mapping of elements of $i_{2,4,l}$: $k_{l,i,f}^{(2)}$ to $p_{l,i,f}^{(2)}$

$k_{l,i,f}^{(2)}$	$p_{l,i,f}^{(2)}$
0	$\frac{1}{8\sqrt{2}}$
1	$\frac{1}{8}$
2	$\frac{1}{4\sqrt{2}}$
3	$\frac{1}{4}$
4	$\frac{1}{2\sqrt{2}}$
5	$\frac{1}{2}$
6	$\frac{1}{\sqrt{2}}$
7	1

The elements of n_1 and n_2 are found from $i_{1,2}$ using the algorithm described in 5.2.2.2.3, where the values of $C(x, y)$ are given in Table 5.2.2.2.5-4.

For $N_3 > 19$, $M_{initial}$ is identified by $i_{1,5}$.

For all values of N_3, $n_{3,l}^{(0)} = 0$ for $l = 1, \ldots, v$. If $M_v > 1$, the nonzero elements of $n_{3,l}$, identified by $n_{3,l}^{(1)}, \ldots, n_{3,l}^{(M_v-1)}$, are found from $i_{1,6,l}$ $(l = 1, \ldots, v)$, for $N_3 \leq 19$, and from $i_{1,6,l}$ $(l = 1, \ldots, v)$ and $M_{initial}$, for $N_3 > 19$, using $C(x, y)$ as defined in Table 5.2.2.2.5-4 and the algorithm:

$s_0 = 0$

for $f = 1, \ldots, M_v - 1$

Find the largest $x^* \in \{M_v - 1 - f, \ldots, N_3 - 1 - f\}$ in Table 5.2.2.2.5-4 such that

$i_{1,6,l} - s_{f-1} \geq C(x^*, M_v - f)$

$e_f = C(x^*, M_v - f)$

$s_f = s_{f-1} + e_f$

if $N_3 \leq 19$

$n_{3,l}^{(f)} = N_3 - 1 - x^*$

else

$n_l^{(f)} = 2M_v - 1 - x^*$

if $n_l^{(f)} \leq M_{initial} + 2M_v - 1$

$n_{3,l}^{(f)} = n_l^{(f)}$

else

$n_{3,l}^{(f)} = n_l^{(f)} + (N_3 - 2M_\upsilon)$

end if

end if

Table 5.2.2.2.5-4: Combinatorial coefficients $C(x, y)$

x \ y	1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0
2	2	1	0	0	0	0	0	0	0
3	3	3	1	0	0	0	0	0	0
4	4	6	4	1	0	0	0	0	0
5	5	10	10	5	1	0	0	0	0
6	6	15	20	15	6	1	0	0	0
7	7	21	35	35	21	7	1	0	0
8	8	28	56	70	56	28	8	1	0
9	9	36	84	126	126	84	36	9	1
10	10	45	120	210	252	210	120	45	10
11	11	55	165	330	462	462	330	165	55
12	12	66	220	495	792	924	792	495	220
13	13	78	286	715	1287	1716	1716	1287	715
14	14	91	364	1001	2002	3003	3432	3003	2002
15	15	105	455	1365	3003	5005	6435	6435	5005
16	16	120	560	1820	4368	8008	11440	12870	11440
17	17	136	680	2380	6188	12376	19448	24310	24310
18	18	153	816	3060	8568	18564	31824	43758	48620

When $n_{3,l}$ and $M_{initial}$ are known, $i_{1,5}$ and $i_{1,6,l}$ $(l = 1, \dots, \upsilon)$ are found as follows:

- If $N_3 \leq 19$, $i_{1,5} = 0$ and is not reported. If $M_\nu = 1$, $i_{1,6,l} = 0$, for $l = 1, \dots, \nu$, and is not reported. If $M_\nu > 1$, $i_{1,6,l} = \sum_{f=1}^{M_\upsilon - 1} C\left(N_3 - 1 - n_{3,l}^{(f)}, M_\upsilon - f\right)$, where $C(x, y)$ is given in Table 5.2.2.2.5-4 and where the indices $f = 1, \dots, M_\upsilon - 1$ are assigned such that $n_{3,l}^{(f)}$ increases as f increases.
- If $N_3 > 19$, $M_{initial}$ is indicated by $i_{1,5}$, which is reported and given by

$$i_{1,5} = \begin{cases} M_{initial} & M_{initial} = 0 \\ M_{initial} + 2M_\upsilon & M_{initial} < 0 \end{cases}$$

Only the nonzero indices $n_{3,l}^{(f)} \in IntS$, where $IntS = \{(M_{initial} + i) \mod N_3, i = 0,1, \dots, 2M_\upsilon - 1\}$, are reported, where the indices $f = 1, \dots, M_\upsilon - 1$ are assigned such that $n_{3,l}^{(f)}$ increases as f increases. Let

$$n_l^{(f)} = \begin{cases} n_{3,l}^{(f)} & n_{3,l}^{(f)} \leq M_{initial} + 2M_\upsilon - 1 \\ n_{3,l}^{(f)} - (N_3 - 2M_\upsilon) & n_{3,l}^{(f)} > M_{initial} + N_3 - 1 \end{cases},$$

then $i_{1,6,l} = \sum_{f=1}^{M_\upsilon - 1} C\left(2M_\upsilon - 1 - n_l^{(f)}, M_\upsilon - f\right)$, where $C(x, y)$ is given in Table 5.2.2.2.5-4.

The codebooks for 1-4 layers are given in Table 5.2.2.2.5-5, where $m_1^{(i)}$, $m_2^{(i)}$, for $i = 0,1,\ldots,L-1$, $v_{m_1^{(i)},m_2^{(i)}}$ are obtained as in clause 5.2.2.2.3, and the quantities $\varphi_{l,i,f}$ and $y_{t,l}$ are given by

$$\varphi_{l,i,f} = e^{j\frac{2\pi c_{l,i,f}}{16}}$$

$$y_{t,l} = \left[y_{t,l}^{(0)} \quad y_{t,l}^{(1)} \quad \ldots \quad y_{t,l}^{(M_v-1)}\right]$$

where $t = \{0,1,\ldots,N_3-1\}$, is the index associated with the precoding matrix, $l = \{1,\ldots,v\}$, and with

$$y_{t,l}^{(f)} = e^{j\frac{2\pi t n_{3,l}^{(f)}}{N_3}}$$

for $f = 0,1,\ldots,M_v-1$.

Table 5.2.2.2.5-5: Codebook for 1-layer. 2-layer, 3-layer and 4-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

Layers	
$v=1$	$W^{(1)}_{q_1,q_2,n_1,n_2,n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t} = W^1_{q_1,q_2,n_1,n_2,n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t}$
$v=2$	$W^{(2)}_{q_1,q_2,n_1,n_2,n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},t} = \frac{1}{\sqrt{2}}\left[W^1_{q_1,q_2,n_1,n_2,n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t} \quad W^2_{q_1,q_2,n_1,n_2,n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},t}\right]$
$v=3$	$W^{(3)}_{q_1,q_2,n_1,n_2,n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},n_{3,3},p_3^{(1)},p_3^{(2)},i_{2,5,3},t} = \frac{1}{\sqrt{3}}\left[W^1_{q_1,q_2,n_1,n_2,n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t} \quad W^2_{q_1,q_2,n_1,n_2,n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},t} \quad W^3_{q_1,q_2,n_1,n_2,n_{3,3},p_3^{(1)},p_3^{(2)},i_{2,5,3},t}\right]$
$v=4$	$W^{(4)}_{q_1,q_2,n_1,n_2,n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},n_{3,3},p_3^{(1)},p_3^{(2)},i_{2,5,3},n_{3,4},p_4^{(1)},p_4^{(2)},i_{2,5,4},t} = \frac{1}{2}\left[W^1_{q_1,q_2,n_1,n_2,n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t} \quad W^2_{q_1,q_2,n_1,n_2,n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},t} \quad W^3_{q_1,q_2,n_1,n_2,n_{3,3},p_3^{(1)},p_3^{(2)},i_{2,5,3},t} \quad W^4_{q_1,q_2,n_1,n_2,n_{3,4},p_4^{(1)},p_4^{(2)},i_{2,5,4},t}\right]$
Where $W^l_{q_1,q_2,n_1,n_2,n_3,p_l^{(1)},p_l^{(2)},i_{2,5,l},t} = \frac{1}{\sqrt{N_1N_2\gamma_{t,l}}}\begin{bmatrix}\sum_{i=0}^{L-1} v_{m_1^{(i)},m_2^{(i)}} p_{l,0}^{(1)} \sum_{f=0}^{M_v-1} y_{t,l}^{(f)} p_{l,i,f}^{(2)}\varphi_{l,i,f} \\ \sum_{i=0}^{L-1} v_{m_1^{(i)},m_2^{(i)}} p_{l,1}^{(1)} \sum_{f=0}^{M_v-1} y_{t,l}^{(f)} p_{l,i+L,f}^{(2)}\varphi_{l,i+L,f}\end{bmatrix}, l=1,2,3,4,$ $\gamma_{t,l} = \sum_{i=0}^{2L-1}\left(p_{l,\lfloor\frac{i}{L}\rfloor}^{(1)}\right)^2\left\lvert\sum_{f=0}^{M_v-1} y_{t,l}^{(f)} p_{l,i,f}^{(2)}\varphi_{l,i,f}\right\rvert^2$ and the mappings from i_1 to q_1, q_2, n_1, n_2, $n_{3,1}$, $n_{3,2}$, $n_{3,3}$, $n_{3,4}$, and from i_2 to $i_{2,5,1}$, $i_{2,5,2}$, $i_{2,5,3}$, $i_{2,5,4}$, $p_1^{(1)}$, $p_2^{(1)}$, $p_3^{(1)}$ and $p_4^{(1)}$, $p_1^{(2)}$, $p_2^{(2)}$, $p_3^{(2)}$ and $p_4^{(2)}$ are as described above, including the ranges of the constituent indices of i_1 and i_2.	

For coefficients with $k_{l,i,f}^{(3)} = 0$, amplitude and phase are set to zero, i.e., $p_{l,i,f}^{(2)} = 0$ and $\varphi_{l,i,f} = 0$.

The bitmap parameter *typeII-RI-Restriction-r16* forms the bit sequence r_3, r_2, r_1, r_0 where r_0 is the LSB and r_3 is the MSB. When r_i is zero, $i \in \{0,1,\ldots,3\}$, PMI and RI reporting are not allowed to correspond to any precoder associated with $v = i+1$ layers.

The bitmap parameter *n1-n2-codebookSubsetRestriction-r16* forms the bit sequence $B = B_1B_2$ and configures the vector group indices $g^{(k)}$ as in clause 5.2.2.2.3. Bits $b_2^{(k,2(N_1x_2+x_1)+1)}b_2^{(k,2(N_1x_2+x_1))}$ indicate the maximum allowed average amplitude, γ_{i+pL} $(p = 0,1)$, with $i \in \{0,1,\ldots,L-1\}$, of the coefficients associated with the vector in group $g^{(k)}$ indexed by x_1, x_2, where the maximum amplitudes are given in Table 5.2.2.2.5-6 and the average coefficient amplitude is restricted as follows

$$\sqrt{\frac{1}{\sum_{f=0}^{M_v-1} k_{l,i+pL,f}^{(3)}}\sum_{f=0}^{M_v-1} k_{l,i+pL,f}^{(3)}\left(p_{l,p}^{(1)} p_{l,i+pL,f}^{(2)}\right)^2} \le \gamma_{i+pL}$$

for $l = 1, \ldots, \upsilon$, and $p = 0,1$. A UE that does not report the parameter *softAmpRestriction-r16* = 'supported' in its capability signaling is not expected to be configured with $b_2^{(k,2(N_1x_2+x_1)+1)} b_2^{(k,2(N_1x_2+x_1))} = 01$ or 10.

Table 5.2.2.2.5-6: Maximum allowed average coefficient amplitudes for restricted vectors

Bit $\boldsymbol{b_2^{(k,2(N_1x_2+x_1)+1)} b_2^{(k,2(N_1x_2+x_1))}}$	Maximum Average Coefficient Amplitude $\boldsymbol{\gamma_{i+pL}}$
00	0
01	$\sqrt{1/4}$
10	$\sqrt{1/2}$
11	1

5.2.2.2.6 Enhanced Type II Port Selection Codebook

For 4 antenna ports {3000, 3001, …, 3003}, 8 antenna ports {3000, 3001, …, 3007}, 12 antenna ports {3000, 3001, …, 3011}, 16 antenna ports {3000, 3001, …, 3015}, 24 antenna ports {3000, 3001, …, 3023}, and 32 antenna ports {3000, 3001, …, 3031}, and the UE configured with higher layer parameter *codebookType* set to ' typeII-PortSelection-r16 '

- The number of CSI-RS ports is configured as in Clause 5.2.2.2.4
- The value of d is configured with the higher layer parameter *portSelectionSamplingSize-r16*, where $d \in \{1,2,3,4\}$ and $d \leq L$.
- The values L, β and p_υ are configured as in Clause 5.2.2.2.5, where the supported configurations are given in Table 5.2.2.2.6-1.

Table 5.2.2.2.6-1: Codebook parameter configurations for $\boldsymbol{L}$, $\boldsymbol{\beta}$ and $\boldsymbol{p_\upsilon}$

paramCombination-r16	L	p_υ		β
		$\upsilon \in \{1,2\}$	$\upsilon \in \{3,4\}$	
1	2	¼	1/8	¼
2	2	¼	1/8	½
3	4	¼	1/8	¼
4	4	¼	1/8	½
5	4	¼	¼	¾
6	4	½	¼	½

- The UE shall report the RI value υ according to the configured higher layer parameter *typeII-PortSelectionRI-Restriction-r16*. The UE shall not report $\upsilon > 4$.
- The values of R is configured as in Clause 5.2.2.2.5.

The UE is also configured with the higher layer bitmap parameter *typeII-PortSelectionRI-Restriction-r16*, which forms the bit sequence r_3, r_2, r_1, r_0, where r_0 is the LSB and r_3 is the MSB. When r_i is zero, $i \in \{0,1,\ldots,3\}$, PMI and RI reporting are not allowed to correspond to any precoder associated with $\upsilon = i + 1$ layers.

The PMI value corresponds to the codebook indices i_1 and i_2 where

$$i_1 = \begin{cases} [i_{1,1} \quad i_{1,5} \quad i_{1,6,1} \quad i_{1,7,1} \quad i_{1,8,1}] \\ [i_{1,1} \quad i_{1,5} \quad i_{1,6,1} \quad i_{1,7,1} \quad i_{1,8,1} \quad i_{1,6,2} \quad i_{1,7,2} \quad i_{1,8,2}] \\ [i_{1,1} \quad i_{1,5} \quad i_{1,6,1} \quad i_{1,7,1} \quad i_{1,8,1} \quad i_{1,6,2} \quad i_{1,7,2} \quad i_{1,8,2} \quad i_{1,6,3} \quad i_{1,7,3} \quad i_{1,8,3}] \\ [i_{1,1} \quad i_{1,5} \quad i_{1,6,1} \quad i_{1,7,1} \quad i_{1,8,1} \quad i_{1,6,2} \quad i_{1,7,2} \quad i_{1,8,2} \quad i_{1,6,3} \quad i_{1,7,3} \quad i_{1,8,3} \quad i_{1,6,4} \quad i_{1,7,4} \quad i_{1,8,4}] \end{cases}$$

$$i_2 = \begin{cases} [i_{2,3,1} \quad i_{2,4,1} \quad i_{2,5,1}] \\ [i_{2,3,1} \quad i_{2,4,1} \quad i_{2,5,1} \quad i_{2,3,2} \quad i_{2,4,2} \quad i_{2,5,2}] \\ [i_{2,3,1} \quad i_{2,4,1} \quad i_{2,5,1} \quad i_{2,3,2} \quad i_{2,4,2} \quad i_{2,5,2} \quad i_{2,3,3} \quad i_{2,4,3} \quad i_{2,5,3}] \\ [i_{2,3,1} \quad i_{2,4,1} \quad i_{2,5,1} \quad i_{2,3,2} \quad i_{2,4,2} \quad i_{2,5,2} \quad i_{2,3,3} \quad i_{2,4,3} \quad i_{2,5,3} \quad i_{2,3,4} \quad i_{2,4,4} \quad i_{2,5,4}] \end{cases}$$

The $2L$ antenna ports are selected by the index $i_{1,1}$ as in clause 5.2.2.2.4.

Parameters N_3, M_υ, $M_{initial}$ (for $N_3 > 19$) and K_0 are defined as in clause 5.2.2.2.5.

For layer l, $l = 1, \ldots, \upsilon$, the strongest coefficient $i_{1,8,l}$, the amplitude coefficient indicators $i_{2,3,l}$ and $i_{2,4,l}$, the phase coefficient indicator $i_{2,5,l}$ and the bitmap indicator $i_{1,7,l}$ are defined and indicated as in clause 5.2.2.2.5, where the mapping from $k_{l,p}^{(1)}$ to the amplitude coefficient $p_{l,p}^{(1)}$ is given in Table 5.2.2.2.5-2 and the mapping from $k_{l,i,f}^{(2)}$ to the amplitude coefficient $p_{l,i,f}^{(2)}$ is given inTable 5.2.2.2.5-3.

The number of nonzero coefficients for layer l, K_l^{NZ}, and the total number of nonzero coefficients K^{NZ} are defined as in Clause 5.2.2.2.5.

The amplitude coefficients $p_l^{(1)}$ and $p_l^{(2)}$ $(l = 1, \ldots, \upsilon\ )$ are represented as in clause 5.2.2.2.5.

The amplitude and phase coefficient indicators are reported as in clause 5.2.2.2.5.

Codebook indicators $i_{1,5}$ and $i_{1,6,l}$ $(l = 1, \ldots, \upsilon)$ are found as in clause 5.2.2.2.5.

The codebooks for 1-4 layers are given in Table 5.2.2.2.6-2, where v_m is a $P_{CSI-RS}/2$ -element column vector containing a value of 1 in element $(m \mod P_{CSI-RS}/2\ )$ and zeros elsewhere (where the first element is element 0), and the quantities $\varphi_{l,i,f}$ and $y_{t,l}$ are defined as in clause 5.2.2.2.5.

Table 5.2.2.2.6-2: Codebook for 1-layer. 2-layer, 3-layer and 4-layer CSI reporting using antenna ports 3000 to 2999+$P_{\text{CSI-RS}}$

Layers	

$\upsilon=1$	$W^{(1)}_{i_{1,1},n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t} = W^{1}_{i_{1,1},n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t}$
$\upsilon=2$	$W^{(2)}_{i_{1,1},n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},t} = \frac{1}{\sqrt{2}}\begin{bmatrix} W^{1}_{i_{1,1},n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t} & W^{2}_{i_{1,1},n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},t}\end{bmatrix}$
$\upsilon=3$	$W^{(3)}_{i_{1,1},n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},n_{3,3},p_3^{(1)},p_3^{(2)},i_{2,5,3},t} = \frac{1}{\sqrt{3}}\begin{bmatrix} W^{1}_{i_{1,1},n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t} & W^{2}_{i_{1,1},n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},t} & W^{3}_{i_{1,1},n_{3,3},p_3^{(1)},p_3^{(2)},i_{2,5,3},t}\end{bmatrix}$
$\upsilon=4$	$W^{(4)}_{i_{1,1},n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},n_{3,3},p_3^{(1)},p_3^{(2)},i_{2,5,3},n_{3,4},p_4^{(1)},p_4^{(2)},i_{2,5,4},t} = \frac{1}{2}\begin{bmatrix} W^{1}_{i_{1,1},n_{3,1},p_1^{(1)},p_1^{(2)},i_{2,5,1},t} & W^{2}_{i_{1,1},n_{3,2},p_2^{(1)},p_2^{(2)},i_{2,5,2},t} & W^{3}_{i_{1,1},n_{3,3},p_3^{(1)},p_3^{(2)},i_{2,5,3},t} & W^{4}_{i_{1,1},n_{3,4},p_4^{(1)},p_4^{(2)},i_{2,5,4},t}\end{bmatrix}$
Where $W^{l}_{i_{1,1},n_3,p_l^{(1)},p_l^{(2)},i_{2,5,l},t} = \frac{1}{\sqrt{\gamma_{t,l}}}\begin{bmatrix} \sum_{i=0}^{L-1} v_{i_{1,1}d+i} p_{l,0}^{(1)} \sum_{f=0}^{M_\upsilon-1} y_{t,l}^{(f)} p_{l,i,f}^{(2)} \varphi_{l,i,f} \\ \sum_{i=0}^{L-1} v_{i_{1,1}d+i} p_{l,1}^{(1)} \sum_{f=0}^{M_\upsilon-1} y_{t,l}^{(f)} p_{l,i+L,f}^{(2)} \varphi_{l,i+L,f} \end{bmatrix}$, $l=1,2,3,4$, $$\gamma_{t,l} = \sum_{i=0}^{2L-1}\left(p^{(1)}_{l,\left\lfloor \frac{i}{L}\right\rfloor}\right)^2 \left\| \sum_{f=0}^{M_\upsilon-1} y_{t,l}^{(f)} p_{l,i,f}^{(2)} \varphi_{l,i,f}\right\|^2$$ and the mappings from i_1 to $i_{1,1}$, $n_{3,1}$, $n_{3,2}$, $n_{3,3}$, $n_{3,4}$, and from i_2 to $i_{2,5,1}$, $i_{2,5,2}$, $i_{2,5,3}$, $i_{2,5,4}$, $p_1^{(1)}$, $p_2^{(1)}$, $p_3^{(1)}$and $p_4^{(1)}$, $p_1^{(2)}$, $p_2^{(2)}$, $p_3^{(2)}$ and $p_4^{(2)}$ are as described above, including the ranges of the constituent indices of i_1 and i_2.	

For coefficients with $k_{l,i,f}^{(3)} = 0$, amplitude and phase are set to zero, i.e., $p_{l,i,f}^{(2)} = 0$ and $\varphi_{l,i,f} = 0$.

5.2.2.3 Reference signal (CSI-RS)

5.2.2.3.1 NZP CSI-RS

The UE can be configured with one or more NZP CSI-RS resource set configuration(s) as indicated by the higher layer parameters *CSI-ResourceConfig*, and *NZP-CSI-RS-ResourceSet*. Each NZP CSI-RS resource set consists of $K\geq1$ NZP CSI-RS resource(s).

The following parameters for which the UE shall assume non-zero transmission power for CSI-RS resource are configured via the higher layer parameter *NZP-CSI-RS-Resource, CSI-ResourceConfig* and *NZP-CSI-RS-ResourceSet* for each CSI-RS resource configuration:

- *nzp-CSI-RS-ResourceId* determines CSI-RS resource configuration identity.
- *periodicityAndOffset* defines the CSI-RS periodicity and slot offset for periodic/semi-persistent CSI-RS. All the CSI-RS resources within one set are configured with the same periodicity, while the slot offset can be same or different for different CSI-RS resources.
- *resourceMapping* defines the number of ports, CDM-type, and OFDM symbol and subcarrier occupancy of the CSI-RS resource within a slot that are given in Clause 7.4.1.5 of [4, TS 38.211].
- *nrofPorts* in *resourceMapping* defines the number of CSI-RS ports, where the allowable values are given in Clause 7.4.1.5 of [4, TS 38.211].
- *density* in *resourceMapping* defines CSI-RS frequency density of each CSI-RS port per PRB, and CSI-RS PRB offset in case of the density value of 1/2, where the allowable values are given in Clause 7.4.1.5 of [4, TS 38.211]. For density 1/2, the odd/even PRB allocation indicated in *density* is with respect to the common resource block grid.
- *cdm-Type* in *resourceMapping* defines CDM values and pattern, where the allowable values are given in Clause 7.4.1.5 of [4, TS 38.211].
- *powerControlOffset*: which is the assumed ratio of PDSCH EPRE to NZP CSI-RS EPRE when UE derives CSI feedback and takes values in the range of [-8, 15] dB with 1 dB step size.
- *powerControlOffsetSS*: which is the assumed ratio of NZP CSI-RS EPRE to SS/PBCH block EPRE.
- *scramblingID* defines scrambling ID of CSI-RS with length of 10 bits.

- *BWP-Id* in *CSI-ResourceConfig* defines which bandwidth part the configured CSI-RS is located in.

- *repetition* in *NZP-CSI-RS-ResourceSet* is associated with a CSI-RS resource set and defines whether UE can assume the CSI-RS resources within the NZP CSI-RS Resource Set are transmitted with the same downlink spatial domain transmission filter or not as described in Clause 5.1.6.1.2. and can be configured only when the higher layer parameter *reportQuantity* associated with all the reporting settings linked with the CSI-RS resource set is set to 'cri-RSRP', 'cri-SINR' or 'none'.

- *qcl-InfoPeriodicCSI-RS* contains a reference to a *TCI-State* indicating QCL source RS(s) and QCL type(s). If the *TCI-State* is configured with a reference to an RS configured with *qcl-Type* set to 'typeD' association, that RS may be an SS/PBCH block located in the same or different CC/DL BWP or a CSI-RS resource configured as periodic located in the same or different CC/DL BWP.

- *trs-Info* in *NZP-CSI-RS-ResourceSet* is associated with a CSI-RS resource set and for which the UE can assume that the antenna port with the same port index of the configured NZP CSI-RS resources in the *NZP-CSI-RS-ResourceSet* is the same as described in Clause 5.1.6.1.1 and can be configured when reporting setting is not configured or when the higher layer parameter *reportQuantity* associated with all the reporting settings linked with the CSI-RS resource set is set to 'none'.

All CSI-RS resources within one set are configured with same *density* and same *nrofPorts*, except for the NZP CSI-RS resources used for interference measurement.

The UE expects that all the CSI-RS resources of a resource set are configured with the same starting RB and number of RBs and the same *cdm-type*.

The bandwidth and initial common resource block (CRB) index of a CSI-RS resource within a BWP, as defined in Clause 7.4.1.5 of [4, TS 38.211], are determined based on the higher layer parameters *nrofRBs* and *startingRB*, respectively, within the CSI-FrequencyOccupation IE configured by the higher layer parameter *freqBand* within the *CSI-RS-ResourceMapping* IE. Both *nrofRBs* and *startingRB* are configured as integer multiples of 4 RBs, and the reference point for *startingRB* is CRB 0 on the common resource block grid. If $startingRB < N_{BWP}^{start}$, the UE shall assume that the initial CRB index of the CSI-RS resource is $N_{initial\ RB} = N_{BWP}^{start}$, otherwise $N_{initial\ RB} = startingRB$. If $nrofRBs > N_{BWP}^{size} + N_{BWP}^{start} - N_{initial\ RB}$, the UE shall assume that the bandwidth of the CSI-RS resource is $N_{CSI-RS}^{BW} = N_{BWP}^{size} + N_{BWP}^{start} - N_{initial\ RB}$, otherwise $N_{CSI-RS}^{BW} = nrofRBs$. In all cases, the UE shall expect that $N_{CSI-RS}^{BW} \geq \min(24, N_{BWP}^{size})$.

5.2.2.4 Channel State Information – Interference Measurement (CSI-IM)

The UE can be configured with one or more CSI-IM resource set configuration(s) as indicated by the higher layer parameter *CSI-IM-ResourceSet*. Each CSI-IM resource set consists of $K\geq 1$ CSI-IM resource(s).

The following parameters are configured via higher layer parameter *CSI-IM-Resource* for each CSI-IM resource configuration:

- *csi-IM-ResourceId* determines CSI-IM resource configuration identity

- *subcarrierLocation-p0* or *subcarrierLocation-p1* defines subcarrier occupancy of the CSI-IM resource within a slot for *csi-IM-ResourceElementPattern* set to 'pattern0' or 'pattern1', respectively.

- *symbolLocation-p0* or *symbolLocation-p1* defines OFDM symbol location of the CSI-IM resource within a slot for *csi-IM-ResourceElementPattern* set to 'pattern0' or 'pattern1', respectively.

- *periodicityAndOffset* defines the CSI-IM periodicity and slot offset for periodic/semi-persistent CSI-IM.

- f*reqBand* includes parameters to enable configuration of frequency-occupancy of CSI-IM

In each of the PRBs configured by f*reqBand,* the UE shall assume each CSI-IM resource is located in,

- resource elements (k_{CSI-IM}, l_{CSI-IM}), $(k_{CSI-IM}, l_{CSI-IM}+1)$, $(k_{CSI-IM}+1, l_{CSI-IM})$ and $(k_{CSI-IM}+1, l_{CSI-IM}+1)$, if *csi-IM-ResourceElementPattern* is set to 'pattern0',

- resource elements (k_{CSI-IM}, l_{CSI-IM}), $(k_{CSI-IM}+1, l_{CSI-IM})$, $(k_{CSI-IM}+2, l_{CSI-IM})$ and $(k_{CSI-IM}+3, l_{CSI-IM})$ if *csi-IM-ResourceElementPattern* is set to 'pattern1', where k_{CSI-IM} and l_{CSI-IM} are the configured frequency-domain location and time-domain location, respectively, given by the higher layer parameters in the above list.

5.2.2.5 CSI reference resource definition

The CSI reference resource for a serving cell is defined as follows:

- In the frequency domain, the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the derived CSI relates.
- In the time domain, the CSI reference resource for a CSI reporting in uplink slot *n'* is defined by a single downlink slot *n*-n_{CSI_ref},
  - where $n = \left\lfloor n' \cdot \frac{2^{\mu_{DL}}}{2^{\mu_{UL}}} \right\rfloor + \left\lfloor \left(\frac{N_{slot,offset,UL}^{CA}}{2^{\mu_{offset,UL}}} - \frac{N_{slot,offset,DL}^{CA}}{2^{\mu_{offset,DL}}} \right) \cdot 2^{\mu_{DL}} \right\rfloor$ and μ_{DL} and μ_{UL} are the subcarrier spacing configurations for DL and UL, respectively, and $N_{\text{slot, offset}}^{\text{CA}}$ and μ_{offset} are determined by higher-layer configured *ca-SlotOffset* for the cells transmitting the uplink and downlink, as defined in clause 4.5 of [4, TS 38.211]
  - where for periodic and semi-persistent CSI reporting
    - if a single CSI-RS/SSB resource is configured for channel measurement n_{CSI_ref} is the smallest value greater than or equal to $4 \cdot 2^{\mu_{DL}}$, such that it corresponds to a valid downlink slot, or
    - if multiple CSI-RS/SSB resources are configured for channel measurement n_{CSI_ref} is the smallest value greater than or equal to $5 \cdot 2^{\mu_{DL}}$, such that it corresponds to a valid downlink slot.
  - where for aperiodic CSI reporting, if the UE is indicated by the DCI to report CSI in the same slot as the CSI request, n_{CSI_ref} is such that the reference resource is in the same valid downlink slot as the corresponding CSI request, otherwise n_{CSI_ref} is the smallest value greater than or equal to $\lfloor Z' / N_{symb}^{slot} \rfloor$, such that slot *n*- n_{CSI_ref} corresponds to a valid downlink slot, where *Z'* corresponds to the delay requirement as defined in Clause 5.4.
  - when periodic or semi-persistent CSI-RS/CSI-IM or SSB is used for channel/interference measurements, the UE is not expected to measure channel/interference on the CSI-RS/CSI-IM/SSB whose last OFDM symbol is received up to *Z'* symbols before transmission time of the first OFDM symbol of the aperiodic CSI reporting.

A slot in a serving cell shall be considered to be a valid downlink slot if:

- it comprises at least one higher layer configured downlink or flexible symbol, and
- it does not fall within a configured measurement gap for that UE

If there is no valid downlink slot for the CSI reference resource corresponding to a CSI Report Setting in a serving cell, CSI reporting is omitted for the serving cell in uplink slot *n'*.

After the CSI report (re)configuration, serving cell activation, BWP change, or activation of SP-CSI, the UE reports a CSI report only after receiving at least one CSI-RS transmission occasion for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than CSI reference resource and drops the report otherwise.

When DRX is configured, the UE reports a CSI report only if receiving at least one CSI-RS transmission occasion for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in DRX Active Time no later than CSI reference resource and drops the report otherwise. When the UE is configured to monitor DCI format 2_6 and if the UE configured by higher layer parameter *ps-TransmitOtherPeriodicCSI* to report CSI with the higher layer parameter *reportConfigType* set to 'periodic' and *reportQuantity* set to quantities other than 'cri-RSRP' and 'ssb-Index-RSRP' when *drx-onDurationTimer* is not started, the UE shall report CSI during the time duration indicated by *drx-onDurationTimer* in *DRX-Config* also outside active time according to the procedure described in Clause 5.2.1.4 if receiving at least one CSI-RS transmission occasion for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement during the time duration indicated by *drx-onDurationTimer* in *DRX-Config* outside DRX active time or in DRX Active Time no later than CSI reference resource and drops the report otherwise. When the UE is configured to monitor DCI format 2_6 and if the UE configured by higher layer parameter *ps-TransmitPeriodicL1-RSRP* to report L1-RSRP with the higher layer parameter *reportConfigType* set to 'periodic' and *reportQuantity* set to 'cri-RSRP' or 'ssb-Index-RSRP' when *drx-onDurationTimer* is not started, the UE shall report L1-RSRP during the time duration indicated by *drx-onDurationTimer* in *DRX-Config* also outside active time according to the procedure described in clause 5.2.1.4 and when *reportQuantity* set to '*cri-RSRP'* if receiving at least one CSI-RS transmission occasion for channel measurement during the time duration indicated by *drx-onDurationTimer* in *DRX-Config* outside DRX active time or in DRX Active Time no later than CSI reference resource and drops the report otherwise.

When deriving CSI feedback, the UE is not expected that a NZP CSI -RS resource for channel measurement overlaps with CSI-IM resource for interference measurement or NZP CSI -RS resource for interference measurement.

If configured to report CQI index, in the CSI reference resource, the UE shall assume the following for the purpose of deriving the CQI index, and if also configured, for deriving PMI and RI:

- The first 2 OFDM symbols are occupied by control signaling.
- The number of PDSCH and DM-RS symbols is equal to 12.
- The same bandwidth part subcarrier spacing configured as for the PDSCH reception
- The bandwidth as configured for the corresponding CQI report.
- The reference resource uses the CP length and subcarrier spacing configured for PDSCH reception
- No resource elements used by primary or secondary synchronization signals or PBCH.
- Redundancy Version 0.
- The ratio of PDSCH EPRE to CSI-RS EPRE is as given in Clause 5.2.2.3.1.
- Assume no REs allocated for NZP CSI-RS and ZP CSI-RS.
- Assume the same number of front-loaded DM-RS symbols as the maximum front-loaded symbols configured by the higher layer parameter *maxLength* in *DMRS-DownlinkConfig.*
- Assume the same number of additional DM-RS symbols as the additional symbols configured by the higher layer parameter *dmrs-AdditionalPosition.*
- Assume the PDSCH symbols are not containing DM-RS.
- Assume PRB bundling size of 2 PRBs.
- The PDSCH transmission scheme where the UE may assume that PDSCH transmission would be performed with up to 8 transmission layers as defined in Clause 7.3.1.4 of [4, TS 38.211]. For CQI calculation, the UE should assume that PDSCH signals on antenna ports in the set [1000,…, 1000+ν-1] for ν layers would result in signals equivalent to corresponding symbols transmitted on antenna ports [3000,…, 3000+*P*-1], as given by

$$\begin{bmatrix} y^{(3000)}(i) \\ \cdots \\ y^{(3000+P-1)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \cdots \\ x^{(\nu-1)}(i) \end{bmatrix}$$

  where $x(i) = \left[x^{(0)}(i)..x^{(\nu-1)}(i)\right]^T$ is a vector of PDSCH symbols from the layer mapping defined in Clause 7.3.1.4 of [4, TS 38.211], $P \in \left[1,2,4,8,12,16,24,32\right]$ is the number of CSI-RS ports. If only one CSI-RS port is configured, *W(i)* is 1. If the higher layer parameter *reportQuantity* in *CSI-ReportConfig* for which the CQI is reported is set to either 'cri-RI-PMI-CQI' or 'cri-RI-LI-PMI-CQI', *W(i)* is the precoding matrix corresponding to the reported PMI applicable to *x(i).* If the higher layer parameter *reportQuantity* in *CSI-ReportConfig* for which the CQI is reported is set to 'cri-RI-CQI', *W(i)* is the precoding matrix corresponding to the procedure described in Clause 5.2.1.4.2. If the higher layer parameter *reportQuantity* in *CSI-ReportConfig* for which the CQI is reported is set to 'cri-RI-i1-CQI', *W(i)* is the precoding matrix corresponding to the reported i1 according to the procedure described in Clause 5.2.1.4.2.The corresponding PDSCH signals transmitted on antenna ports [3000,…,3000 + *P* - 1] would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in Clause 5.2.2.3.1.

5.2.3 CSI reporting using PUSCH

A UE shall perform aperiodic CSI reporting using PUSCH on serving cell c upon successful decoding of a DCI format 0_1 or DCI format 0_2 which triggers an aperiodic CSI trigger state.

When a DCI format 0_1 schedules two PUSCH allocations, the aperiodic CSI report is carried on the second scheduled PUSCH. When a DCI format 0_1 schedules more than two PUSCH allocations, the aperiodic CSI report is carried on the penultimate scheduled PUSCH.

An aperiodic CSI report carried on the PUSCH supports wideband, and sub-band frequency granularities. An aperiodic CSI report carried on the PUSCH supports Type I, Type II and Enhanced Type II CSI.

A UE shall perform semi-persistent CSI reporting on the PUSCH upon successful decoding of a DCI format 0_1 or DCI format 0_2 which activates a semi-persistent CSI trigger state. DCI format 0_1 and DCI format 0_2 contains a CSI request field which indicates the semi-persistent CSI trigger state to activate or deactivate. Semi-persistent CSI reporting on the PUSCH supports Type I, Type II with wideband, and sub-band frequency granularities and Enhanced Type II CSI. The PUSCH resources and MCS shall be allocated semi-persistently by an uplink DCI.

CSI reporting on PUSCH can be multiplexed with uplink data on PUSCH except that semi-persistent CSI reporting on PUSCH activated by a DCI format is not expected to be multiplexed with uplink data on the PUSCH. CSI reporting on PUSCH can also be performed without any multiplexing with uplink data from the UE.

Type I CSI feedback is supported for CSI Reporting on PUSCH. Type I wideband and sub-band CSI is supported for CSI Reporting on the PUSCH. Type II CSI is supported for CSI Reporting on the PUSCH.

For Type I, Type II and Enhanced Type II CSI feedback on PUSCH, a CSI report comprises of two parts. Part 1 has a fixed payload size and is used to identify the number of information bits in Part 2. Part 1 shall be transmitted in its entirety before Part 2.

- For Type I CSI feedback, Part 1 contains RI (if reported), CRI (if reported), CQI for the first codeword (if reported). Part 2 contains PMI (if reported) and contains the CQI for the second codeword (if reported) when RI (if reported) is larger than 4.

- For Type II CSI feedback, Part 1 contains RI (if reported), CQI, and an indication of the number of non-zero wideband amplitude coefficients per layer for the Type II CSI (see Clause 5.2.2.2.3). The fields of Part 1 – RI (if reported), CQI, and the indication of the number of non-zero wideband amplitude coefficients for each layer – are separately encoded. Part 2 contains the PMI of the Type II CSI. The elements of $i_{1,4,l}$, $i_{2,1,l}$ (if reported) and $i_{2,2,l}$ (if reported) are reported in the increasing order of their indices, $i = 0,1,\dots,L-1$, where the element of the lowest index is mapped to the most significant bits and the element of the highest index is mapped to the least significant bits. Part 1 and 2 are separately encoded.

- For Enhanced Type II CSI feedback, Part 1 contains RI, CQI, and an indication of the overall number of non-zero amplitude coefficients across layers for the Enhanced Type II CSI (see Clause 5.2.2.2.5). The fields of Part 1 – RI, CQI, and the indication of the overall number of non-zero amplitude coefficients across layers – are separately encoded. Part 2 contains the PMI of the Enhanced Type II CSI. Part 1 and 2 are separately encoded.

A Type II CSI report that is carried on the PUSCH shall be computed independently from any Type II CSI report that is carried on the PUCCH formats 3 or 4 (see Clause 5.2.4 and 5.2.2).

When the higher layer parameter *reportQuantity* is configured with one of the values 'cri-RSRP', 'ssb-Index-RSRP', 'cri-SINR' or 'ssb-Index-SINR', the CSI feedback consists of a single part.

For both Type I and Type II reports configured for PUCCH but transmitted on PUSCH, the determination of the payload for CSI part 1 and CSI part 2 follows that of PUCCH as described in Clause 5.2.4.

When CSI reporting on PUSCH comprises two parts, the UE may omit a portion of the Part 2 CSI. Omission of Part 2 CSI is according to the priority order shown in Table 5.2.3-1, where N_{Rep} is the number of CSI reports configured to be carried on the PUSCH. Priority 0 is the highest priority and priority $2N_{\mathrm{Rep}}$ is the lowest priority and the CSI report n corresponds to the CSI report with the nth smallest $\mathrm{Pri}_{i,\mathrm{CSI}}(y,k,c,s)$ value among the N_{Rep} CSI reports as defined in Clause 5.2.5. The subbands for a given CSI report n indicated by the higher layer parameter *csi-ReportingBand* are numbered continuously in increasing order with the lowest subband of *csi-ReportingBand* as subband 0. When omitting Part 2 CSI information for a particular priority level, the UE shall omit all of the information at that priority level.

- For Enhanced Type II reports, for a given CSI report n, each reported element of indices $i_{2,4,l}$ $i_{2,5,l}$ and $i_{1,7,l}$, indexed by l, i and f, is associated with a priority value $\mathrm{Pri}(l,i,f) = 2 \cdot L \cdot v \cdot \pi(f) + v \cdot i + l$, with $\pi(f) = \min(2 \cdot n_{3,l}^{(f)}, 2 \cdot (N_3 - n_{3,l}^{(f)}) - 1)$ with $l = 1,2,\dots,v$, $i = 0,1,\dots,2L-1$, and $f = 0,1,\dots,M_v - 1$, and where

$n_{3,l}^{(f)}$ is defined in Clause 5.2.2.2.5. The element with the highest priority has the lowest associated value $\mathrm{Pri}(l,i,f)$. Omission of Part 2 CSI is according to the priority order shown in Table 5.2.3-1, where

- Group 0 includes indices $i_{1,1}$, $i_{1,2}$ (if reported) and $i_{1,8,l}$ $(l = 1, \dots, \upsilon)$.
- Group 1 includes indices $i_{1,5}$ (if reported), $i_{1,6,l}$ (if reported), the $\upsilon 2LM_\upsilon - \lfloor K^{NZ}/2 \rfloor$ highest priority elements of $i_{1,7,l}$, $i_{2,3,l}$, the $\lceil K^{NZ}/2 \rceil - \upsilon$ highest priority elements of $i_{2,4,l}$ and the $\lceil K^{NZ}/2 \rceil - \upsilon$ highest priority elements of $i_{2,5,l}$ $(l = 1, \dots, \upsilon)$.
- Group 2 includes the $\lfloor K^{NZ}/2 \rfloor$ lowest priority elements of $i_{1,7,l}$, the $\lfloor K^{NZ}/2 \rfloor$ lowest priority elements of $i_{2,4,l}$ and the $\lfloor K^{NZ}/2 \rfloor$ lowest priority elements of $i_{2,5,l}$ $(l = 1, \dots, \upsilon)$.

Table 5.2.3-1: Priority reporting levels for Part 2 CSI

Priority 0: For CSI reports 1 to N_{Rep}, Group 0 CSI for CSI reports configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 wideband CSI for CSI reports configured otherwise
Priority 1: Group 1 CSI for CSI report 1, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of even subbands for CSI report 1, if configured otherwise
Priority 2: Group 2 CSI for CSI report 1, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of odd subbands for CSI report 1, if configured otherwise
Priority 3: Group 1 CSI for CSI report 2, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of even subbands for CSI report 2, if configured otherwise
Priority 4: Group 2 CSI for CSI report 2, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'. Part 2 subband CSI of odd subbands for CSI report 2, if configured otherwise
⋮
Priority $2N_{Rep} - 1$: Group 1 CSI for CSI report N_{Rep}, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of even subbands for CSI report N_{Rep}, if configured otherwise
Priority $2N_{Rep}$: Group 2 CSI for CSI report N_{Rep}, if configured as 'typeII-r16' or 'typeII-PortSelection-r16'; Part 2 subband CSI of odd subbands for CSI report N_{Rep}, if configured otherwise

When the UE is scheduled to transmit a transport block on PUSCH not using repetition type B multiplexed with a CSI report(s), Part 2 CSI is omitted only when $\left\lceil (O_{\text{CSI-2}} + L_{\text{CSI-2}}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l) \Big/ \sum_{r=0}^{C_{\text{UL-SCH}}-1} K_r \right\rceil$ is larger than $\left\lceil \alpha \cdot \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l) \right\rceil - Q'_{ACK/CG-UCI} - Q'_{\text{CSI-1}}$, where parameters $O_{\text{CSI-2}}$, $L_{\text{CSI-2}}$, $\beta_{\text{offset}}^{\text{PUSCH}}$, $N_{\text{symb,all}}^{\text{PUSCH}}$, $M_{\text{sc}}^{\text{UCI}}(l)$, $C_{\text{UL-SCH}}$, K_r, $Q'_{\text{CSI-1}}$, $Q'_{ACK/CG-UCI}$ and α are defined in Clause 6.3.2.4 of [5, TS 38.212].

Part 2 CSI is omitted level by level, beginning with the lowest priority level until the lowest priority level is reached which causes the $\left\lceil (O_{\text{CSI-2}} + L_{\text{CSI-2}}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l) \Big/ \sum_{r=0}^{C_{\text{UL-SCH}}-1} K_r \right\rceil$ to be less than or equal to $\left\lceil \alpha \cdot \sum_{l=0}^{N_{\text{symb,all}}^{\text{PUSCH}}-1} M_{\text{sc}}^{\text{UCI}}(l) \right\rceil - Q'_{ACK/CG-UCI} - Q'_{\text{CSI-1}}$.

When the UE is scheduled to transmit a transport block on PUSCH using repetition type B multiplexed with a CSI report(s), Part 2 CSI is omitted only when

$$\left\lceil (O_{\text{CSI-2}} + L_{\text{CSI-2}}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{symb,nominal}}^{\text{PUSCH}}-1} M_{\text{sc,nominal}}^{\text{UCI}}(l) \Big/ \sum_{r=0}^{C_{\text{UL-SCH}}-1} K_r \right\rceil$$

is larger than

$$\min\left\{ \begin{array}{c} \left\lceil \alpha \cdot \sum_{l=0}^{N_{\text{symb,nominal}}^{\text{PUSCH}}-1} M_{\text{sc,nominal}}^{\text{UCI}}(l) \right\rceil - Q'_{ACK/CG-UCI} - Q'_{\text{CSI-1}}\ , \\ \sum_{l=0}^{N_{\text{symb,actual}}^{\text{PUSCH}}-1} M_{\text{sc,actual}}^{\text{UCI}}(l) - Q'_{ACK/CG-UCI} - Q'_{\text{CSI-1}} \end{array} \right\},$$

where parameters $O_{\text{CSI-2}}$, $L_{\text{CSI-2}}$, $\beta_{\text{offset}}^{\text{PUSCH}}$, $N_{symb,\text{nominal}}^{PUSCH}$, $N_{symb,\text{actual}}^{PUSCH}$, $M_{sc,\text{nominal}}^{UCI}(l)$, $M_{sc,\text{actual}}^{UCI}(l)$, $C_{\text{UL-SCH}}$, K_r, $Q'_{ACK/CG-UCI}$, $Q'_{\text{CSI-1}}$, and α are defined in Clause 6.3.2.4 of [5, TS 38.212].

Part 2 CSI is omitted level by level, beginning with the lowest priority level until the lowest priority level is reached which causes

$$\left\lceil (O_{\text{CSI-2}} + L_{\text{CSI-2}}) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \cdot \sum_{l=0}^{N_{\text{symb,nominal}}^{\text{PUSCH}}-1} M_{\text{sc,nominal}}^{\text{UCI}}(l) \Big/ \sum_{r=0}^{C_{\text{UL-SCH}}-1} K_r \right\rceil$$

to be less than or equal to

$$\min\left\{ \begin{array}{c} \left\lceil \alpha \cdot \sum_{l=0}^{N_{\text{symb,nominal}}^{\text{PUSCH}}-1} M_{\text{sc,nominal}}^{\text{UCI}}(l) \right\rceil - Q'_{ACK/CG-UCI} - Q'_{\text{CSI-1}}\ , \\ \sum_{l=0}^{N_{\text{symb,actual}}^{\text{PUSCH}}-1} M_{\text{sc,actual}}^{\text{UCI}}(l) - Q'_{ACK/CG-UCI} - Q'_{\text{CSI-1}} \end{array} \right\}.$$

When part 2 CSI is transmitted on PUSCH with no transport block, lower priority bits are omitted until Part 2 CSI code rate, which is given by $(O_{\text{CSI-2}} + L_{\text{CSI-2}})/(N_L \cdot Q'_{\text{CSI,2}} \cdot Q_m)$ where $O_{\text{CSI-2}}$, $L_{\text{CSI-2}}$, $N_L, Q'_{\text{CSI,2}}, Q_m$ are given in clause 6.3.2.4 of [5, 38.212] before HARQ-ACK puncturing part 2 CSI if any, is below a threshold code rate c_{T} lower than one, where

$$c_T = \frac{R}{\beta_{\text{offset}}^{\text{CSI-part2}}}$$

- $\beta_{\text{offset}}^{\text{CSI-part2}}$ is the CSI offset value from Table 9.3-2 of [6, TS 38.213]

- R is signaled code rate in DCI

If the UE is in an active semi-persistent CSI reporting configuration on PUSCH, the CSI reporting is deactivated when either the downlink BWP or the uplink BWP is changed. Another activation command is required to enable the semi-persistent CSI reporting.

5.2.4 CSI reporting using PUCCH

A UE is semi-statically configured by higher layers to perform periodic CSI Reporting on the PUCCH. A UE can be configured by higher layers for multiple periodic CSI Reports corresponding to multiple higher layer configured CSI Reporting Settings, where the associated CSI Resource Settings are higher layer configured. Periodic CSI reporting on PUCCH formats 2, 3, 4 supports Type I CSI with wideband granularity.

A UE shall perform semi-persistent CSI reporting on the PUCCH applied starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$ when the UE would transmit a PUCCH with HARQ-ACK information in slot *n* corresponding to the PDSCH carrying the activation command described in clause 6.1.3.16 of [10, TS 38.321] where μ is the SCS configuration for the PUCCH. The activation command will contain one or more Reporting Settings where the associated CSI Resource Settings are configured. Semi-persistent CSI reporting on the PUCCH supports Type I CSI. Semi-persistent CSI reporting on the PUCCH format 2 supports Type I CSI with wideband frequency granularity. Semi-persistent CSI reporting on PUCCH formats 3 or 4 supports Type I CSI with wideband and sub-band frequency granularities and Type II CSI Part 1.

When the PUCCH carry Type I CSI with wideband frequency granularity, the CSI payload carried by the PUCCH format 2 and PUCCH formats 3, or 4 are identical and the same irrespective of RI (if reported), CRI (if reported). For type I CSI sub-band reporting on PUCCH formats 3, or 4, the payload is split into two parts. The first part contains RI (if reported), CRI (if reported), CQI for the first codeword. The second part contains PMI and contains the CQI for the second codeword when RI > 4.

A semi-persistent report carried on the PUCCH formats 3 or 4 supports Type II CSI feedback, but only Part 1 of Type II CSI feedback (See Clause 5.2.2 and 5.2.3). Supporting Type II CSI reporting on the PUCCH formats 3 or 4 is a UE capability *type2-SP-CSI-Feedback-LongPUCCH*. A Type II CSI report (Part 1 only) carried on PUCCH formats 3 or 4 shall be calculated independently of any Type II CSI reports carried on the PUSCH (see Clause 5.2.3).

When the UE is configured with CSI Reporting on PUCCH formats 2, 3 or 4, each PUCCH resource is configured for each candidate UL BWP.

If the UE is in an active semi-persistent CSI reporting configuration on PUCCH and has not received a deactivation command, the CSI reporting takes place when the BWP in which the reporting is configured to take place is the active BWP, otherwise the CSI reporting is suspended.

A UE is not expected to report CSI with a total number of UCI bits and CRC bits larger than 115 bits when configured with PUCCH format 4. For CSI reports transmitted on a PUCCH, if all CSI reports consist of one part, the UE may omit a portion of CSI reports. Omission of CSI is according to the priority order determined from the $\mathrm{Pri}_{i,\mathrm{CSI}}(y,k,c,s)$ value as defined in Clause 5.2.5. CSI report is omitted beginning with the lowest priority level until the CSI report code rate is less or equal to the one configured by the higher layer parameter *maxCodeRate*.

If any of the CSI reports consist of two parts, the UE may omit a portion of Part 2 CSI. Omission of Part 2 CSI is according to the priority order shown in Table 5.2.3-1. Part 2 CSI is omitted beginning with the lowest priority level until the Part 2 CSI code rate is less or equal to the one configured by higher layer parameter *maxCodeRate*.

5.2.5 Priority rules for CSI reports

CSI reports are associated with a priority value $\mathrm{Pri}_{iCSI}(y,k,c,s) = 2 \cdot N_{cells} \cdot M_s \cdot y + N_{cells} \cdot M_s \cdot k + M_s \cdot c + s$ where

- $y=0$ for aperiodic CSI reports to be carried on PUSCH $y=1$ for semi-persistent CSI reports to be carried on PUSCH, $y=2$ for semi-persistent CSI reports to be carried on PUCCH and $y=3$ for periodic CSI reports to be carried on PUCCH;
- $k=0$ for CSI reports carrying L1-RSRP or L1-SINR and $k=1$ for CSI reports not carrying L1-RSRP or L1-SINR;
- *c* is the serving cell index and N_{cells} is the value of the higher layer parameter *maxNrofServingCells*;

- s is the *reportConfigID* and M_s is the value of the higher layer parameter *maxNrofCSI-ReportConfigurations.*

A first CSI report is said to have priority over second CSI report if the associated $\mathrm{Pri}_{iCSI}(y,k,c,s)$ value is lower for the first report than for the second report.

Two CSI reports are said to collide if the time occupancy of the physical channels scheduled to carry the CSI reports overlap in at least one OFDM symbol and are transmitted on the same carrier. When a UE is configured to transmit two colliding CSI reports,

- if y values are different between the two CSI reports, the following rules apply except for the case when one of the y value is 2 and the other y value is 3 (for CSI reports transmitted on PUSCH, as described in Clause 5.2.3; for CSI reports transmitted on PUCCH, as described in Clause 5.2.4):
  - The CSI report with higher $\mathrm{Pri}_{iCSI}(y,k,c,s)$ value shall not be sent by the UE.
- otherwise, the two CSI reports are multiplexed or either is dropped based on the priority values, as described in Clause 9.2.5.2 in [6, TS 38.213].

If a semi-persistent CSI report to be carried on PUSCH overlaps in time with PUSCH data transmission in one or more symbols on the same carrier, and if the earliest symbol of these PUSCH channels starts no earlier than $N_2+d_{2,1}$ symbols after the last symbol of the DCI scheduling the PUSCH where $d_{2,1}$ is the maximum of the $d_{2,1}$ associated with the PUSCH carrying semi-persistent CSI report and the PUSCH with data transmission, the CSI report shall not be transmitted by the UE. Otherwise, if the timeline requirement is not satisfied this is an error case.

If a UE would transmit a first PUSCH that includes semi-persistent CSI reports and a second PUSCH that includes an UL-SCH and the first PUSCH transmission would overlap in time with the second PUSCH transmission, the UE does not transmit the first PUSCH and transmits the second PUSCH. The UE expects that the first and second PUSCH transmissions satisfy the above timing conditions for PUSCH transmissions that overlap in time when at least one of the first or second PUSCH transmissions is in response to a DCI format detection by the UE.

5.3 UE PDSCH processing procedure time

If the first uplink symbol of the PUCCH which carries the HARQ-ACK information, as defined by the assigned HARQ-ACK timing K_1 and the PUCCH resource to be used and including the effect of the timing advance, starts no earlier than at symbol L_1, where L_1 is defined as the next uplink symbol with its CP starting after $T_{proc,1} = (N_1 + d_{1,1} + d_2)(2048+144)\cdot\kappa 2^{-\mu}\cdot T_C + T_{ext}$ after the end of the last symbol of the PDSCH carrying the TB being acknowledged, then the UE shall provide a valid HARQ-ACK message.

- N_1 is based on μ of table 5.3-1 and table 5.3-2 for UE processing capability 1 and 2 respectively, where μ corresponds to the one of (μ_{PDCCH}, μ_{PDSCH}, μ_{UL}) resulting with the largest $T_{proc,1}$, where the μ_{PDCCH} corresponds to the subcarrier spacing of the PDCCH scheduling the PDSCH, the μ_{PDSCH} corresponds to the subcarrier spacing of the scheduled PDSCH, and μ_{UL} corresponds to the subcarrier spacing of the uplink channel with which the HARQ-ACK is to be transmitted, and κ is defined in clause 4.1 of [4, TS 38.211].
- For operation with shared spectrum channel access, T_{ext} is calculated according to [4, TS 38.211], otherwise T_{ext} =0.
- If the PDSCH DM-RS position l_1 for the additional DM-RS in Table 7.4.1.1.2-3 in clause 7.4.1.1.2 of [4, TS 38.211] is $l_1 = 12$ then $N_{1,0}=14$ in Table 5.3-1, otherwise $N_{1,0}=13$.
- If the UE is configured with multiple active component carriers, the first uplink symbol which carries the HARQ-ACK information further includes the effect of timing difference between the component carriers as given in [11, TS 38.133].
- For the PDSCH mapping type A as given in clause 7.4.1.1 of [4, TS 38.211]: if the last symbol of PDSCH is on the i-th symbol of the slot where $i < 7$, then $d_{1,1} = 7 - i$, otherwise $d_{1,1} = 0$
- If a PUCCH of a larger priority index would overlap with PUCCH/PUSCH of a smaller priority index, d_2 for the PUCCH of a larger priority is set as reported by the UE; otherwise $d_2 = 0$.

- For UE processing capability 1: If the PDSCH is mapping type B as given in clause 7.4.1.1 of [4, TS 38.211], and
  - if the number of PDSCH symbols allocated is $L \geq 7$, then $d_{1,1} = 0$,
  - if the number of PDSCH symbols allocated is $L \geq 4$ and $L \leq 6$, then $d_{1,1} = 7 - L$.
  - if the number of PDSCH symbols allocated is $L = 3$ then $d_{1,1} = 3 + \min(d,1)$, where d is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH.
  - if the number of PDSCH symbols allocated is 2, then $d_{1,1} = 3+d$, where d is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH.
- For UE processing capability 2: If the PDSCH is mapping type B as given in clause 7.4.1.1 of [4, TS 38.211],
  - if the number of PDSCH symbols allocated is $L \geq 7$, then $d_{1,1} = 0$,
  - if the number of PDSCH symbols allocated is $L \geq 3$ and $L \leq 6$, then $d_{1,1}$ is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH,
  - if the number of PDSCH symbols allocated is 2,
    - if the scheduling PDCCH was in a 3-symbol CORESET and the CORESET and the PDSCH had the same starting symbol, then $d_{1,1} = 3$,
    - otherwise $d_{1,1}$ is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH.
- For UE processing capability 2 with scheduling limitation when $\mu_{PDSCH} = 1$, if the scheduled RB allocation exceeds 136 RBs, the UE defaults to capability 1 processing time. The UE may skip decoding a number of PDSCHs with last symbol within 10 symbols before the start of a PDSCH that is scheduled to follow Capability 2, if any of those PDSCHs are scheduled with more than 136 RBs with 30kHz SCS and following Capability 1 processing time.
- For a UE that supports capability 2 on a given cell, the processing time according to UE processing capability 2 is applied if the high layer parameter *processingType2Enabled* in *PDSCH-ServingCellConfig* is configured for the cell and set to 'enable'.
- If this PUCCH resource is overlapping with another PUCCH or PUSCH resource, then HARQ-ACK is multiplexed following the procedure in clause 9.2.5 of [6, TS 38.213], otherwise the HARQ-ACK message is transmitted on PUCCH.

Otherwise the UE may not provide a valid HARQ-ACK corresponding to the scheduled PDSCH. The value of $T_{proc,1}$ is used both in the case of normal and extended cyclic prefix.

For a PDSCH that consists of two PDSCH transmission occasions in time domain in one slot, $d_{1,1}$ is calculated based on the first PDSCH transmission occasion in the slot, and as described above.

Table 5.3-1: PDSCH processing time for PDSCH processing capability 1

μ	PDSCH decoding time N_1 [symbols]	
	dmrs-AdditionalPosition* = 'pos0' in *DMRS-DownlinkConfig* in both of *dmrs-DownlinkForPDSCH-MappingTypeA*, *dmrs-DownlinkForPDSCH-MappingTypeB	***dmrs-AdditionalPosition* ≠ 'pos0' in *DMRS-DownlinkConfig* in either of *dmrs-DownlinkForPDSCH-MappingTypeA*, *dmrs-DownlinkForPDSCH-MappingTypeB* or if the higher layer parameter is not configured**
0	8	$N_{1,0}$
1	10	13
2	17	20
3	20	24

Table 5.3-2: PDSCH processing time for PDSCH processing capability 2

μ	PDSCH decoding time N_1 [symbols] *dmrs-AdditionalPosition* = 'pos0' in *DMRS-DownlinkConfig* in both of *dmrs-DownlinkForPDSCH-MappingTypeA*, *dmrs-DownlinkForPDSCH-MappingTypeB*
0	3
1	4.5
2	9 for frequency range 1

5.3.1 Application delay of the minimum scheduling offset restriction

When the UE is scheduled with DCI format 0_1 or 1_1 with a '*Minimum applicable scheduling offset indicator*' field in slot n, it shall determine the $K_{0\min}$ and $K_{2\min}$ values, if configured respectively, to be applied, while the previously applied $K_{0\min}$ and/or $K_{2\min}$ values are applied until the new values take effect. If the DCI in slot n also indicates an active DL (UL) BWP change for a serving cell, the indicated $K_{0\min}$ ($K_{2\min}$) value in the new active DL (UL) BWP, if configured, is applied from the slot indicated by the slot offset value of the time domain resource assignment field in the DCI. Otherwise, change of applied minimum scheduling offset restriction indication carried by DCI in slot n, shall be applied in slot $n+X$ of the scheduling cell. The UE does not expect to be scheduled with DCI format 0_1 or 1_1 with '*Minimum applicable scheduling offset indicator*' field indicating another change to $K_{0\min}$ or $K_{2\min}$ for the same active BWP of the scheduled cell before slot $n+X$ of the scheduling cell.

When the DCI format 0_1 or 1_1 with '*Minimum applicable scheduling offset indicator*' field indicating a change to the applied $K_{0\min}$ or $K_{2\min}$ is contained within the first three symbols of slot n, the value of application delay X is determined by, $X = max\left(\left\lceil K_{0minOld} \cdot \frac{2^{\mu_{PDCCH}}}{2^{\mu_{PDSCH}}}\right\rceil, Z_\mu\right)$ where $K_{0\text{minOld}}$ is the currently applied $K_{0\min}$ value of the active DL BWP in the scheduled cell and is zero, if *minimumSchedulingOffsetK0* is not configured for the active DL BWP in the scheduled cell, Z_μ is determined by the subcarrier spacing of the active DL BWP in the scheduling cell in slot n, and given in Table 5.3.1-1, and μ_{PDCCH} and μ_{PDSCH} are the sub-carrier spacing configurations for PDCCH of the active DL BWP in the scheduling cell and PDSCH of the active DL BWP in the scheduled cell, respectively, in slot n. After indication of a change to the applied $K_{0\min}$ or $K_{2\min}$ of the scheduled cell in slot n of the scheduling cell, if there is an active DL BWP change in the scheduling cell before slot $n+X$, the new $K_{0\min}$ and/or $K_{2\min}$ values are applied from the first slot no earlier than the start of slot $n+X$ based on the sub-carrier spacing configuration of the active DL BWP in the scheduling cell in slot n.

When the DCI format 0_1 or 1_1 with '*Minimum applicable scheduling offset indicator*' field is received outside the first three symbols of the slot, value of Z_μ from Table 5.3.1-1 is incremented by one before determining the application delay X.

Table 5.3.1-1: Definition of Z_μ

μ	Z_μ
0	1
1	1
2	2
3	2

5.4 UE CSI computation time

When the *CSI request* field on a DCI triggers a CSI report(s) on PUSCH, the UE shall provide a valid CSI report for the n-th triggered report,

- if the first uplink symbol to carry the corresponding CSI report(s) including the effect of the timing advance, starts no earlier than at symbol Z_{ref}, and

- if the first uplink symbol to carry the n-th CSI report including the effect of the timing advance, starts no earlier than at symbol $Z'_{ref}(n)$,

where Z_{ref} is defined as the next uplink symbol with its CP starting $T_{proc,CSI} = (Z)(2048+144)\cdot\kappa 2^{-\mu}\cdot T_C + T_{switch}$ after the end of the last symbol of the PDCCH triggering the CSI report(s), and where $Z'_{ref}(n)$, is defined as the next uplink symbol with its CP starting $T'_{proc,CSI} = (Z')(2048+144)\cdot\kappa 2^{-\mu}\cdot T_C$ after the end of the last symbol in time of the latest of: aperiodic

CSI-RS resource for channel measurements, aperiodic CSI-IM used for interference measurements, and aperiodic NZP CSI-RS for interference measurement, when aperiodic CSI-RS is used for channel measurement for the *n*-th triggered CSI report, and where T_{switch} is defined in clause 6.4 and is applied only if Z_1 of table 5.4-1 is applied.

If the PUSCH indicated by the DCI is overlapping with another PUCCH or PUSCH, then the CSI report(s) are multiplexed following the procedure in clause 9.2.5 of [6, TS 38.213] and clause 5.2.5 when applicable, otherwise the CSI report(s) are transmitted on the PUSCH indicated by the DCI.

When the *CSI request* field on a DCI triggers a CSI report(s) on PUSCH, if the first uplink symbol to carry the corresponding CSI report(s) including the effect of the timing advance, starts earlier than at symbol Z_{ref},

- the UE may ignore the scheduling DCI if no HARQ-ACK or transport block is multiplexed on the PUSCH.

When the *CSI request* field on a DCI triggers a CSI report(s) on PUSCH, if the first uplink symbol to carry the *n*-th CSI report including the effect of the timing advance, starts earlier than at symbol $Z'_{ref}(n)$,

- the UE may ignore the scheduling DCI if the number of triggered reports is one and no HARQ-ACK or transport block is multiplexed on the PUSCH
- Otherwise, the UE is not required to update the CSI for the *n*-th triggered CSI report.

Z, *Z'* and μ are defined as:

$Z = \max_{m=0,\dots,M-1}(Z(m))$ and $Z' = \max_{m=0,\dots,M-1}(Z'(m))$, where *M* is the number of updated CSI report(s) according to Clause 5.2.1.6, $(Z(m), Z'(m))$ corresponds to the *m*-th updated CSI report and is defined as

- (Z_1, Z'_1) of the table 5.4-1 if the CSI is triggered without a PUSCH with either transport block or HARQ-ACK or both when $L = 0$ CPUs are occupied (according to Clause 5.2.1.6) and the CSI to be transmitted is a single CSI and corresponds to wideband frequency-granularity where the CSI corresponds to at most 4 CSI-RS ports in a single resource without CRI report and where *CodebookType* is set to 'typeI-SinglePanel' or where *reportQuantity* is set to 'cri-RI-CQI', or
- (Z_1, Z'_1) of the table 5.4-2 if the CSI to be transmitted corresponds to wideband frequency-granularity where the CSI corresponds to at most 4 CSI-RS ports in a single resource without CRI report and where *CodebookType* is set to 'typeI-SinglePanel' or where *reportQuantity* is set to 'cri-RI-CQI', or
- (Z_1, Z'_1) of the table 5.4-2 if the CSI to be transmitted corresponds to wideband frequency-granularity where the *reportQuantity* is set to 'ssb-Index-SINR', or *reportQuantity* is set to 'cri-SINR', or
- (Z_3, Z'_3) of the table 5.4-2 if *reportQuantity* is set to 'cri-RSRP' or 'ssb-Index-RSRP', where $X\mu$ is according to UE reported capability *beamReportTiming* and KB_l is according to UE reported capability *beamSwitchTiming* as defined in [13, TS 38.306], or
- (Z_2, Z'_2) of table 5.4-2 otherwise.
- μ of table 5.4-1 and table 5.4-2 corresponds to the min (μ_{PDCCH}, $\mu_{CSI\text{-}RS}$, μ_{UL}) where the μ_{PDCCH} corresponds to the subcarrier spacing of the PDCCH with which the DCI was transmitted and μ_{UL} corresponds to the subcarrier spacing of the PUSCH with which the CSI report is to be transmitted and $\mu_{CSI\text{-}RS}$ corresponds to the minimum subcarrier spacing of the aperiodic CSI-RS triggered by the DCI

Table 5.4-1: CSI computation delay requirement 1

μ	Z_1 [symbols]	
	Z_1	Z'_1
0	10	8
1	13	11
2	25	21
3	43	36

Table 5.4-2: CSI computation delay requirement 2

μ	Z_1 [symbols]		Z_2 [symbols]		Z_3 [symbols]	
	Z_1	Z'_1	Z_2	Z'_2	Z_3	Z'_3
0	22	16	40	37	22	X_0
1	33	30	72	69	33	X_1
2	44	42	141	140	min(44,X_2+ KB_1)	X_2
3	97	85	152	140	min(97, X_3+ KB_2)	X_3

5.5 UE PDSCH reception preparation time with cross carrier scheduling with different subcarrier spacings for PDCCH and PDSCH

This clause applies only if the PDCCH carrying the scheduling DCI is received on one carrier with one OFDM subcarrier spacing (μ_{PDCCH}), and the PDSCH scheduled to be received by the DCI is on another carrier with another OFDM subcarrier spacing (μ_{PDSCH}).

If the $\mu_{PDCCH} < \mu_{PDSCH}$, the UE is expected to receive the scheduled PDSCH, if the first symbol in the PDSCH allocation, including the DM-RS, as defined by the slot offset K_0 and the start and length indicator *SLIV* of the scheduling DCI starts no earlier than the first symbol of the slot of the PDSCH reception starting at least N_{pdsch} PDCCH symbols after the end of the PDCCH scheduling the PDSCH, not taking into account the effect of receive timing difference between the scheduling cell and the scheduled cell.

If the $\mu_{PDCCH} > \mu_{PDSCH}$, the UE is expected to receive the scheduled PDSCH, if the first symbol in the PDSCH allocation, including the DM-RS, as defined by the slot offset K_0 and the start and length indicator *SLIV* of the scheduling DCI starts no earlier than N_{pdsch} PDCCH symbols after the end of the PDCCH scheduling the PDSCH, not taking into account the effect of receive timing difference between the scheduling cell and the scheduled cell.

Table 5.5-1: N_{pdsch} as a function of the subcarrier spacing of the scheduling PDCCH

μ_{PDCCH}	N_{pdsch} [symbols]
0	4
1	5
2	10
3	14

6 Physical uplink shared channel related procedure

6.1 UE procedure for transmitting the physical uplink shared channel

PUSCH transmission(s) can be dynamically scheduled by an UL grant in a DCI, or the transmission can correspond to a configured grant Type 1 or Type 2. The configured grant Type 1 PUSCH transmission is semi-statically configured to operate upon the reception of higher layer parameter of *configuredGrantConfig* including *rrc-ConfiguredUplinkGrant* without the detection of an UL grant in a DCI. The configured grant Type 2 PUSCH transmission is semi-persistently scheduled by an UL grant in a valid activation DCI according to Clause 10.2 of [6, TS 38.213] after the reception of higher layer parameter *configuredGrantConfig* not including *rrc-ConfiguredUplinkGrant*. If *configuredGrantConfigToAddModList* is configured, more than one configured grant configuration of configured grant Type 1 and/or configured grant Type 2 may be active at the same time on an active BWP of a serving cell.

For the PUSCH transmission corresponding to a Type 1 configured grant or a Type 2 configured grant activated by DCI format 0_0 or 0_1, the parameters applied for the transmission are provided by *configuredGrantConfig* except for *dataScramblingIdentityPUSCH*, *txConfig*, *codebookSubset*, *maxRank*, *scaling* of *UCI-OnPUSCH*, which are provided by *pusch-Config*. For the PUSCH transmission corresponding to a Type 2 configured grant activated by DCI format 0_2, the parameters applied for the transmission are provided by *configuredGrantConfig* except for *dataScramblingIdentityPUSCH*, *txConfig*, *codebookSubsetDCI-0-2*, *maxRankForDCI-Format0-2*, *scaling* of *UCI-OnPUSCH*, *resourceAllocationType1GranularityDCI-0-2* provided by *pusch-Config*. If the UE is provided with *transformPrecoder* in *configuredGrantConfig*, the UE applies the higher layer parameter *tp-pi2BPSK*, if provided in *pusch-Config*, according to the procedure described in Clause 6.1.4 for the PUSCH transmission corresponding to a configured grant.

For the PUSCH retransmission scheduled by a PDCCH with CRC scrambled by CS-RNTI with NDI=1, the parameters in *pusch-Config* are applied for the PUSCH transmission except for *p0-NominalWithoutGrant, p0-PUSCH-Alpha,*

powerControlLoopToUse, pathlossReferenceIndex described in Clause 7.1 of [6, TS 38.213], *mcs-Table, mcs-TableTransformPrecoder* described in Clause 6.1.4.1 and *transformPrecoder* described in Clause 6.1.3.

For a UE configured with two uplinks in a serving cell, PUSCH retransmission for a TB on the serving cell is not expected to be on a different uplink than the uplink used for the PUSCH initial transmission of that TB.

A UE shall upon detection of a PDCCH with a configured DCI format 0_0, 0_1 or 0_2 transmit the corresponding PUSCH as indicated by that DCI unless the UE does not generate a transport block as described in [10, TS38.321]. Upon detection of a DCI format 0_1 or 0_2 with '*UL-SCH indicator*' set to '0' and with a non-zero '*CSI request*' where the associated *reportQuantity* in *CSI-ReportConfig* set to '*none*' for all CSI report(s) triggered by '*CSI request*' in this DCI format 0_1 or 0_2, the UE ignores all fields in this DCI except the '*CSI request*' and the UE shall not transmit the corresponding PUSCH as indicated by this DCI format 0_1 or 0_2. When the UE is scheduled with multiple PUSCHs by a DCI, HARQ process ID indicated by this DCI applies to the first PUSCH, as described in clause 6.1.2.1, HARQ process ID is then incremented by 1 for each subsequent PUSCH(s) in the scheduled order, with modulo 16 operation applied. For any HARQ process ID(s) in a given scheduled cell, the UE is not expected to transmit a PUSCH that overlaps in time with another PUSCH. Except for the case when a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet* for the active BWP of a serving cell and PDCCHs that schedule two non-overlapping in time domain PUSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex*, for any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start a first PUSCH transmission starting in symbol *j* by a PDCCH ending in symbol *i*, the UE is not expected to be scheduled to transmit a PUSCH starting earlier than the end of the first PUSCH by a PDCCH that ends later than symbol *i*. The UE is not expected to be scheduled to transmit another PUSCH by a DCI format 0_0 with CRC scrambled by TC-RNTI, for a given HARQ process with the DCI received before the end of the expected transmission of the last PUSCH for that HARQ process if the latter is scheduled by a DCI format 0_0 with CRC scrambled by TC-RNTI or by an UL grant in RA Response. The UE is not expected to be scheduled to transmit another PUSCH by DCI format 0_0, 0_1 or 0_2 scrambled by C-RNTI, CS-RNTI or MCS-C-RNTI for a given HARQ process with the DCI received before the end of the expected transmission of the last PUSCH for that HARQ process if the latter is scheduled by a DCI with CRC scrambled by C-RNTI, CS-RNTI or MCS-C-RNTI.

If a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet* for the active BWP of a serving cell and PDCCHs that schedule two non-overlapping in time domain PUSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex*, for any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start a first PUSCH transmission starting in symbol *j* by a PDCCH associated with a value of *coresetPoolIndex* ending in symbol *i*, the UE can be scheduled to transmit a PUSCH starting earlier than the end of the first PUSCH by a PDCCH associated with a different value of *coresetPoolIndex* that ends later than symbol *i*.

A UE is not expected to be scheduled by a PDCCH ending in symbol i to transmit a PUSCH on a given serving cell overlapping in time with a transmission occasion, where the UE is allowed to transmit a PUSCH with configured grant according to [10, TS38.321], starting in a symbol j on the same serving cell if the end of symbol i is not at least N_2 symbols before the beginning of symbol j. The value N_2 in symbols is determined according to the UE processing capability defined in Clause 6.4, and N_2 and the symbol duration are based on the minimum of the subcarrier spacing corresponding to the PUSCH with configured grant and the subcarrier spacing of the PDCCH scheduling the PUSCH.

If a UE receives an ACK for a given HARQ process in CG-DFI in a PDCCH ending in symbol *i* to terminate a transport block repetition in a PUSCH transmission with a configured grant on a given serving cell with the same HARQ process after symbol *i*, the UE is expected to terminate the repetition of the transport block in a PUSCH transmission starting from a symbol *j* if the gap between the end of PDCCH of symbol *i* and the start of the PUSCH transmission in symbol *j* is equal to or more than *N2* symbols. The value *N2* in symbols is determined according to the UE processing capability defined in Clause 6.4, and *N2* and the symbol duration are based on the minimum of the subcarrier spacing corresponding to the PUSCH and the subcarrier spacing of the PDCCH indicating CG-DFI.

A UE is not expected to be scheduled by a PDCCH ending in symbol i to transmit a PUSCH on a given serving cell for a given HARQ process, if there is a transmission occasion where the UE is allowed to transmit a PUSCH with configured grant according to [10, TS38.321] with the same HARQ process on the same serving cell starting in a symbol j after symbol i, and if the gap between the end of PDCCH and the beginning of symbol j is less than N_2

symbols. The value N_2 in symbols is determined according to the UE processing capability defined in Clause 6.4, and N_2 and the symbol duration are based on the minimum of the subcarrier spacing corresponding to the PUSCH with configured grant and the subcarrier spacing of the PDCCH scheduling the PUSCH.

For PUSCH scheduled by DCI format 0_0 on a cell, the UE shall transmit PUSCH according to the spatial relation, if applicable, corresponding to the dedicated PUCCH resource with the lowest ID within the active UL BWP of the cell, as described in Clause 9.2.1 of [6, TS 38.213].

For PUSCH scheduled by DCI format 0_0 on a cell and if the higher layer parameter *enableDefaultBeamPL-ForPUSCH0-0* is set 'enabled', the UE is not configured with PUCCH resources on the active UL BWP and the UE is in RRC connected mode, the UE shall transmit PUSCH according to the spatial relation, if applicable, with a reference to the RS configured with *qcl-Type* set to 'typeD' corresponding to the QCL assumption of the CORESET with the lowest ID on the active DL BWP of the cell.

For PUSCH scheduled by DCI format 0_0 on a cell and if the higher layer parameter *enableDefaultBeamPL-ForPUSCH0-0* is set 'enabled', the UE is configured with PUCCH resources on the active UL BWP where all the PUCCH resource(s) are not configured with any spatial relation and the UE is in RRC connected mode, the UE shall transmit PUSCH according to the spatial relation, if applicable, with a reference to the RS configured with *qcl-Type* set to 'typeD' corresponding to the QCL assumption of the CORESET with the lowest ID on the active DL BWP of the cell in case CORESET(s) are configured on the cell.

For uplink, 16 HARQ processes per cell is supported by the UE.

6.1.1 Transmission schemes

Two transmission schemes are supported for PUSCH: codebook based transmission and non-codebook based transmission. The UE is configured with codebook based transmission when the higher layer parameter *txConfig* in *pusch-Config* is set to 'codebook', the UE is configured non-codebook based transmission when the higher layer parameter *txConfig* is set to 'nonCodebook'. If the higher layer parameter *txConfig* is not configured, the UE is not expected to be scheduled by DCI format 0_1 or 0_2. If PUSCH is scheduled by DCI format 0_0, the PUSCH transmission is based on a single antenna port. Except if the higher layer parameter *enableDefaultBeamPL-ForPUSCH0-0* is set 'enabled', the UE shall not expect PUSCH scheduled by DCI format 0_0 in a BWP without configured PUCCH resource with *PUCCH-SpatialRelationInfo* in frequency range 2 in RRC connected mode.

6.1.1.1 Codebook based UL transmission

For codebook based transmission, PUSCH can be scheduled by DCI format 0_0, DCI format 0_1, DCI format 0_2 or semi-statically configured to operate according to Clause 6.1.2.3. If this PUSCH is scheduled by DCI format 0_1, DCI format 0_2, or semi-statically configured to operate according to Clause 6.1.2.3, the UE determines its PUSCH transmission precoder based on SRI, TPMI and the transmission rank, where the SRI, TPMI and the transmission rank are given by DCI fields of SRS resource indicator and Precoding information and number of layers in clause 7.3.1.1.2 and 7.3.1.1.3 of [5, TS 38.212] for DCI format 0_1 and 0_2 or given by *srs-ResourceIndicator* and *precodingAndNumberOfLayers* according to clause 6.1.2.3. The *SRS-ResourceSet(s)* applicable for PUSCH scheduled by DCI format 0_1 and DCI format 0_2 are defined by the entries of the higher layer parameter *srs-ResourceSetToAddModList* and *srs-ResourceSetToAddModListDCI-0-2* in *SRS-config*, respectively. Only one SRS resource set can be configured in *srs-ResourceSetToAddModList* with higher layer parameter *usage* in *SRS-ResourceSet* set to 'codebook', and only one SRS resource set can be configured in *srs-ResourceSetToAddModListDCI-0-2* with higher layer parameter *usage* in *SRS-ResourceSet* set to 'codebook'. The TPMI is used to indicate the precoder to be applied over the layers {0…v-1} and that corresponds to the SRS resource selected by the SRI when multiple SRS resources are configured, or if a single SRS resource is configured TPMI is used to indicate the precoder to be applied over the layers {0…v-1} and that corresponds to the SRS resource. The transmission precoder is selected from the uplink codebook that has a number of antenna ports equal to higher layer parameter *nrofSRS-Ports* in SRS-Config, as defined in Clause 6.3.1.5 of [4, TS 38.211]. When the UE is configured with the higher layer parameter *txConfig* set to 'codebook', the UE is configured with at least one SRS resource. The indicated SRI in slot *n* is associated with the most recent transmission of SRS resource identified by the SRI, where the SRS resource is prior to the PDCCH carrying the SRI.

For codebook based transmission, the UE determines its codebook subsets based on TPMI and upon the reception of higher layer parameter *codebookSubset* in *pusch-Config* for PUSCH associated with DCI format 0_1 and *codebookSubsetDCI-0-2* in *pusch-Config* for PUSCH associated with DCI format 0_2 which may be configured with 'fullyAndPartialAndNonCoherent', or 'partialAndNonCoherent', or 'nonCoherent' depending on the UE capability. When higher layer parameter *ul-FullPowerTransmission* is set to '*fullpowerMode2'* and the higher layer parameter *codebookSubset* or the higher layer parameter *codebookSubsetForDCI-Format0-2* is set to 'partialAndNonCoherent', and when the SRS-resourceSet with usage set to "codebook" includes at least one SRS resource with 4 ports and one SRS resource with 2 ports, the codebookSubset associated with the 2-port SRS resource is 'nonCoherent'. The maximum transmission rank may be configured by the higher layer parameter *maxRank* in *pusch-Config* for PUSCH scheduled with DCI format 0_1 and *maxRank-ForDCIFormat0_2* for PUSCH scheduled with DCI format 0_2.

A UE reporting its UE capability of 'partialAndNonCoherent' transmission shall not expect to be configured by either *codebookSubset* or *codebookSubsetForDCI-Format0-2* with 'fullyAndPartialAndNonCoherent'.

A UE reporting its UE capability of 'nonCoherent' transmission shall not expect to be configured by either *codebookSubset* or *codebookSubsetForDCI-Format0-2* with 'fullyAndPartialAndNonCoherent' or with 'partialAndNonCoherent'.

A UE shall not expect to be configured with the higher layer parameter *codebookSubset* or the higher layer parameter *codebookSubsetForDCI-Format0-2* set to 'partialAndNonCoherent' when higher layer parameter *nrofSRS-Ports* in an *SRS-ResourceSet* with *usage* set to 'codebook' indicates that the maximum number of the configured SRS antenna ports in the *SRS-ResourceSet* is two.

For codebook based transmission, only one SRS resource can be indicated based on the SRI from within the SRS resource set. Except when higher layer parameter *ul-FullPowerTransmission* is set to 'fullpowerMode2', the maximum number of configured SRS resources for codebook based transmission is 2. If aperiodic SRS is configured for a UE, the SRS request field in DCI triggers the transmission of aperiodic SRS resources.

A UE shall not expect to be configured with higher layer parameter *ul-FullPowerTransmission* set to 'fullpowerMode1' and *codebookSubset* or *codebookSubsetDCI-0-2* set to 'fullAndPartialAndNonCoherent' simultaneously.

The UE shall transmit PUSCH using the same antenna port(s) as the SRS port(s) in the SRS resource indicated by the DCI format 0_1 or 0_2 or by *configuredGrantConfig* according to clause 6.1.2.3.

The DM-RS antenna ports $\{\tilde{p}_{0,...,}\ \tilde{p}_{\upsilon-1}\}$ in Clause 6.4.1.1.3 of [4, TS38.211] are determined according to the ordering of DM-RS port(s) given by Tables 7.3.1.1.2-6 to 7.3.1.1.2-23 in Clause 7.3.1.1.2 of [5, TS 38.212].

Except when higher layer parameter *ul-FullPowerTransmission* is set to 'fullpowerMode2', when multiple SRS resources are configured by *SRS-ResourceSet* with *usage* set to 'codebook', the UE shall expect that higher layer parameters *nrofSRS-Ports* in *SRS-Resource* in *SRS-ResourceSet* shall be configured with the same value for all these SRS resources.

When higher layer parameter *ul-FullPowerTransmission* is set to 'fullpowerMode2',

- the UE can be configured with one SRS resource or multiple SRS resources with same or different number of SRS ports within an SRS resource set with *usage* set to 'codebook'.
- up to 2 different spatial relations can be configured for all SRS resources in the SRS resource set with *usage* set to 'codebook' when multiple SRS resources are configured in the SRS resource set.
- subject to UE capability, a maximum of 2 or 4 SRS resources are supported in an SRS resource set with *usage* set to 'codebook'.

6.1.1.2 Non-Codebook based UL transmission

For non-codebook based transmission, PUSCH can be scheduled by DCI format 0_0, DCI format 0_1, DCI format 0_2 or semi-statically configured to operate according to Clause 6.1.2.3. If this PUSCH is scheduled by DCI format 0_1, DCI format 0_2, or semi-statically configured to operate according to Clause 6.1.2.3, the UE can determine its PUSCH precoder and transmission rank based on the SRI when multiple SRS resources are configured, where the SRI is given by the SRS resource indicator in DCI according to clause 7.3.1.1.2 and 7.3.1.1.3 of [5, 38.212] for DCI format 0_1 and DCI format 0_2, or the SRI is given by *srs-ResourceIndicator* according to clause 6.1.2.3. The *SRS-ResourceSet(s)* applicable for PUSCH scheduled by DCI format 0_1 and DCI format 0_2 are defined by the entries of the higher layer parameter *srs-ResourceSetToAddModList* and *srs-ResourceSetToAddModListDCI-0-2* in *SRS-config,* respectively. The UE shall use one or multiple SRS resources for SRS transmission, where, in a SRS resource set, the maximum number of SRS resources which can be configured to the UE for simultaneous transmission in the same symbol and the maximum number of SRS resources are UE capabilities. The SRS resources transmitted simultaneously occupy the same RBs. Only one SRS port for each SRS resource is configured. Only one SRS resource set can be configured in *srs-ResourceSetToAddModList* with higher layer parameter *usage* in *SRS-ResourceSet* set to 'nonCodebook', and only one SRS resource set can be configured in *srs-ResourceSetToAddModListDCI-0-2* with higher layer parameter *usage* in *SRS-ResourceSet* set to 'nonCodebook'. The maximum number of SRS resources that can be configured for non-codebook based uplink transmission is 4. The indicated SRI in slot *n* is associated with the most recent transmission of SRS resource(s) identified by the SRI, where the SRS transmission is prior to the PDCCH carrying the SRI.

For non-codebook based transmission, the UE can calculate the precoder used for the transmission of SRS based on measurement of an associated NZP CSI-RS resource. A UE can be configured with only one NZP CSI-RS resource for the SRS resource set with higher layer parameter usage in *SRS-ResourceSet* set to 'nonCodebook' if configured.

- If aperiodic SRS resource set is configured, the associated NZP-CSI-RS is indicated via SRS request field in DCI format 0_1 and 1_1, as well as DCI format 0_2 (if SRS request field is present) and DCI format 1_2 (if SRS request field is present), where *AperiodicSRS-ResourceTrigger* and *AperiodicSRS-ResourceTriggerList* (indicating the association between aperiodic SRS triggering state(s) and SRS resource sets), triggered SRS resource(s) *srs-ResourceSetId*, *csi-RS* (indicating the associated *NZP-CSI-RS-ResourceId*) are higher layer configured in *SRS-ResourceSet*. The *SRS-ResourceSet(s)* associated with the SRS request by DCI format 0_1 and 1_1 are defined by the entries of the higher layer parameter *srs-ResourceSetToAddModList* and the *SRS-ResourceSet(s)* associated with the SRS request by DCI format 0_2 and 1_2 are defined by the entries of the higher layer parameter. A UE is not expected to update the SRS precoding information if the gap from the last symbol of the reception of the aperiodic NZP-CSI-RS resource and the first symbol of the aperiodic SRS transmission is less than 42 OFDM symbols.

- If the UE configured with aperiodic SRS associated with aperiodic NZP CSI-RS resource, the presence of the associated CSI-RS is indicated by the SRS request field if the value of the SRS request field is not '00' as in Table 7.3.1.1.2-24 of [5, TS 38.212] and if the scheduling DCI is not used for cross carrier or cross bandwidth part scheduling. If UE is configured with *minimumSchedulingOffsetK0* in the active DL BWP and the currently applicable minimum scheduling offset restriction $K_{0,min}$ is larger than 0, the UE does not expected to receive the scheduling DCI with the SRS request field value other than '00'. The CSI-RS is located in the same slot as the SRS request field. If the UE configured with aperiodic SRS associated with aperiodic NZP CSI-RS resource, any of the TCI states configured in the scheduled CC shall not be configured with *qcl-Type* set to 'typeD'.

- If periodic or semi-persistent SRS resource set is configured, the *NZP-CSI-RS-ResourceId* for measurement is indicated via higher layer parameter *associatedCSI-RS* in *SRS-ResourceSet*.

The UE shall perform one-to-one mapping from the indicated SRI(s) to the indicated DM-RS ports(s) and their corresponding PUSCH layers {0 … ν-1} given by DCI format 0_1 or 0_2 or by *configuredGrantConfig* according to clause 6.1.2.3 in increasing order.

The UE shall transmit PUSCH using the same antenna ports as the SRS port(s) in the SRS resource(s) indicated by SRI(s) given by DCI format 0_1 or 0_2 or by *configuredGrantConfig* according to clause 6.1.2.3, where the SRS port in (i+1)-th SRS resource in the SRS resource set is indexed as $p_i = 1000 + i$.

The DM-RS antenna ports $\{\tilde{p}_{0,...,}\ \tilde{p}_{\upsilon-1}\}$ in Clause 6.4.1.1.3 of [4, TS 38.211] are determined according to the ordering of DM-RS port(s) given by Tables 7.3.1.1.2-6 to 7.3.1.1.2-23 in Clause 7.3.1.1.2 of [5, TS 38.212].

For non-codebook based transmission, the UE does not expect to be configured with both *spatialRelationInfo* for SRS resource and *associatedCSI-RS* in *SRS-ResourceSet* for SRS resource set.

For non-codebook based transmission, the UE can be scheduled with DCI format 0_1 or 0_2 when at least one SRS resource is configured in *SRS-ResourceSet* with *usage* set to 'nonCodebook'.

6.1.2 Resource allocation

6.1.2.1 Resource allocation in time domain

When the UE is scheduled to transmit a transport block and no CSI report, or the UE is scheduled to transmit a transport block and a CSI report(s) on PUSCH by a DCI, the '*Time domain resource assignment'* field value *m* of the DCI provides a row index *m* + 1 to an allocated table. The determination of the used resource allocation table is defined in Clause 6.1.2.1.1. The indexed row defines the slot offset K_2, the start and length indicator *SLIV*, or directly the start symbol *S* and the allocation length *L*, the PUSCH mapping type, and the number of repetitions (if *numberOfRepetitions* is present in the resource allocation table) to be applied in the PUSCH transmission.

When the UE is scheduled to transmit a PUSCH with no transport block and with a CSI report(s) by a '*CSI request'* field on a DCI, the '*Time domain resource assignment'* field value *m* of the DCI provides a row index *m* + 1 to the allocated table as defined in Clause 6.1.2.1.1. The indexed row defines the start and length indicator SLIV, or directly the start symbol *S* and the allocation length *L*, and the PUSCH mapping type to be applied in the PUSCH transmission and the

K_2 value is determined as $K_2 = \max_j Y_j(m+1)$, where $Y_j, j = 0,\ldots,N_{\mathrm{Rep}}-1$ are the corresponding list entries of the higher layer parameter

- *reportSlotOffsetListDCI-0-2*, if PUSCH is scheduled by DCI format 0_2 and *reportSlotOffsetListDCI-0-2* is configured;
- *reportSlotOffsetListDCI-0-1*, if PUSCH is scheduled by DCI format 0_1 and *reportSlotOffsetListDCI-0-1* is configured;
- *reportSlotOffsetList*, otherwise;

in *CSI-ReportConfig* for the N_{Rep} triggered CSI Reporting Settings and $Y_j(m+1)$ is the *(m+1)*th entry of Y_j.

- The slot K_s where the UE shall transmit the PUSCH is determined by K_2 as $K_s = \left\lfloor n \cdot \frac{2^{\mu_{PUSCH}}}{2^{\mu_{PDCCH}}} \right\rfloor + K_2 + \left\lfloor \left(\frac{N_{slot,offset,PDCCH}^{CA}}{2^{\mu_{offset,PDCCH}}} - \frac{N_{slot,offset,PUSCH}^{CA}}{2^{\mu_{offset,PUSCH}}} \right) \cdot 2^{\mu_{PUSCH}} \right\rfloor$, if UE is configured with *ca-SlotOffset* for at least one of the scheduled and scheduling cell, $K_s = \left\lfloor n \cdot \frac{2^{\mu_{PUSCH}}}{2^{\mu_{PDCCH}}} \right\rfloor + K_2$, otherwise, and where n is the slot with the scheduling DCI, K_2 is based on the numerology of PUSCH, and μ_{PUSCH} and μ_{PDCCH} are the subcarrier spacing configurations for PUSCH and PDCCH, respectively,
- $N_{\mathrm{slot,\,offset,\,PDCCH}}^{\mathrm{CA}}$ and $\mu_{\mathrm{offset,\,PDCCH}}$ are the $N_{\mathrm{slot,\,offset}}^{\mathrm{CA}}$ and the μ_{offset}, respectively, which are determined by higher-layer configured *ca-SlotOffset* for the cell receiving the PDCCH, $N_{\mathrm{slot,\,offset,\,PUSCH}}^{\mathrm{CA}}$ and $\mu_{\mathrm{offset,\,PUSCH}}$ are the $N_{\mathrm{slot,\,offset}}^{\mathrm{CA}}$ and the μ_{offset},respectively, which are determined by higher-layer configured *ca-SlotOffset* for the cell transmitting the PUSCH, as defined in clause 4.5 of [4, TS 38.211], and
- for PUSCH scheduled by DCI format 0_1, if *pusch-RepTypeIndicatorDCI-0-1* is set to 'pusch-RepTypeB', the UE applies PUSCH repetition Type B procedure when determining the time domain resource allocation. For PUSCH scheduled by DCI format 0_2, if *pusch-RepTypeIndicatorDCI-0-2* is set to 'pusch-RepTypeB', the UE applies PUSCH repetition Type B procedure when determining the time domain resource allocation. Otherwise, the UE applies PUSCH repetition Type A procedure when determining the time domain resource allocation for PUSCH scheduled by PDCCH.
- For PUSCH repetition Type A, 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 PUSCH are determined from the start and length indicator *SLIV* of the indexed row:

  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

- For PUSCH repetition Type B, 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 PUSCH are provided by *startSymbol* and *length* of the indexed row of the resource allocation table, respectively.
- For PUSCH repetition Type A, the PUSCH mapping type is set to Type A or Type B as defined in Clause 6.4.1.1.3 of [4, TS 38.211] as given by the indexed row.
- For PUSCH repetition Type B, the PUSCH mapping type is set to Type B.

The UE shall consider the S and L combinations defined in table 6.1.2.1-1 as valid PUSCH allocations

Table 6.1.2.1-1: Valid *S* and *L* combinations

PUSCH mapping type	Normal cyclic prefix			Extended cyclic prefix		
	S	***L***	***S+L***	***S***	***L***	***S+L***
Type A (repetition Type A only)	0	{4,…,14}	{4,…,14}	0	{4,…,12}	{4,…,12}
Type B	{0,…,13}	{1,…,14}	{1,…,14} for repetition Type A, {1,…,27} for repetition Type B	{0,…, 11}	{1,…,12}	{1,…,12} for repetition Type A, {1,…,23} for repetition Type B

For PUSCH repetition Type A, when transmitting PUSCH scheduled by DCI format 0_1 or 0_2 in PDCCH with CRC scrambled with C-RNTI, MCS-C-RNTI, or CS-RNTI with NDI=1, the number of repetitions *K* is determined as

- if *numberOfRepetitions* is present in the resource allocation table, the number of repetitions K is equal to *numberOfRepetitions*;
- elseif the UE is configured with *pusch-AggregationFactor*, the number of repetitions *K* is equal to *pusch-AggregationFactor*;
- otherwise $K=1$.

If a UE is configured with higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH*, the UE does not expect to be configured with *pusch-AggregationFactor*.

For PUSCH repetition Type A, in case $K>1$, the same symbol allocation is applied across the *K* consecutive slots and the PUSCH is limited to a single transmission layer. The UE shall repeat the TB across the *K* consecutive slots applying the same symbol allocation in each slot. The redundancy version to be applied on the *n*th transmission occasion of the TB, where n = 0, 1, … *K*-1, is determined according to table 6.1.2.1-2.

Table 6.1.2.1-2: Redundancy version for PUSCH transmission

rv_{id} indicated by the DCI scheduling the PUSCH	rv_{id} to be applied to n^{th} transmission occasion (repetition Type A) or n^{th} actual repetition (repetition Type B)			
	***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

When transmitting MsgA PUSCH on a non-initial UL BWP, if the UE is configured with *startSymbolAndLengthMsgA-PO*, the UE shall determine the *S* and *L* from *startSymbolAndLengthMsgA-PO*.

When transmitting MsgA PUSCH, if the UE is not configured with *startSymbolAndLengthMsgA-PO*, and if the TDRA list *PUSCH-TimeDomainResourceAllocationList* is provided in *PUSCH-ConfigCommon*, the UE shall use *msgA-PUSCH-TimeDomainAllocation* to indicate which values are used in the list. If *PUSCH-TimeDomainResourceAllocationList* is not provided in *PUSCH-ConfigCommon*, the UE shall use parameters *S* and *L* from table 6.1.2.1.1-2 or table 6.1.2.1.1-3 where *msgA-PUSCH-TimeDomainAllocation* indicates which values are used in the list. The time offset for PUSCH transmission is described in [6, TS38.213].

For PUSCH repetition Type A, a PUSCH transmission in a slot of a multi-slot PUSCH transmission is omitted according to the conditions in Clause 9, Clause 11.1 and Clause 11.2A of [6, TS38.213].

For PUSCH repetition Type B, except for PUSCH transmitting CSI report(s) with no transport block, the number of nominal repetitions is given by *numberOfRepetitions*. For the *n*-th nominal repetition, $n = 0, \ldots,$ *numberOfRepetitions* - 1,

- The slot where the nominal repetition starts is given by $K_s + \left\lfloor \frac{S + n \cdot L}{N_{symb}^{slot}} \right\rfloor$, and the starting symbol relative to the start of the slot is given by $\mathrm{mod}\left(S + n \cdot L, N_{symb}^{slot}\right)$.

- The slot where the nominal repetition ends is given by $K_s + \left\lfloor \frac{S+(n+1)\cdot L-1}{N_{symb}^{slot}} \right\rfloor$, and the ending symbol relative to the start of the slot is given by $\bmod\left(S+(n+1)\cdot L-1, N_{symb}^{slot}\right)$.

Here K_s is the slot where the PUSCH transmission starts, and N_{symb}^{slot} is the number of symbols per slot as defined in Clause 4.3.2 of [4, TS38.211].

For PUSCH repetition Type B, the UE determines invalid symbol(s) for PUSCH repetition Type B transmission as follows:

- A symbol that is indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* is considered as an invalid symbol for PUSCH repetition Type B transmission.
- For operation in unpaired spectrum, symbols indicated by *ssb-PositionsInBurst* in SIB1 or *ssb-PositionsInBurst* in *ServingCellConfigCommon* for reception of SS/PBCH blocks are considered as invalid symbols for PUSCH repetition Type B transmission.
- For operation in unpaired spectrum, symbol(s) indicated by *pdcch-ConfigSIB1* in *MIB* for a CORESET for Type0-PDCCH CSS set are considered as invalid symbol(s) for PUSCH repetition Type B transmission.
- For operation in unpaired spectrum, if *numberOfInvalidSymbolsForDL-UL-Switching* is configured, *numberOfInvalidSymbolsForDL-UL-Switching* symbol(s) after the last symbol that is indicated as downlink in each consecutive set of all symbols that are indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* are considered as invalid symbol(s) for PUSCH repetition Type B transmission. The symbol(s) given by *numberOfInvalidSymbolsForDL-UL-Switching* are defined using the reference SCS configuration *referenceSubcarrierSpacing* provided in *tdd-UL-DL-ConfigurationCommon*.
- The UE may be configured with the higher layer parameter *invalidSymbolPattern*, which provides a symbol level bitmap spanning one or two slots (higher layer parameter *symbols* given by *invalidSymbolPattern*). A bit value equal to 1 in the symbol level bitmap *symbols* indicates that the corresponding symbol is an invalid symbol for PUSCH repetition Type B transmission. The UE may be additionally configured with a time-domain pattern (higher layer parameter *periodicityAndPattern* given by *invalidSymbolPattern*), where each bit of *periodicityAndPattern* corresponds to a unit equal to a duration of the symbol level bitmap *symbols*, and a bit value equal to 1 indicates that the symbol level bitmap *symbols* is present in the unit. The *periodicityAndPattern* can be {1, 2, 4, 5, 8, 10, 20 or 40} units long, but maximum of 40 msec. The first symbol of *periodicityAndPattern* every 40 msec/P periods is a first symbol in frame n_f mod 4 = 0, where P is the duration of *periodicityAndPattern-r16* in units of msec. When *periodicityAndPattern* is not configured, for a symbol level bitmap spanning two slots, the bits of the first and second slots correspond respectively to even and odd slots of a radio frame, and for a symbol level bitmap spanning one slot, the bits of the slot correspond to every slot of a radio frame. If *invalidSymbolPattern* is configured, when the UE applies the invalid symbol pattern is determined as follows:
  - if the PUSCH is scheduled by DCI format 0_1, or corresponds to a Type 2 configured grant activated by DCI format 0_1, and if *invalidSymbolPatternIndicatorDCI-0-1* is configured,
    - if invalid symbol pattern indicator field is set 1, the UE applies the invalid symbol pattern;
    - otherwise, the UE does not apply the invalid symbol pattern;
  - if the PUSCH is scheduled by DCI format 0_2, or corresponds to a Type 2 configured grant activated by DCI format 0_2, and if *invalidSymbolPatternIndicatorDCI-0-2* is configured,
    - if invalid symbol pattern indicator field is set 1, the UE applies the invalid symbol pattern;
    - otherwise, the UE does not apply the invalid symbol pattern;
  - otherwise, the UE applies the invalid symbol pattern.
- If the UE
  - is configured with multiple serving cells within a cell group and is provided with *directionalCollisionHandling-r16* = 'enabled' for a set of serving cell(s) among the multiple serving cells, and

- indicates support of *half-DuplexTDD-CA-SameSCS-r16* capability, and
- is not configured to monitor PDCCH for detection of DCI format 2-0 on any of the multiple serving cells,
  - a symbol indicated to the UE for reception of SS/PBCH blocks in a first cell of the multiple serving cells by *ssb-PositionsInBurst* in *SIB1* or *ssb-PositionsInBurst* in *ServingCellConfigCommon* is considered as an invalid symbol for PUSCH repetition Type B transmission in
    - any of the multiple serving cells if the UE is not capable of simultaneous transmission and reception as indicated by *simultaneousRxTxInterBandCA* among the multiple serving cells, and
    - any one of the cells corresponding to the same band as the first cell, irrespective of any capability indicated by *simultaneousRxTxInterBandCA*

  and

  - a symbol is considered as an invalid symbol in another cell among the set of serving cell(s) provided with *directionalCollisionHandling-r16* for PUSCH repetition Type B transmission with Type 1 or Type 2 configured grant except for the first Type 2 PUSCH transmission (including all repetitions) after activation if the symbol is indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* on the reference cell as defined in Clause 11.1 of [6, TS 38.213], or the UE is configured by higher layers to receive PDCCH, PDSCH, or CSI-RS on the reference cell in the symbol.

For PUSCH repetition Type B, after determining the invalid symbol(s) for PUSCH repetition type B transmission for each of the K nominal repetitions, the remaining symbols are considered as potentially valid symbols for PUSCH repetition Type B transmission. If the number of potentially valid symbols for PUSCH repetition type B transmission is greater than zero for a nominal repetition, the nominal repetition consists of one or more actual repetitions, where each actual repetition consists of a consecutive set of all potentially valid symbols that can be used for PUSCH repetition Type B transmission within a slot. An actual repetition with a single symbol is omitted except for the case of L=1. An actual repetition is omitted according to the conditions in Clause 9, Clause 11.1 and Clause 11.2A of [6, TS38.213]. The UE shall repeat the TB across actual repetitions. The redundancy version to be applied on the nth actual repetition (with the counting including the actual repetitions that are omitted) is determined according to table 6.1.2.1-2.

For PUSCH repetition Type B, when a UE receives a DCI that schedules aperiodic CSI report(s) or activates semi-persistent CSI report(s) on PUSCH with no transport block by a '*CSI request'* field on a DCI, the number of nominal repetitions is always assumed to be 1, regardless of the value of *numberOfRepetitions*. When the UE is scheduled to transmit a PUSCH repetition Type B with no transport block and with aperiodic or semi-persistent CSI report(s) by a '*CSI request'* field on a DCI, the first nominal repetition is expected to be the same as the first actual repetition. For PUSCH repetition Type B carrying semi-persistent CSI report(s) without a corresponding PDCCH after being activated on PUSCH by a '*CSI request'* field on a DCI, if the first nominal repetition is not the same as the first actual repetition, the first nominal repetition is omitted; otherwise, the first nominal repetition is omitted according to the conditions in Clause 9, Clause 11.1 and Clause 11.2A of [6, TS38.213].

For PUSCH repetition Type B, when a UE is scheduled to transmit a transport block and aperiodic CSI report(s) on PUSCH by a '*CSI request'* field on a DCI, the CSI report(s) is multiplexed only on the first actual repetition. The UE does not expect that the first actual repetition has a single symbol duration.

If *pusch-TimeDomainAllocationListForMultiPUSCH* in *pusch-Config* contains row indicating resource allocation for two to eight contiguous PUSCHs, K_2 indicates the slot where UE shall transmit the first PUSCH of the multiple PUSCHs. Each PUSCH has a separate SLIV and mapping type. The number of scheduled PUSCHs is signalled by the number of indicated valid SLIVs in the row of the *pusch-TimeDomainAllocationListForMultiPUSCH* signalled in DCI format 0_1.

When the UE is configured with *minimumSchedulingOffsetK2* in an active UL BWP it applies a minimum scheduling offset restriction indicated by the '*Minimum applicable scheduling offset indicator*' field in DCI format 0_1 or DCI format 1_1 if the same field is available. When the UE configured with *minimumSchedulingOffsetK2* in an active UL BWP and it has not received '*Minimum applicable scheduling offset indicator*' field in DCI format 0_1 or 1_1, the UE shall apply a minimum scheduling offset restriction indicated based on '*Minimum applicable scheduling offset indicator*' value '0'. When the minimum scheduling offset restriction is applied the UE is not expected to be scheduled with a DCI in slot n to transmit a PUSCH scheduled with C-RNTI, CS-RNTI, MCS-C-RNTI or SP-CSI-RNTI with K_2 smaller than $\left\lceil K_{2min} \cdot \frac{2^{\mu'}}{2^{\mu}} \right\rceil$, where $K_{2\min}$ and μ are the applied minimum scheduling offset restriction and the numerology of the active UL BWP of the scheduled cell when receiving the DCI in slot n, respectively, and μ' is the numerology of the new active UL BWP in case of active UL BWP change in the scheduled cell and is equal to μ, otherwise. The minimum scheduling offset restriction is not applied when PUSCH transmission is scheduled by RAR UL grant or fallbackRAR UL grant for RACH procedure, or when PUSCH is scheduled with TC-RNTI. The application delay of the change of the minimum scheduling offset restriction is determined in Clause 5.3.1.

6.1.2.1.1 Determination of the resource allocation table to be used for PUSCH

Table 6.1.2.1.1-1, Table 6.1.2.1.1-1A and Table 6.1.2.1.1-1B define which PUSCH time domain resource allocation configuration to apply.

Table 6.1.2.1.1-4 defines the subcarrier spacing specific values *j*. *j* is used in determination of K_2 in conjunction to table 6.1.2.1.1-2, for normal CP or table 6.1.2.1.1.-3 for extended CP, where μ_{PUSCH} is the subcarrier spacing configurations for PUSCH.

Table 6.1.2.1.1-5 defines the additional subcarrier spacing specific slot delay value for the first transmission of PUSCH scheduled by the RAR or by the fallbackRAR. When the UE transmits a PUSCH scheduled by RAR or by the fallbackRAR, the Δ value specific to the PUSCH subcarrier spacing μ_{PUSCH} is applied in addition to the K_2 value.

Table 6.1.2.1.1-1: Applicable PUSCH time domain resource allocation for common search space and DCI format 0_0 in UE specific search space

RNTI	PDCCH search space	*pusch-ConfigCommon* includes *pusch-TimeDomainAllocationList*	*pusch-Config* includes *pusch-TimeDomainAllocationList*	PUSCH time domain resource allocation to apply
PUSCH scheduled by MAC RAR as described in clause 8.2 of [6, TS 38.213] or MAC fallbackRAR as described in clause 8.2A of [6, 38.213] or for MsgA PUSCH transmission		No	-	Default A
		Yes		*pusch-TimeDomainAllocationList* provided in *pusch-ConfigCommon*
C-RNTI, MCS-C-RNTI, TC-RNTI, CS-RNTI	Any common search space associated with CORESET 0	No	-	Default A
		Yes		*pusch-TimeDomainAllocationList* provided in *pusch-ConfigCommon*
C-RNTI, MCS-C-RNTI, TC-RNTI, CS-RNTI	Any common search space not associated with CORESET 0, DCI format 0_0 in UE specific search space	No	No	Default A
		Yes	No	*pusch-TimeDomainAllocationList* provided in *pusch-ConfigCommon*
		No/Yes	Yes	*pusch-TimeDomainAllocationList* provided in *pusch-Config*

Table 6.1.2.1.1-1A: Applicable PUSCH time domain resource allocation for DCI format 0_1 in UE specific search space scrambled with C-RNTI, MCS-C-RNTI, CS-RNTI or SP-CSI-RNTI

pusch-ConfigCommon* includes *pusch-TimeDomainAllocationList	***pusch-Config* includes *pusch-TimeDomainAllocationList***	***pusch-Config* includes *pusch-TimeDomainAllocationListDCI-0-1***	***pusch-Config* includes *pusch-TimeDomainAllocationList-ForMultiPUSCH***	**PUSCH time domain resource allocation to apply**
No	No	No	No	Default A
Yes	No	No	No	*pusch-TimeDomainAllocationList* provided in *pusch-ConfigCommon*
No/Yes	Yes	No	No	*pusch-TimeDomainAllocationList* provided in *pusch-Config*
No/Yes	No/Yes	Yes	-	*pusch-TimeDomainAllocationListDCI-0-1* provided in *pusch-Config*
No/Yes	No/Yes	-	Yes	*pusch-TimeDomainAllocationList-ForMultiPUSCH* provided in *pusch-Config*

Table 6.1.2.1.1-1B: Applicable PUSCH time domain resource allocation for DCI format 0_2 in UE specific search space scrambled with C-RNTI, MCS-C-RNTI, CS-RNTI or SP-CSI-RNTI

pusch-ConfigCommon* includes *pusch-TimeDomainAllocationList	***pusch-Config* includes *pusch-TimeDomainAllocationList***	***pusch-Config* includes *pusch-TimeDomainAllocationListDCI-0-2***	**PUSCH time domain resource allocation to apply**
No	No	No	Default A
Yes	No	No	*pusch-TimeDomainAllocationList* provided in *pusch-ConfigCommon*
No/Yes	Yes	No	*pusch-TimeDomainAllocationList* provided in *pusch-Config*
No/Yes	No/Yes	Yes	*pusch-TimeDomainAllocationListDCI-0-2* provided in *pusch-Config*

Table 6.1.2.1.1-2: Default PUSCH time domain resource allocation A for normal CP

Row index	PUSCH mapping type	K_2	S	L
1	Type A	j	0	14
2	Type A	j	0	12
3	Type A	j	0	10
4	Type B	j	2	10
5	Type B	j	4	10
6	Type B	j	4	8
7	Type B	j	4	6
8	Type A	j+1	0	14
9	Type A	j+1	0	12
10	Type A	j+1	0	10
11	Type A	j+2	0	14
12	Type A	j+2	0	12
13	Type A	j+2	0	10
14	Type B	j	8	6
15	Type A	j+3	0	14
16	Type A	j+3	0	10

Table 6.1.2.1.1-3: Default PUSCH time domain resource allocation A for extended CP

Row index	PUSCH mapping type	K_2	S	L
1	Type A	j	0	8
2	Type A	j	0	12
3	Type A	j	0	10
4	Type B	j	2	10
5	Type B	j	4	4
6	Type B	j	4	8
7	Type B	j	4	6
8	Type A	j+1	0	8
9	Type A	j+1	0	12
10	Type A	j+1	0	10
11	Type A	j+2	0	6
12	Type A	j+2	0	12
13	Type A	j+2	0	10
14	Type B	j	8	4
15	Type A	j+3	0	8
16	Type A	j+3	0	10

Table 6.1.2.1.1-4: Definition of value *j*

μ_{PUSCH}	j
0	1
1	1
2	2
3	3

Table 6.1.2.1.1-5: Definition of value *Δ*

μ_{PUSCH}	Δ
0	2
1	3
2	4
3	6

6.1.2.2 Resource allocation in frequency domain

The UE shall determine the resource block assignment in frequency domain using the resource allocation field in the detected PDCCH DCI except for a PUSCH transmission scheduled by a RAR UL grant or fallbackRAR UL grant, in which case the frequency domain resource allocation is determined according to clause 8.3 of [6, 38.213] or a MsgA PUSCH transmission with frequency domain resource allocation determined according to clause 8.1A of [6, 38.213]. Three uplink resource allocation schemes type 0, type 1 and type 2 are supported. Uplink resource allocation scheme type 0 is supported for PUSCH only when transform precoding is disabled. Uplink resource allocation scheme type 1 and type 2 are supported for PUSCH for both cases when transform precoding is enabled or disabled.

If the scheduling DCI is configured to indicate the uplink resource allocation type as part of the '*Frequency domain resource'* assignment field by setting a higher layer parameter r*esourceAllocation* in *pusch-Config* to 'dynamicSwitch', for DCI format 0_1 or setting a higher layer parameter *resourceAllocationDCI-0-2* in *pusch-Config* to 'dynamicSwitch' for DCI format 0_2, the UE shall use uplink resource allocation type 0 or type 1 as defined by this DCI field. Otherwise the UE shall use the uplink frequency resource allocation type as defined by the higher layer parameter *resourceAllocation* for DCI format 0_1 or the higher layer parameter *resourceAllocationDCI-0-2* for DCI format 0_2. The UE shall assume that when the scheduling PDCCH is received with DCI format 0_1 and *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* is configured, uplink type 2 resource allocation is used.

The UE shall assume that when the scheduling PDCCH is received with DCI format 0_0, then uplink resource allocation type 1 is used, except when any of the higher layer parameters *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* and *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* is configured in which case uplink resource allocation type 2 is used.

The UE expects that either none or both of *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* and *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* is configured.

If a bandwidth part indicator field is not configured in the scheduling DCI or the UE does not support active bandwidth part change via DCI, the RB indexing for uplink type 0, type 1 and type 2 resource allocation is determined within the UE's active bandwidth part. If a bandwidth part indicator field is configured in the scheduling DCI and the UE supports active bandwidh part change via DCI, the RB indexing for uplink type 0, type 1, type 2 resource allocation is determined within the UE's bandwidth part indicated by bandwidth part indicator field value in the DCI. The UE shall upon detection of PDCCH intended for the UE determine first the uplink bandwidth part and then the resource allocation within the bandwidth part. RB numbering starts from the lowest RB in the determined uplink bandwidth part.

6.1.2.2.1 Uplink resource allocation type 0

In uplink resource allocation of type 0, the resource block assignment information includes a bitmap indicating the Resource Block Groups (RBGs) that are allocated to the scheduled UE where a RBG is a set of consecutive virtual resource blocks defined by higher layer parameter *rbg-Size* configured in *pusch-Config* and the size of the bandwidth part as defined in Table 6.1.2.2.1-1.

Table 6.1.2.2.1-1: Nominal RBG size *P*

Bandwidth Part Size	Configuration 1	Configuration 2
1 – 36	*2*	4
37 – 72	4	8
73 – 144	8	16
145 – 275	16	16

The total number of RBGs (N_{RBG}) for a uplink bandwidth part i of size $N_{\mathrm{BWP,i}}^{size}$ PRBs is given by

$N_{RBG} = \left\lceil \left(N_{BWP,i}^{size} + \left(N_{BWP,i}^{start} \bmod P \right) \right) / P \right\rceil$ where

- the size of the first RBG is $RBG_0^{size} = P - N_{BWP,i}^{start} \bmod P$,
- the size of the last RBG is $RBG_{last}^{size} = \left(N_{BWP,i}^{start} + N_{BWP,i}^{size}\right) \bmod P$ if $\left(N_{BWP,i}^{start} + N_{BWP,i}^{size}\right) \bmod P > 0$ and P otherwise.
- the size of all other RBG is P.

The bitmap is of size N_{RBG} bits with one bitmap bit per RBG such that each RBG is addressable. The RBGs shall be indexed in the order of increasing frequency of the bandwidth part and starting at the lowest frequency. The order of

RBG bitmap is such that RBG 0 to RBG $N_{\mathrm{RBG}}-1$ are mapped from MSB to LSB of the bitmap. The RBG is allocated to the UE if the corresponding bit value in the bitmap is 1, the RBG is not allocated to the UE otherwise.

In frequency range 1, only 'almost contiguous allocation' defined in [8, TS 38.101-1] is allowed as non-contiguous allocation per component carrier for UL RB allocation for CP-OFDM.

In frequency range 2, non-contiguous allocation per component carrier for UL RB allocation for CP-OFDM is not supported.

6.1.2.2.2 Uplink resource allocation type 1

In uplink resource allocation of type 1, the resource block assignment information indicates to a scheduled UE a set of contiguously allocated non-interleaved virtual resource blocks within the active bandwidth part of size N_{BWP}^{size} PRBs except for the case when DCI format 0_0 is decoded in any common search space in which case the size of the initial UL bandwidth part $N_{\mathrm{BWP},0}^{size}$ shall be used.

An uplink type 1 resource allocation field consists of a resource indication value (*RIV*) corresponding to a starting virtual resource block (RB_{start}) and a length in terms of contiguously allocated resource blocks L_{RBs} . The resource indication value is defined by

if $(L_{RBs}-1)\le\lfloor N_{BWP}^{size}/2\rfloor$ then

$$RIV=N_{BWP}^{size}(L_{RBs}-1)+RB_{start}$$

else

$$RIV=N_{BWP}^{size}(N_{BWP}^{size}-L_{RBs}+1)+(N_{BWP}^{size}-1-RB_{start})$$

where $L_{RBs}\ge 1$ and shall not exceed $N_{BWP}^{size}-RB_{start}$.

When the DCI size for DCI format 0_0 in USS is derived from the initial UL BWP with size $N_{\mathrm{BWP}}^{initial}$ but applied to another active BWP with size of $N_{\mathrm{BWP}}^{active}$, an uplink type 1 resource block assignment field consists of a resource indication value (*RIV*) corresponding to a starting resource block $RB_{start}=0,K,2\cdot K,\ldots,(N_{\mathrm{BWP}}^{initial}-1)\cdot K$ and a length in terms of virtually contiguously allocated resource blocks $L_{RBs}=K,2\cdot K,\ldots,N_{\mathrm{BWP}}^{initial}\cdot K$.

The resource indication value is defined by

if $(L'_{RBs}-1)\le\lfloor N_{BWP}^{initial}/2\rfloor$ then

$$RIV=N_{BWP}^{initial}(L'_{RBs}-1)+RB'_{start}$$

else

$$RIV=N_{BWP}^{initial}(N_{BWP}^{initial}-L'_{RBs}+1)+(N_{BWP}^{initial}-1-RB'_{start})$$

where $L'_{RBs}=L_{RBs}/K$, $RB'_{start}=RB_{start}/K$ and where L'_{RBs} shall not exceed $N_{BWP}^{initial}-RB'_{start}$.

If $N_{BWP}^{active}>N_{BWP}^{initial}$, *K* is the maximum value from set {1, 2, 4, 8} which satisfies $K\le\lfloor N_{BWP}^{active}/N_{BWP}^{initial}\rfloor$; otherwise *K* = 1.

When the scheduling grant is received with DCI format 0_2, an uplink type 1 resource allocation field consists of a resource indication value (*RIV*) corresponding to a starting resource block group RBG_{start}=0, 1, …, N_{RBG}-1 and a length in terms of virtually contiguously allocated resource block groups L_{RBGs}=1, …, N_{RBG}, where the resource block groups are defined as in 6.1.2.2.1 with *P* defined by *resourceAllocationType1GranularityDCI-0-2* if the UE is configured with higher layer parameter *resourceAllocationType1GranularityDCI-0-2*, and *P*=1 otherwise. The resource indication value is defined by if $(L_{RBGs}-1) \le \lfloor N_{RBG}/2 \rfloor$ then

$$RIV = N_{RBG}(L_{RBGs}-1) + RBG_{start}$$

else

$$RIV = N_{RBG}(N_{RBG} - L_{RBGs} + 1) + (N_{RBG} - 1 - RBG_{start})$$

where $L_{RBGs} \ge 1$ and shall not exceed $N_{RBG} - RBG_{start}$.

6.1.2.2.3 Uplink resource allocation type 2

In uplink resource allocation of type 2, the resource block assignment information defined in [5, TS 38.212] indicates to a UE a set of up to M interlace indices, and for DCI 0_0 monitored in a UE-specific search space and DCI 0_1 a set of up to $N_{\text{RB-set,UL}}^{\text{BWP}}$ contiguous RB sets, where M and interlace indexing are defined in Clause 4.4.4.6 in [4, TS 38.211]. Within the active UL BWP, the assigned physical resource block n is mapped to virtual resource block n. For DCI 0_0 monitored in a UE-specific search space and DCI 0_1, the UE shall determine the resource allocation in frequency domain as an intersection of the resource blocks of the indicated interlaces and the union of the indicated set of RB sets and intra-cell guard bands defined in Clause 7 between the indicated RB sets, if any. For DCI 0_0 monitored in a common search space, the UE shall determine the resource allocation in frequency domain as an intersection of the resource blocks of the indicated interlaces and a single uplink RB set of the active UL BWP. For DCI 0_0 monitored in a CSS with CRC scrambled by an RNTI other than TC-RNTI, the uplink RB set is the lowest indexed one amongst uplink RB set(s) that intersects the lowest-indexed CCE of the PDCCH in which the UE detects the DCI 0_0 in the active downlink BWP. If there is no intersection, the uplink RB set is RB set 0 in the active uplink BWP. For DCI 0_0 with CRC scrambled by TC-RNTI, the uplink RB set is the same one in which the UE transmits the PRACH associated with the RAR UL grant, in which case the UE assumes that the uplink RB set is defined as when the UE is not configured with *intraCellGuardBandsUL-List* (see Clause 7).

For μ=0, the X=6 MSBs of the resource block assignment information indicates to a UE a set of allocated interlace indices $m_0 + l$, where the indication consists of a resource indication value (*RIV*). For $0 \le RIV < M(M+1)/2$, $l = 0,1,\cdots L-1$ the resource indication value corresponds to the starting interlace index m_0 and the number of contiguous interlace indices $L(L \ge 1)$. The resource indication value is defined by:

if $(L-1) \le \lfloor M/2 \rfloor$ then

$$RIV = M(L-1) + m_0$$

else

$$RIV = M(M-L+1) + (M-1-m_0)$$

For $RIV \ge M(M+1)/2$, the resource indication value corresponds to the starting interlace index m_0 and the set of values l according to Table 6.1.2.2.3-1.

Table 6.1.2.2.3-1: m_0 and l for $RIV \ge M(M+1)/2$.

$RIV - M(M+1)/2$	m_0	l
0	0	{0, 5}
1	0	{0, 1, 5, 6}
2	1	{0, 5}
3	1	{0, 1, 2, 3, 5, 6, 7, 8}
4	2	{0, 5}
5	2	{0, 1, 2, 5, 6, 7}
6	3	{0, 5}
7	4	{0, 5}

For μ=1, the X=5 MSBs of the resource block assignment information comprise a bitmap indicating the interlaces that are allocated to the scheduled UE. The bitmap is of size M bits with one bitmap bit per interlace such that each interlace is addressable, where M and interlace indexing is defined in Clause 4.4.4.6 in [4, TS 38.211]. The order of interlace bitmap is such that interlace 0 to interlace $M-1$ are mapped from MSB to LSB of the bitmap. An interlace is allocated to the UE if the corresponding bit value in the bitmap is 1; otherwise the interlace is not allocated to the UE.

For DCI 0_0 monitored in a UE-specific search space and DC 0_1 for both μ=0 and μ=1, the $Y = \left\lceil \log_2 \frac{N_{\text{RB-set,UL}}^{\text{BWP}}(N_{\text{RB-set,UL}}^{\text{BWP}}+1)}{2} \right\rceil$ LSBs of the resource block assignment information indicate to a UE a set of contiguously allocated RB sets for PUSCH scheduled by DCI 0_0 monitored in a UE-specific search space, DCI 0_1 and Type 1 and Type 2 configured grant. The resource allocation field consists of a resource indication value ($RIV_{\text{RB-set}}$). For $0 \le RIV_{\text{RB-set}} < N_{\text{RB-set,UL}}^{\text{BWP}}(N_{\text{RB-set,UL}}^{\text{BWP}}+1)/2$, $l = 0,1,\cdots L_{RBset}-1$ the resource indication value corresponds to the starting RB set index $N_{\text{RB-set,UL}}^{\text{start}}$ and the number of contiguous RB sets $L_{\text{RB-set}}$. The resource indication value is defined by;

if $(L_{\text{RB-set}}-1) \le \lfloor N_{\text{RB-set,UL}}^{\text{BWP}}/2 \rfloor$ then

$$RIV_{\text{RB-set}} = N_{\text{RB-set,UL}}^{\text{BWP}}(L_{\text{RB-set}}-1) + N_{\text{RB-set,UL}}^{\text{start}}$$

else

$$RIV_{\text{RB-set}} = N_{\text{RB-set,UL}}^{\text{BWP}}(N_{\text{RB-set,UL}}^{\text{BWP}} - L_{\text{RB-set}}+1) + (N_{\text{RB-set,UL}}^{\text{BWP}} - 1 - N_{\text{RB-set,UL}}^{\text{start}})$$

where $N_{\text{RB-set,UL}}^{\text{start}} = 0,1,\cdots N_{\text{RB-set,UL}}^{\text{BWP}}-1$, $L_{\text{RB-set}} \ge 1$ and shall not exceed $N_{\text{RB-set,UL}}^{\text{BWP}} - N_{\text{RB-set,UL}}^{\text{start}}$

If transform precoding is enabled according to the procedure in Clause 6.1.3, then the UE transmits PUSCH on the lowest-indexed $M_{\text{RB}}^{\text{PUSCH}}$ PRBs amongst the PRBs indicated by the frequency domain resource assignment information. $M_{\text{RB}}^{\text{PUSCH}}$ is the largest integer not greater than the number of RBs indicated by the frequency domain resource assignment information that fulfils the conditions in Clause 6.3.1.4 of [4, TS 38.211].

6.1.2.3 Resource allocation for uplink transmission with configured grant

When PUSCH resource allocation is semi-statically configured by higher layer parameter *configuredGrantConfig* in *BWP-UplinkDedicated* information element, and the PUSCH transmission corresponding to a configured grant, the following higher layer parameters are applied in the transmission:

- For Type 1 PUSCH transmissions with a configured grant, the following parameters are given in *configuredGrantConfig* unless mentioned otherwise:
  - For the determination of the PUSCH repetition type, if the higher layer parameter *pusch-RepTypeIndicator* in *rrc-ConfiguredUplinkGrant* is configured and set to 'pusch-RepTypeB', PUSCH repetition type B is applied; otherwise, PUSCH repetition type A is applied;
  - For PUSCH repetition type A, the selection of the time domain resource allocation table follows the rules for DCI format 0_0 on UE specific search space, as defined in Clause 6.1.2.1.1.
  - For PUSCH repetition type B, the selection of the time domain resource allocation table is as follows:
    - If *pusch-RepTypeIndicatorDCI-0-1* in *pusch-Config* is configured and set to 'pusch-RepTypeB', *pusch-TimeDomainResourceAllocationListDCI-0-1* in *pusch-Config* is used;
    - Otherwise, *pusch-TimeDomainResourceAllocationListDCI-0-2* in *pusch-Config* is used.
    - It is not expected that *pusch-RepTypeIndicator* in *rrc-ConfiguredUplinkGrant* is configured with 'pusch-RepTypeB' when none of *pusch-RepTypeIndicatorDCI-0-1* and *pusch-RepTypeIndicatorDCI-0-2* in *pusch-Config* is set to 'pusch-RepTypeB'.
  - The higher layer parameter *timeDomainAllocation* value *m* provides a row index *m*+1 pointing to the determined time domain resource allocation table, where the start symbol and length are determined following the procedure defined in Clause 6.1.2.1;
  - Frequency domain resource allocation is determined by the *N* LSB bits in the higher layer parameter *frequencyDomainAllocation*, forming a bit sequence $f_{17},...,f_1,f_0$, where f_0 is the LSB, according to the procedure in Clause 6.1.2.2 and *N* is determined as the size of frequency domain resource assignment field in DCI format 0_1 for a given resource allocation type indicated by *resourceAllocation*, except if *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* is configured, in which case uplink type 2 resource allocation is used wherein the UE interprets the LSB bits in the higher layer parameter *frequencyDomainAllocation* as for the frequency domain resource assignment field of DCI 0_1 according to the procedure in Clause 6.1.2.2.3;

- The I_{MCS} is provided by higher layer parameter *mcsAndTBS;*
- Number of DM-RS CDM groups, DM-RS ports, SRS resource indication and DM-RS sequence initialization are determined as in Clause 7.3.1.1.2 of [5, TS 38.212], and the antenna port value, the bit value for DM-RS sequence initialization, precoding information and number of layers, SRS resource indicator are provided by *antennaPort, dmrs-SeqInitialization, precodingAndNumberOfLayers*, and *srs-ResourceIndicator* respectively;
- When frequency hopping is enabled, the frequency offset between two frequency hops can be configured by higher layer parameter *frequencyHoppingOffset.*

- For Type 2 PUSCH transmissions with a configured grant: the resource allocation follows the higher layer configuration according to [10, TS 38.321], and UL grant received on the DCI.
  - The PUSCH repetition type and the time domain resource allocation table are determined by the PUSCH repetition type and the time domain resource allocation table associated with the UL grant received on the DCI, respectively, as defined in Clause 6.1.2.1.

For PUSCH transmissions with a Type 1 or Type 2 configured grant, the number of (nominal) repetitions K to be applied to the transmitted transport block is provided by the indexed row in the time domain resource allocation table if *numberOfRepetitions* is present in the table; otherwise K is provided by the higher layer configured parameters *repK*.

The UE shall not transmit anything on the resources configured by *configuredGrantConfig* if the higher layers did not deliver a transport block to transmit on the resources allocated for uplink transmission without grant.

A set of allowed periodicities P are defined in [12, TS 38.331]. The higher layer parameter *cg-nrofSlots*, provides the number of consecutive slots allocated within a configured grant period. The higher layer parameter *cg-nrofPUSCH-InSlot* provides the number of consecutive PUSCH allocations within a slot, where the first PUSCH allocation follows the higher layer parameter *timeDomainAllocation* for Type 1 PUSCH transmission or the higher layer configuration according to [10, TS 38.321], and UL grant received on the DCI for Type 2 PUSCH transmissions, and the remaining PUSCH allocations have the same length and PUSCH mapping type, and are appended following the previous allocations without any gaps. The same combination of start symbol and length and PUSCH mapping type repeats over the consecutively allocated slots.

For operation with shared spectrum channel access where a UE is performing uplink transmission with configured grants in contiguous OFDM symbols on all resource blocks of an RB set, for the first such UL transmission the UE determines a duration of a cyclic prefix extension T_{ext} to be applied for transmission according to [4, TS 38.211] where the index for Δ_i [4, TS 38.211] is chosen randomly from a set of values configured by higher layers according to the following rule:

- If the first such UL transmission is within a channel occupancy initiated by the gNB (defined in Clause 4 of [16, TS 37.213]), the set of values is determined by *cg-StartingFullBW-InsideCOT*;
- otherwise, the set of values is determined by *cg-StartingFullBW-OutsideCOT*.

For operation with shared spectrum channel access where a UE is performing uplink transmission with configured grants in contiguous OFDM symbols on fewer than all resource blocks of an RB set, for the first such UL transmission the UE determines a duration of a cyclic prefix extension T_{ext} to be applied for transmission according to [4, TS 38.211] according to the following rule:

- If the first such UL transmission is within a channel occupancy initiated by the gNB (defined in Clause 4 of [16, TS 37.213]), the index for Δ_i [4, TS 38.211] is equal to *cg-StartingPartialBW-InsideCOT*;
- otherwise, the index for Δ_i [4, TS 38.211] is equal to *cg-StartingPartialBW-OutsideCOT*.

6.1.2.3.1 Transport Block repetition for uplink transmissions of PUSCH repetition Type A with a configured grant

The procedures described in this clause apply to PUSCH transmissions of PUSCH repetition Type A with a Type 1 or Type 2 configured grant.

The higher layer parameter *repK-RV* defines the redundancy version pattern to be applied to the repetitions. If *cg-RetransmissionTimer* is provided, the redundancy version for uplink transmission with a configured grant is determined by the UE. If the parameter *repK-RV* is not provided in the *configuredGrantConfig* and *cg-RetransmissionTimer* is not provided, the redundancy version for uplink transmissions with a configured grant shall be set to 0. If the parameter *repK-RV* is provided in the *configuredGrantConfig* and *cg-RetransmissionTimer* is not provided, for the *n*th transmission occasion among *K* repetitions, *n*=1, 2, …, *K*, it is associated with $(mod(n\text{-}1,4)+1)^{th}$ value in the configured RV sequence. If a configured grant configuration is configured with *startingFromRV0* set to *'off'*, the initial transmission of a transport block may only start at the first transmission occasion of the *K* repetitions. Otherwise, the initial transmission of a transport block may start at

- the first transmission occasion of the *K* repetitions if the configured RV sequence is {0,2,3,1},
- any of the transmission occasions of the *K* repetitions that are associated with RV=0 if the configured RV sequence is {0,3,0,3},
- any of the transmission occasions of the *K* repetitions if the configured RV sequence is {0,0,0,0}, except the last transmission occasion when $K\geq 8$.

For any RV sequence, the repetitions shall be terminated after transmitting *K* repetitions, or at the last transmission occasion among the *K* repetitions within the period *P*, or from the starting symbol of the repetition that overlaps with a PUSCH with the same HARQ process scheduled by DCI format 0_0, 0_1 or 0_2, whichever is reached first. In addition, the UE shall terminate the repetition of a transport block in a PUSCH transmission if the UE receives a DCI format 0_1 with DFI flag provided and set to '1', and if in this DCI the UE detects ACK for the HARQ process corresponding to that transport block.

The UE is not expected to be configured with the time duration for the transmission of *K* repetitions larger than the time duration derived by the periodicity *P*. If the UE determines that, for a transmission occasion, the number of symbols available for the PUSCH transmission in a slot is smaller than transmission duration *L*, the UE does not transmit the PUSCH in the transmission occasion.

For both Type 1 and Type 2 PUSCH transmissions with a configured grant, when $K > 1$, the UE shall repeat the TB across the *K* consecutive slots applying the same symbol allocation in each slot, except if the UE is provided with higher layer parameters *cg-nrofSlots* and *cg-nrofPUSCH-InSlot*, in which case the UE repeats the TB in the *repK* earliest consecutive transmission occasion candidates within the same configuration. A Type 1 or Type 2 PUSCH transmission with a configured grant in a slot is omitted according to the conditions in Clause 9, Clause 11.1 and Clause 11.2A of [6, TS38.213].

6.1.2.3.2 Transport Block repetition for uplink transmissions of PUSCH repetition Type B with a configured grant

The procedures described in this Clause apply to PUSCH transmissions of PUSCH repetition type B with a Type 1 or Type 2 configured grant.

For PUSCH transmissions with a Type 1 or Type 2 configured grant, the nominal repetitions and the actual repetitions are determined according to the procedures for PUSCH repetition Type B defined in Clause 6.1.2.1. The higher layer configured parameters *repK-RV* defines the redundancy version pattern to be applied to the repetitions. If the parameter *repK-RV* is not provided in the *configuredGrantConfig*, the redundancy version for each actual repetition with a configured grant shall be set to 0. Otherwise, for the *n*th transmission occasion among all the actual repetitions (including the actual repetitions that are omitted) of the *K* nominal repetitions, it is associated with $(mod(n\text{-}1,4)+1)^{th}$ value in the configured RV sequence. If a configured grant configuration is configured with *startingFromRV0* set to 'off', the initial transmission of a transport block may only start at the first transmission occasion of the actual repetitions. Otherwise, the initial transmission of a transport block may start at

- the first transmission occasion of the actual repetitions if the configured RV sequence is {0,2,3,1},
- any of the transmission occasions of the actual repetitions that are associated with RV=0 if the configured RV sequence is {0,3,0,3},
- any of the transmission occasions of the actual repetitions if the configured RV sequence is {0,0,0,0}, except the actual repetitions within the last nominal repetition when $K\geq 8$.

For any RV sequence, the repetitions shall be terminated after transmitting K nominal repetitions, or at the last transmission occasion among the *K* nominal repetitions within the period *P*, or from the starting symbol of an actual repetition that overlaps with a PUSCH with the same HARQ process scheduled by DCI format 0_0, 0_1 or 0_2, whichever is reached first. The UE is not expected to be configured with the time duration for the transmission of *K* nominal repetitions larger than the time duration derived by the periodicity *P*.

6.1.3 UE procedure for applying transform precoding on PUSCH

For a PUSCH scheduled by RAR UL grant, or for a PUSCH scheduled by fallbackRAR UL grant, or for a PUSCH scheduled by DCI format 0_0 with CRC scrambled by TC-RNTI, the UE shall consider the transform precoding either 'enabled' or 'disabled' according to the higher layer configured parameter *msg3-transformPrecoder*.

For a MsgA PUSCH, the UE shall consider the transform precoding either 'enabled' or 'disabled' according to the higher layer configured parameter *msgA-TransformPrecoder.* If higher layer parameter *msgA-TransformPrecoder* is not configured, the UE shall consider the transform precoding either 'enabled' or 'disabled' according to the higher layer configured parameter *msg3-transformPrecoder.*

For PUSCH transmission scheduled by a PDCCH with CRC scrambled by CS-RNTI with NDI=1, C-RNTI, or MCS-C-RNTI or SP-CSI-RNTI:

- If the DCI with the scheduling grant was received with DCI format 0_0, the UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to the higher layer configured parameter *msg3-transformPrecoder.*

- If the DCI with the scheduling grant was not received with DCI format 0_0

  - If the UE is configured with the higher layer parameter *transformPrecoder* in *pusch-Config*, the UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to this parameter.

  - If the UE is not configured with the higher layer parameter *transformPrecoder* in *pusch-Config*, the UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to the higher layer configured parameter *msg3-transformPrecoder*.

For PUSCH transmission with a configured grant

- If the UE is configured with the higher layer parameter *transformPrecoder* in *configuredGrantConfig*, the UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to this parameter.

- If the UE is not configured with the higher layer parameter *transformPrecoder* in *configuredGrantConfig*, the UE shall, for this PUSCH transmission, consider the transform precoding either enabled or disabled according to the higher layer configured parameter *msg3-transformPrecoder*.

6.1.4 Modulation order, redundancy version and transport block size determination

To determine the modulation order, target code rate, redundancy version and transport block size for the physical uplink shared channel, the UE shall first

- read the 5-bit modulation and coding scheme field (I_{MCS}) in the DCI scheduling PUSCH or provided in a DCI activating a configured grant Type 2 PUSCH, or as provided by *mcsAndTBS* as described in Clause 6.1.2.3 for a configured grant Type 1 PUSCH to determine the modulation order (Q_m) and target code rate (R) based on the procedure defined in Clause 6.1.4.1

- read redundancy version field (*rv*) in the DCI to determine the redundancy version for PUSCH scheduled by DCI, or determine the redundancy version according to Clause 6.1.2.3.1 for configured grant Type 1 and Type 2 PUSCH,

and second

- use the number of layers (υ), the total number of allocated PRBs (n_{PRB}) to determine the transport block size based on the procedure defined in Clause 6.1.4.2.

When the UE is scheduled with multiple PUSCHs by a DCI, as described in clause 6.1.2.1, the bits of *rv* field and NDI field, respectively, in the DCI are one to one mapped to the scheduled PUSCH(s) with the corresponding transport block(s) in the scheduled order where the LSB bits of the *rv* field and NDI field, respectively, correspond to the last scheduled PUSCH.

Within a cell group, a UE is not required to handle PUSCH(s) transmissions in slot s_j in serving cell-*j*, and for j = 0,1,2.. *J-1*, slot s_j overlapping with any given point in time, if the following condition is not satisfied at that point in time:

$$\sum_{j=0}^{J-1} \frac{\sum_{m=0}^{M-1} V_{j,m}}{T_{slot}^{\mu(j)}} \leq DataRate,$$

where

- J is the number of configured serving cells belong to a frequency range
  - for the *j-th* serving cell,
    - M is the number of TB(s) transmitted in slot-s_j. For PUSCH repetition Type B, each actual repetition is counted separately.
    - $T_{slot}^{\mu(j)} = 10^{-3}/2^{\mu(j)}$, where $\mu(j)$ is the numerology for PUSCH(s) in slot s_j of the j-th serving cell.
    - for the m-th TB, $V_{j,m} = C' \cdot \left\lfloor \frac{A}{C} \right\rfloor$
      - A is the number of bits in the transport block as defined in Clause 6.2.1 [5, TS 38.212]
      - C is the total number of code blocks for the transport block defined in Clause 5.2.2 [5, TS 38.212].
      - $C'$is the number of scheduled code blocks for the transport block as defined in Clause 5.4.2.1 [5,38.212]
- $DataRate$ [Mbps] is computed as the maximum data rate summed over all the carriers in the frequency range for any signaled band combination and feature set consistent with the configured servings cells, where the data rate value is given by the formula in Clause 4.1.2 in [13, TS 38.306], including the scaling factor *f(i).*

For a j-th serving cell, if higher layer parameter *processingType2Enabled* of *PUSCH-ServingCellConfig* is configured for the serving cell and set to 'enable', or if at least one $I_{MCS} > W$ for a PUSCH, where W = 28 for MCS tables 5.1.3.1-1 and 5.1.3.1-3, and W = 27 for MCS tables 5.1.3.1-2, 6.1.4.1-1, and 6.1.4.1-2, or if it is an actual repetition for PUSCH repetition Type B, the UE is not required to handle PUSCH transmissions, if the following condition is not satisfied:

$$\frac{\sum_{m=0}^{M-1} V_{j,m}}{L \times T_s^{\mu}} \leq DataRateCC$$

where

- L is the number of symbols assigned to the PUSCH
- M is the number of TB in the PUSCH
- $T_s^{\mu} = \frac{10^{-3}}{2^{\mu} \cdot N_{symb}^{slot}}$ where μ is the numerology of the PUSCH
- for the m-th TB, $V_{j,m} = C' \cdot \left\lfloor \frac{A}{C} \right\rfloor$
  - A is the number of bits in the transport block as defined in Clause 6.2.1 [5, TS 38.212]
  - C is the total number of code blocks for the transport block defined in Clause 5.2.2 [5, TS 38.212]
  - C' is the number of scheduled code blocks for the transport block as defined in Clause 5.4.2.1 [5, TS 38.212]
- $DataRateCC$ [Mbps] is computed as the maximum data rate for a carrier in the frequency band of the serving cell for any signaled band combination and feature set consistent with the serving cell, where the data rate value is given by the formula in Clause 4.1.2 in [13, TS 38.306], including the scaling factor *f(i)*
- each actual repetition for PUSCH repetition type B is treated as one PUSCH.

6.1.4.1 Modulation order and target code rate determination

For a PUSCH scheduled by RAR UL grant or for a PUSCH scheduled by a fallbackRAR UL grant or

for a MsgA PUSCH transmission, or

for a PUSCH scheduled by a DCI format 0_0 with CRC scrambled by C-RNTI, MCS-C-RNTI, TC-RNTI, CS-RNTI, or

for a PUSCH scheduled by a DCI format 0_1 or DCI format 0_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI, SP-CSI-RNTI, or

for a PUSCH with configured grant using CS-RNTI, and

if transform precoding is disabled for this PUSCH transmission according to Clause 6.1.3

- if *mcs-TableDCI-0-2* in *pusch-Config* is set to 'qam256', and PUSCH is scheduled by a PDCCH with DCI format 0_2 with CRC scrambled by C-RNTI or SP-CSI-RNTI,
  - the UE shall use I_{MCS} and Table 5.1.3.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel;
- elseif the UE is not configured with MCS-C-RNTI, *mcs-TableDCI-0-2* in *pusch-Config* is set to 'qam64LowSE', and the PUSCH is scheduled by a PDCCH by a PDCCH with DCI format 0_2 with CRC scrambled by C-RNTI or SP-CSI-RNTI,
  - the UE shall use I_{MCS} and Table 5.1.3.1-3 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif *mcs-Table* in *pusch-Config* is set to 'qam256', and PUSCH is scheduled by a PDCCH with DCI format 0_1 with CRC scrambled by C-RNTI or SP-CSI-RNTI,
  - the UE shall use I_{MCS} and Table 5.1.3.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif the UE is not configured with MCS-C-RNTI, *mcs-Table* in *pusch-Config* is set to 'qam64LowSE', and the PUSCH is scheduled by a PDCCH with a DCI format other than DCI format 0_2 in a UE-specific search space with CRC scrambled by C-RNTI or SP-CSI-RNTI,
  - the UE shall use I_{MCS} and Table 5.1.3.1-3 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif the UE is configured with MCS-C-RNTI, and the PUSCH is scheduled by a PDCCH with CRC scrambled by MCS-C-RNTI,
  - the UE shall use I_{MCS} and Table 5.1.3.1-3 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif *mcs-Table* in *configuredGrantConfig* is set to 'qam256',
  - if PUSCH is scheduled by a PDCCH with CRC scrambled by CS-RNTI or
  - if PUSCH is transmitted with configured grant
    - the UE shall use I_{MCS} and Table 5.1.3.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif *mcs-Table* in *configuredGrantConfig* is set to 'qam64LowSE',
  - if PUSCH is scheduled by a PDCCH with CRC scrambled by CS-RNTI or
  - if PUSCH is transmitted with configured grant,
    - the UE shall use I_{MCS} and Table 5.1.3.1-3 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif for a MsgA PUSCH transmission,
  - the UE shall use higher layer parameter *msgA-MCS* for I_{MCS} and Table 5.1.3.1-1 to determine the Target code rate (R) used in the physical uplink shared channel.

- else
  - the UE shall use I_{MCS} and Table 5.1.3.1-1 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.

else

- if *mcs-TableTransformPrecoderDCI-0-2* in *pusch-Config* is set to 'qam256', and PUSCH is scheduled by a PDCCH with DCI format 0_2 with CRC scrambled by C-RNTI or SP-CSI-RNTI,
  - the UE shall use I_{MCS} and Table 5.1.3.1.-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif the UE is not configured with MCS-C-RNTI, *mcs-TableTransformPrecoderDCI-0-2* in *pusch-Config* is set to 'qam64LowSE', and the PUSCH is scheduled by a PDCCH with DCI format 0_2 with CRC scrambled by C-RNTI or SP-CSI-RNTI,
  - the UE shall use I_{MCS} and Table 6.1.4.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif *mcs-TableTransformPrecoder* in *pusch-Config* is set to 'qam256', and PUSCH is scheduled by a PDCCH with DCI format 0_1 with CRC scrambled by C-RNTI or SP-CSI-RNTI,
  - the UE shall use I_{MCS} and Table 5.1.3.1.-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif the UE is not configured with MCS-C-RNTI, *mcs-TableTransformPrecoder* in *pusch-Config* is set to 'qam64LowSE', and the PUSCH is scheduled by a PDCCH with a DCI format other than DCI format 0_2 in a UE-specific search space with CRC scrambled by C-RNTI or SP-CSI-RNTI,
  - the UE shall use I_{MCS} and Table 6.1.4.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif the UE is configured with MCS-C-RNTI, and the PUSCH is scheduled by a PDCCH with CRC scrambled by MCS-C-RNTI,
  - the UE shall use I_{MCS} and Table 6.1.4.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif *mcs-TableTransformPrecoder* in *configuredGrantConfig* is set to 'qam256',
  - if PUSCH is scheduled by a PDCCH with CRC scrambled by CS-RNTI or
  - if PUSCH is transmitted with configured grant,
    - the UE shall use I_{MCS} and Table 5.1.3.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif *mcs-TableTransformPrecoder* in *configuredGrantConfig* is set to 'qam64LowSE',
  - if PUSCH is scheduled by a PDCCH with CRC scrambled by CS-RNTI or
  - if PUSCH is transmitted with configured grant,
    - the UE shall use I_{MCS} and Table 6.1.4.1-2 to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.
- elseif for a MsgA PUSCH transmission,
  - the UE shall use higher layer parameter *MsgA-MCS* for I_{MCS} and Table 6.1.4.1-1 to determine the Target code rate (R) used in the physical uplink shared channel.
  - the UE shall use $q=2$ for determining modulation order Q_m in Table 6.1.4.1-1.
- else

- the UE shall use I_{MCS} and Table 6.1.4.1-1to determine the modulation order (Q_m) and Target code rate (R) used in the physical uplink shared channel.

end

For Table 6.1.4.1-1 and Table 6.1.4.1-2, if higher layer parameter *tp-pi2BPSK* is configured, q = 1 otherwise q=2.

Table 6.1.4.1-1: MCS index table for PUSCH with transform precoding and 64QAM

MCS Index I_{MCS}	Modulation Order Q_m	Target code Rate R x 1024	Spectral efficiency
0	q	240/ q	0.2344
1	q	314/ q	0.3066
2	2	193	0.3770
3	2	251	0.4902
4	2	308	0.6016
5	2	379	0.7402
6	2	449	0.8770
7	2	526	1.0273
8	2	602	1.1758
9	2	679	1.3262
10	4	340	1.3281
11	4	378	1.4766
12	4	434	1.6953
13	4	490	1.9141
14	4	553	2.1602
15	4	616	2.4063
16	4	658	2.5703
17	6	466	2.7305
18	6	517	3.0293
19	6	567	3.3223
20	6	616	3.6094
21	6	666	3.9023
22	6	719	4.2129
23	6	772	4.5234
24	6	822	4.8164
25	6	873	5.1152
26	6	910	5.3320
27	6	948	5.5547
28	q	reserved	
29	2	reserved	
30	4	reserved	
31	6	reserved	

Table 6.1.4.1-2: MCS index table 2 for PUSCH with transform precoding and 64QAM

MCS Index I_{MCS}	Modulation Order Q_m	Target code Rate R x 1024	Spectral efficiency
0	q	$60/q$	0.0586
1	q	$80/q$	0.0781
2	q	$100/q$	0.0977
3	q	$128/q$	0.1250
4	q	$156/q$	0.1523
5	q	$198/q$	0.1934
6	2	120	0.2344
7	2	157	0.3066
8	2	193	0.3770
9	2	251	0.4902
10	2	308	0.6016
11	2	379	0.7402
12	2	449	0.8770
13	2	526	1.0273
14	2	602	1.1758
15	2	679	1.3262
16	4	378	1.4766
17	4	434	1.6953
18	4	490	1.9141
19	4	553	2.1602
20	4	616	2.4063
21	4	658	2.5703
22	4	699	2.7305
23	4	772	3.0156
24	6	567	3.3223
25	6	616	3.6094
26	6	666	3.9023
27	6	772	4.5234
28	q	reserved	
29	2	reserved	
30	4	reserved	
31	6	reserved	

6.1.4.2 Transport block size determination

For a PUSCH scheduled by RAR UL grant or

for a PUSCH scheduled by fallbackRAR UL grant or

for a PUSCH scheduled by a DCI format 0_0 with CRC scrambled by C-RNTI, MCS-C-RNTI, TC-RNTI, CS-RNTI, or

for a PUSCH scheduled by a DCI format 0_1 or DCI format 0_2 with CRC scrambled by C-RNTI, MCS-C-RNTI, CS-RNTI, or

for a PUSCH transmission with configured grant, or

for a MsgA PUSCH transmission,

if

- $0 \le I_{MCS} \le 27$ and transform precoding is disabled and Table 5.1.3.1-2 is used, or
- $0 \le I_{MCS} \le 28$ and transform precoding is disabled and a table other than Table 5.1.3.1-2 is used, or
- $0 \le I_{MCS} \le 27$ and transform precoding is enabled, the UE shall first determine the TBS as specified below:

The UE shall first determine the number of REs (N_{RE}) within the slot:

- A UE first determines the number of REs allocated for PUSCH within a PRB $\left(N'_{RE}\right)$ by

- $N'_{RE} = N_{sc}^{RB} \cdot N_{symb}^{sh} - N_{DMRS}^{PRB} - N_{oh}^{PRB}$, where $N_{sc}^{RB} = 12$ is the number of subcarriers in the frequency domain in a physical resource block, N_{symb}^{sh} is the number of symbols L of the PUSCH allocation according to Clause 6.1.2.1 for scheduled PUSCH or Clause 6.1.2.3 for configured PUSCH, N_{DMRS}^{PRB} is the number of REs for DM-RS per PRB in the allocated duration including the overhead of the DM-RS CDM groups without data, as described for PUSCH with a configured grant in Clause 6.1.2.3 or as indicated by DCI format 0_1 or DCI format 0_2 or as described for DCI format 0_0 in Clause 6.2.2, and N_{oh}^{PRB} is the overhead configured by higher layer parameter *xOverhead* in *PUSCH-ServingCellConfig*. If the N_{oh}^{PRB} is not configured (a value from 6, 12, or 18), the N_{oh}^{PRB} is assumed to be 0. For Msg3 or MsgA PUSCH transmission the N_{oh}^{PRB} is always set to 0. In case of PUSCH repetition Type B, N_{DMRS}^{PRB} is determined assuming a nominal repetition with the duration of L symbols without segmentation.

- A UE determines the total number of REs allocated for PUSCH $\left(N_{RE}\right)$ by $N_{RE} = \min\left(156, N'_{RE}\right) \cdot n_{PRB}$ where n_{PRB} is the total number of allocated PRBs for the UE.

- Next, proceed with steps 2-4 as defined in Clause 5.1.3.2

- For a PUSCH scheduled by fallbackRAR UL grant, UE assumes the TB size determined by the UL grant in the fallbackRAR shall be the same as the TB size used in the corresponding MsgA PUSCH transmission.

else if

- $28 \le I_{MCS} \le 31$ and transform precoding is disabled and Table 5.1.3.1-2 is used, or

- $28 \le I_{MCS} \le 31$ and transform precoding is enabled,

- the TBS is assumed to be as determined from the DCI transported in the latest PDCCH for the same transport block using $0 \le I_{MCS} \le 27$. If there is no PDCCH for the same transport block using $0 \le I_{MCS} \le 27$, and if the initial PUSCH for the same transport block is transmitted with configured grant,

  - the TBS shall be determined from *configuredGrantConfig* for a configured grant Type 1 PUSCH.

  - the TBS shall be determined from the most recent PDCCH scheduling a configured grant Type 2 PUSCH.

else

- the TBS is assumed to be as determined from the DCI transported in the latest PDCCH for the same transport block using $0 \le I_{MCS} \le 28$. If there is no PDCCH for the same transport block using $0 \le I_{MCS} \le 28$, and if the initial PUSCH for the same transport block is transmitted with configured grant,

  - the TBS shall be determined from *configuredGrantConfig* for a configured grant Type 1 PUSCH.

  - the TBS shall be determined from the most recent PDCCH scheduling a configured grant Type 2 PUSCH.

6.1.5 Code block group based PUSCH transmission

6.1.5.1 UE procedure for grouping of code blocks to code block groups

If a UE is configured to transmit code block group (CBG) based transmissions by receiving the higher layer parameter *codeBlockGroupTransmission* in *PUSCH-ServingCellConfig*, the UE shall determine the number of CBGs for a PUSCH transmission as

$$M = \min\left(N, C\right),$$

where *N* is the maximum number of CBGs per transport block as configured by *maxCodeBlockGroupsPerTransportBlock* in *PUSCH-ServingCellConfig*, and *C* is the number of code blocks in the PUSCH according to the procedure defined in Clause 6.2.3 of [5, TS 38.212].

Define $M_1 = \mathrm{mod}(C, M)$, $K_1 = \left\lceil \frac{C}{M} \right\rceil$, and $K_2 = \left\lfloor \frac{C}{M} \right\rfloor$.

If $M_1 > 0$, CBG *m*, $m = 0,1,..., M_1 - 1$, consists of code blocks with indices $m \cdot K_1 + k, k = 0,1,..., K_1 - 1$. CBG *m*, $m = M_1, M_1 + 1,..., M - 1$, consists of code blocks with indices $M_1 \cdot K_1 + (m - M_1) \cdot K_2 + k, k = 0,1,..., K_2 - 1$.

6.1.5.2 UE procedure for transmitting code block group based transmissions

If a UE is configured to transmit code block group-based transmissions by receiving the higher layer parameter *codeBlockGroupTransmission* in *PUSCH-ServingCellConfig,*

- For an initial transmission of a TB as indicated by the '*New Data Indicator'* field of the scheduling DCI, the UE may expect that the *CBGTI* field indicates all the CBGs of the TB are to be transmitted, and the UE shall include all the code block groups of the TB.

- For a retransmission of a TB as indicated by the '*New Data Indicator'* field of the scheduling DCI, the UE shall include only the CBGs indicated by the *CBGTI* field of the scheduling DCI.

A bit value of '0' in the *CBGTI* field indicates that the corresponding CBG is not to be transmitted and '1' indicates that it is to be transmitted. The order of *CBGTI* field bits is such that the CBGs are mapped in order from CBG#0 onwards starting from the MSB.

6.1.6 Uplink switching

The UE may omit uplink transmission during the uplink switching gap $N_{\mathrm{Tx1\text{-}Tx2}}$ if the conditions defined in this clause are met and the UE is configured with *uplinkTxSwitching*. The switching gap $N_{\mathrm{Tx1\text{-}Tx2}}$ is indicated by UE capability *uplinkTxSwitchingPeriod*:

- If a UE indicated a capability for uplink switching with *BandCombination-UplinkTxSwitch* for a band combination, and if it is for that band combination
  - Configured with a MCG using E-UTRA radio access and with a SCG using NR radio access (EN-DC), or
  - Configured with uplink carrier aggregation, or
  - Configured in a serving cell with two uplink carriers with higher layer parameter *supplementaryUplink*.

    the conditions under which the switching gap may be present and the location of the switching gap are defined for each of the cases in clauses 6.1.6.1, 6.1.6.2, and 6.1.6.3 respectively.

If an uplink switching is triggered for an uplink transmission starting at T_0, after T_0-T_{offset}, the UE is not expected to cancel the uplink switching, or to trigger any other new uplink switching occurring before T_0 for any other uplink transmission that is scheduled after T_0-T_{offset}, where T_{offset} is the UE processing procedure time defined for the uplink transmission triggering the switch given in clause 5.3, clause 5.4, clause 6.2.1, clause 6.4 and in clause 9 of [6, TS 38.213].

The UE does not expect to perform more than one uplink switching in a slot with $\mu_{UL} = \max(\mu_{UL,1}, \mu_{UL,2})$, where the $\mu_{UL,1}$ corresponds to the subcarrier spacing of the active UL BWP of one uplink carrier before the switching gap and the $\mu_{UL,2}$ corresponds to the subcarrier spacing of the active UL BWP of the other uplink carrier after the switching gap.

6.1.6.1 Uplink switching for EN-DC

For a UE indicating a capability for uplink switching with *BandCombination-UplinkTxSwitch* for a band combination, and if it is for that band combination configured with a MCG using E-UTRA radio access and with a SCG using NR radio access (EN-DC), if the UE is configured with uplink switching with parameter *uplinkTxSwitching*,

- for the UE configured with *switchedUL* by the parameter *uplinkTxSwitchingOption*, when the UE is to transmit in the uplink based on DCI(s) received before $\boldsymbol{T_0 - T_{offset}}$ or based on a higher layer configuration(s):

  - when the UE is to transmit an NR uplink that takes place after an E-UTRA uplink on another uplink carrier then the UE is not expected to transmit for the duration of $N_{\mathrm{Tx1\text{-}Tx2}}$ on any of the two carriers.
  - when the UE is to transmit an E-UTRA uplink that takes place after an NR uplink on another uplink carrier then the UE is not expected to transmit for the duration of $N_{\mathrm{Tx1\text{-}Tx2}}$ on any of the two carriers.
  - the UE is not expected to transmit simultaneously on the NR uplink and the E-UTRA uplink. If the UE is scheduled or configured to transmit any NR uplink transmission overlapping with an E-UTRA uplink transmission, the NR uplink transmission is dropped,
- for the UE configured with *uplinkTxSwitchingOption* set to 'dualUL', when the UE is to transmit in the uplink based on DCI(s) received before $\boldsymbol{T_0 - T_{offset}}$ or based on a higher layer configuration(s):
  - when the UE is to transmit an NR two-port uplink that takes place after an E-UTRA uplink on another uplink carrier then the UE is not expected to transmit for the duration of $N_{\mathrm{Tx1\text{-}Tx2}}$ on any of the two carriers.
  - when the UE is to transmit an E-UTRA uplink that takes place after an NR two-port uplink on another uplink carrier then the UE is not expected to transmit for the duration of $N_{\mathrm{Tx1\text{-}Tx2}}$ on any of the two carriers.
  - the UE is not expected to transmit simultaneously a two- port transmission on the NR uplink and the E-UTRA uplink.
- in all other cases the UE is expected to transmit normally all uplink transmissions without interruptions.
- when the UE is configured with *tdm-PatternConfig* or by *tdm-PatternConfig2*
  - for the E-UTRA subframes designated as uplink by the configuration, the UE assumes the operation state in which one-port E-UTRA uplink can be transmitted.
  - for the E-UTRA subframes other than the ones designated as uplink by the configuration, the UE assumes the operation state in which two-port NR uplink can be transmitted.

6.1.6.2 Uplink switching for carrier aggregation

For a UE indicating a capability for uplink switching with *BandCombination-UplinkTxSwitch* for a band combination, and if it is for that band combination configured with uplink carrier aggregation:

- If the UE is configured with uplink switching with parameter *uplinkTxSwitching*, when the UE is to transmit in the uplink based on DCI(s) received before $\boldsymbol{T_0 - T_{offset}}$ or based on a higher layer configuration(s):
  - When the UE is to transmit a 2-port transmission on one uplink carrier and if the preceding uplink transmission is a 1-port transmission on another uplink carrier, then the UE is not expected to transmit for the duration of $N_{\mathrm{Tx1\text{-}Tx2}}$ on any of the two carriers.
  - When the UE is to transmit a 1-port transmission on one uplink carrier and if the preceding uplink transmission is a 2-port transmission on another uplink carrier, then the UE is not expected to transmit for the duration of $N_{\mathrm{Tx1\text{-}Tx2}}$ on any of the two carriers.
  - For the UE configured with *uplinkTxSwitchingOption* set to 'switchedUL', when the UE is to transmit a 1-port transmission on one uplink carrier and if the preceding uplink transmission was a 1-port transmission on another uplink carrier, then the UE is not expected to transmit for the duration of $N_{\mathrm{Tx1\text{-}Tx2}}$ on any of the two carriers.
  - For the UE configured with *uplinkTxSwitchingOption* set to 'dualUL', when the UE is to transmit a 2-port transmission on one uplink carrier and if the preceding uplink transmission was a 1-port transmission on the same uplink carrier and the UE is under the operation state in which 2-port transmission cannot be supported in the same uplink carrier, then the UE is not expected to transmit for the duration of $N_{\mathrm{Tx1\text{-}Tx2}}$ on any of the two carriers.
  - For the UE configured with *uplinkTxSwitchingOption* set to 'dualUL', when the UE is to transmit a 1-port transmission on one uplink carrier and if the preceding uplink transmission was a 1-port transmission on another uplink carrier and the UE is under the operation state in which 2-port transmission can be supported on the same uplink carrier, then the UE is not expected to transmit for the duration of $N_{\mathrm{Tx1\text{-}Tx2}}$ on any of the two carriers.

  - The UE is not expected to be scheduled or configured with uplink transmissions that result in simultaneous transmission on two antenna ports on one uplink carrier, and any transmission on another uplink carrier.

- In all other cases the UE is expected to transmit normally all uplink transmissions without interruptions.

6.1.6.3 Uplink switching for supplementary uplink

For a UE indicating a capability for uplink switching with *BandCombination-UplinkTxSwitch* for a band combination, and if it is for that band combination configured in a serving cell with two uplink carriers with higher layer parameter *supplementaryUplink*:

- If the UE is configured with uplink switching with parameter *uplinkTxSwitching*,

  - If the UE is to transmit any uplink channel or signal on a different uplink from the preceding transmission occasion based on DCI(s) received before $\boldsymbol{T_0 - T_{offset}}$ or based on a higher layer configuration(s), then the UE assumes that an uplink switching is triggered in a duration of switching gap $\boldsymbol{N}_{\text{Tx1-Tx2}}$, where $\boldsymbol{T_0}$ is the start time of the first symbol of the transmission occasion of the uplink channel or signal and $\boldsymbol{T_{offset}}$ is the preparation procedure time of the transmission occasion of the uplink channel or signal given in clause 5.3, clause 5.4, clause 6.2.1, clause 6.4 and in clause 9 of [6, TS 38.213], respectively. During the switching gap $\boldsymbol{N}_{\text{Tx1-Tx2}}$, the UE is not expected to transmit on any of the two uplinks.

- In all other cases the UE is expected to transmit normally all uplink transmissions without interruptions.

6.2 UE reference signal (RS) procedure

6.2.1 UE sounding procedure

The UE may be configured with one or more Sounding Reference Signal (SRS) resource sets as configured by the higher layer parameter *SRS-ResourceSet* or *SRS-PosResourceSet*. For each SRS resource set configured by *SRS-ResourceSet*, a UE may be configured with $K \geq 1$ SRS resources (higher layer parameter *SRS-Resource*), where the maximum value of K is indicated by UE capability [13, 38.306]. When SRS resource set is configured with the higher layer parameter *SRS-PosResourceSet*, a UE may be configured with $K \geq 1$ SRS resources (higher layer parameter *SRS-PosResource*), where the maximum value of K is 16. The SRS resource set applicability is configured by the higher layer parameter *usage* in *SRS-ResourceSet*. When the higher layer parameter *usage* is set to 'beamManagement', only one SRS resource in each of multiple SRS resource sets may be transmitted at a given time instant, but the SRS resources in different SRS resource sets with the same time domain behaviour in the same BWP may be transmitted simultaneously.

For aperiodic SRS at least one state of the DCI field is used to select at least one out of the configured SRS resource set(s).

The following SRS parameters are semi-statically configurable by higher layer parameter *SRS-Resource* or *SRS-PosResource*.

- *srs-ResourceId* or *SRS-PosResourceId* determines SRS resource configuration identity.

- Number of SRS ports, as defined by the higher layer parameter *nrofSRS-Ports* and described in Clause 6.4.1.4 of [4, TS 38.211]. If not configured, *nrofSRS-Ports* is 1.

- Time domain behaviour of SRS resource configuration as indicated by the higher layer parameter *resourceType*, which may be periodic, semi-persistent, aperiodic SRS transmission as defined in Clause 6.4.1.4 of [4, TS 38.211].

- Slot level periodicity and slot level offset as defined by the higher layer parameters *periodicityAndOffset-p* or *periodicityAndOffset-sp* for an SRS resource of type periodic or semi-persistent. The UE is not expected to be configured with SRS resources in the same SRS resource set *SRS-ResourceSet* or *SRS-PosResourceSet* with different slot level periodicities. For an *SRS-ResourceSet* configured with higher layer parameter *resourceType* set to 'aperiodic', a slot level offset is defined by the higher layer parameter *slotOffset*. For an *SRS-PosResourceSet* configured with higher layer parameter r*esourceType* set to 'aperiodic', the slot level offset is defined by the higher layer parameter *slotOffset* for each SRS resource.

- Number of OFDM symbols in the SRS resource, starting OFDM symbol of the SRS resource within a slot including repetition factor R as defined by the higher layer parameter *resourceMapping* and described in Clause

6.4.1.4 of [4, TS 38.211]. If R is not configured, then R is equal to the number of OFDM symbols in the SRS resource.

- SRS bandwidth B_{SRS} and C_{SRS}, as defined by the higher layer parameter *freqHopping* and described in Clause 6.4.1.4 of [4, TS 38.211]. If not configured, then B_{SRS} = 0.

- Frequency hopping bandwidth b_{hop}, as defined by the higher layer parameter *freqHopping* and described in Clause 6.4.1.4 of [4, TS 38.211]. If not configured, then b_{hop} = 0.

- Defining frequency domain position and configurable shift, as defined by the higher layer parameters *freqDomainPosition* and *freqDomainShift*, respectively, and described in Clause 6.4.1.4 of [4, TS 38.211]. If *freqDomainPosition* is not configured, *freqDomainPosition* is zero.

- Cyclic shift, as defined by the higher layer parameter *cyclicShift-n2*, *cyclicShift-n4, or cyclicShift-n8* for transmission comb value 2, 4 or 8, and described in Clause 6.4.1.4 of [4, TS 38.211].

- Transmission comb value, as defined by the higher layer parameter *transmissionComb* described in Clause 6.4.1.4 of [4, TS 38.211].

- Transmission comb offset, as defined by the higher layer parameter *combOffset-n2*, *combOffset-n4,* and *combOffset-n8* for transmission comb value 2, 4, or 8, and described in Clause 6.4.1.4 of [4, TS 38.211].

- SRS sequence ID, as defined by the higher layer parameter *sequenceId* in Clause 6.4.1.4 of [4].

- The configuration of the spatial relation between a reference RS and the target SRS, where the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos*, if configured, contains the ID of the reference RS. The reference RS may be an SS/PBCH block, CSI-RS configured on serving cell indicated by higher layer parameter *servingCellId* if present, same serving cell as the target SRS otherwise, or an SRS configured on uplink BWP indicated by the higher layer parameter *uplinkBWP*, and serving cell indicated by the higher layer parameter *servingCellId* if present, same serving cell as the target SRS otherwise. When the target SRS is configured by the higher layer parameter *SRS-PosResourceSet*, the reference RS may also be a DL PRS configured on a serving cell or a non-serving cell indicated by the higher layer parameter *dl-PRS*, or an SS/PBCH block of a non-serving cell indicated by the higher layer parameter *ssb-Ncell*.

The UE may be configured by the higher layer parameter *resourceMapping* in *SRS-Resource* with an SRS resource occupying $N_S \in \{1,2,4\}$ adjacent OFDM symbols within the last 6 symbols of the slot, or at any symbol location within the slot if *resourceMapping-r16* is provided subject to UE capability, where all antenna ports of the SRS resources are mapped to each symbol of the resource. When the SRS is configured with the higher layer parameter *SRS-PosResourceSet* the higher layer parameter *resourceMapping-r16* in *SRS-PosResource* indicates an SRS resource occupying $N_S \in \{1,2,4,8,12\}$ adjacent symbols anywhere within the slot.

If a PUSCH with a priority index 0 and SRS configured by *SRS-Resource* are transmitted in the same slot on a serving cell, the UE may only be configured to transmit SRS after the transmission of the PUSCH and the corresponding DM-RS.

If a PUSCH transmission with a priority index 1 or a PUCCH transmission with a priority index 1 would overlap in time with an SRS transmission on a serving cell, the UE does not transmit the SRS in the overlapping symbol(s).

For a UE configured with one or more SRS resource configuration(s), and when the higher layer parameter *resourceType* in *SRS-Resource* or *SRS-PosResource* is set to 'periodic':

- if the UE is configured with the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos* containing the ID of a reference 'ssb-Index', 'ssb-IndexServing', or 'ssb-IndexNcell', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference SS/PBCH block, if the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos* contains the ID of a reference 'csi-RS-Index' or 'csi-RS-IndexServing', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference periodic CSI-RS or of the reference semi-persistent CSI-RS, if the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos* containing the ID of a reference 'srs' or 'srs-spatialRelation', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the transmission of the reference periodic SRS. When the SRS is configured by the higher layer parameter *SRS-PosResource* and if the higher layer parameter *spatialRelationInfoPos* contains the ID of a reference 'dl-PRS', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference DL PRS.

For a UE configured with one or more SRS resource configuration(s), and when the higher layer parameter *resourceType* in *SRS-Resource* or *SRS-PosResource* is set to 'semi-persistent':

- when a UE receives an activation command, as described in clause 6.1.3.17 or 6.1.3.36 of [10, TS 38.321], for an SRS resource, and when the UE would transmit a PUCCH with HARQ-ACK information in slot *n* corresponding to the PDSCH carrying the activation command is transmitted in slot *n*, the corresponding actions in [10, TS 38.321] and the UE assumptions on SRS transmission corresponding to the configured SRS resource set shall be applied starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$ where μ is the SCS configuration for the PUCCH. The activation command also contains spatial relation assumptions provided by a list of references to reference signal IDs, one per element of the activated SRS resource set. When the SRS is configured with the higher layer parameter *SRS-ResourceSet*, each ID in the list refers to a reference SS/PBCH block, NZP CSI-RS resource configured on serving cell indicated by *Resource Serving Cell ID* field in the activation command if present, same serving cell as the SRS resource set otherwise, or SRS resource configured on serving cell and uplink bandwidth part indicated by Resource *Serving Cell ID* field and *Resource BWP ID* field in the activation command if present, same serving cell and bandwidth part as the SRS resource set otherwise. When the SRS is configured with the higher layer parameter *SRS-PosResourceSet*, each ID in the list of reference signal IDs may refer to a reference SS/PBCH block on a serving or non-serving cell indicated by *PCI* field in the activation command, NZP CSI-RS resource configured on serving cell indicated by *Resource Serving Cell ID* field in the activation command if present, same serving cell as the SRS resource set otherwise, SRS resource configured on serving cell and uplink bandwidth part indicated by Resource *Serving Cell ID* field and *Resource BWP ID* field in the activation command if present, same serving cell and bandwidth part as the SRS resource set otherwise, or DL PRS resource of a serving or non-serving cell associated with a *dl-PRS-ID* indicated by *DL-PRS ID* field in the activation command.

- if an SRS resource in the activated resource set is configured with the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos*, the UE shall assume that the ID of the reference signal in the activation command overrides the one configured in *spatialRelationInfo* or *spatialRelationInfoPos.*

- when a UE receives a deactivation command [10, TS 38.321] for an activated SRS resource set, and when the UE would transmit a PUCCH with HARQ-ACK information in slot *n* corresponding to the PDSCH carrying the deactivation command, the corresponding actions in [10, TS 38.321] and UE assumption on cessation of SRS transmission corresponding to the deactivated SRS resource set shall apply starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$ where μ is the SCS configuration for the PUCCH.

- if the UE is configured with the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos* containing the ID of a reference 'ssb-Index', 'ssb-IndexServing', or 'ssb-IndexNcell' the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference SS/PBCH block, if the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos* contains the ID of a reference 'csi-RS-Index' or 'csi-RS-IndexServing', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference periodic CSI-RS or of the reference semi-persistent CSI-RS, if the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos* contains the ID of a reference 'srs' or 'srs-SpatialRelation', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the transmission of the reference periodic SRS or of the reference semi-persistent SRS. When the SRS is configured by the higher layer parameter *SRS-PosResourceSet* and if the higher layer parameter *spatialRelationInfoPos* contains the ID of a reference 'dl-PRS', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference DL PRS.

If the UE has an active semi-persistent SRS resource configuration and has not received a deactivation command, the semi-persistent SRS configuration is considered to be active in the UL BWP which is active, otherwise it is considered suspended.

For a UE configured with one or more SRS resource configuration(s), and when the higher layer parameter *resourceType* in *SRS-Resource* or *SRS-PosResource* is set to 'aperiodic':

- the UE receives a configuration of SRS resource sets,

- the UE receives a downlink DCI, a group common DCI, or an uplink DCI based command where a codepoint of the DCI may trigger one or more SRS resource set(s). For SRS in a resource set with usage set to 'codebook' or 'antennaSwitching', the minimal time interval between the last symbol of the PDCCH triggering the aperiodic SRS transmission and the first symbol of SRS resource is N_2 symbols and an additional time duration T_{switch}. Otherwise, the minimal time interval between the last symbol of the PDCCH triggering the aperiodic SRS transmission and the first symbol of SRS resource is N_2 +14 symbols and an additional time duration T_{switch}. The minimal time interval unit of OFDM symbol is counted based on the minimum subcarrier spacing given by min(μ_{PDCCH}, μ_{UL}) where μ_{UL} is given by min($\mu_{UL,carrier1}$, $\mu_{UL,carrier2}$, μ_{SRS}) when the UE is configured with the higher layer parameter *uplinkTxSwitchingOption* set to 'dualUL' for uplink carrier aggregation, and by μ_{SRS} otherwise. μ_{SRS} and μ_{PDCCH} are the subcarrier spacing configurations for triggered SRS and PDCCH carrying the triggering command respectively.

- T_{switch}, $\mu_{UL,carrier1}$ and $\mu_{UL,carrier2}$ are defined in clause 6.4.

- If the UE receives the DCI triggering aperiodic SRS in slot *n* and except when SRS is configured with the higher layer parameter *SRS-PosResource*, the UE transmits aperiodic SRS in each of the triggered SRS resource set(s) in slot $\left\lfloor n\cdot\frac{2^{\mu_{SRS}}}{2^{\mu_{PDCCH}}}\right\rfloor+k+\left\lfloor\left(\frac{N_{slot,offset,PDCCH}^{CA}}{2^{\mu_{offset,PDCCH}}}-\frac{N_{slot,offset,SRS}^{CA}}{2^{\mu_{offset,SRS}}}\right)\cdot 2^{\mu_{SRS}}\right\rfloor$, if UE is configured with *ca-SlotOffset* for at least one of the triggered and triggering cell, $K_s=\left\lfloor n\cdot\frac{2^{\mu_{SRS}}}{2^{\mu_{PDCCH}}}\right\rfloor+k$, otherwise, and where
  - *k* is configured via higher layer parameter *slotOffset* for each triggered SRS resources set and is based on the subcarrier spacing of the triggered SRS transmission, μ_{SRS} and μ_{PDCCH} are the subcarrier spacing configurations for triggered SRS and PDCCH carrying the triggering command respectively;
  - $N_{\text{slot, offset, PDCCH}}^{\text{CA}}$ and $\mu_{\text{offset, PDCCH}}$ are the $N_{\text{slot, offset}}^{\text{CA}}$ and the μ_{offset}, respectively, which are determined by higher-layer configured *ca-SlotOffset* for the cell receiving the PDCCH, $N_{slot,offset,SRS}^{CA}$ and $\mu_{offset,SRS}$ are the $N_{slot,offset}^{CA}$ and the μ_{offset}, respectively, which are determined by higher-layer configured *ca-SlotOffset* for the cell transmitting the SRS, as defined in [4, TS 38.211] clause 4.5.

- If the UE receives the DCI triggering aperiodic SRS in slot *n* and when SRS is configured with the higher layer parameter *SRS-PosResource*, the UE transmits every aperiodic SRS resource in each of the triggered SRS resource set(s) in slot $\left\lfloor n\cdot\frac{2^{\mu_{SRS}}}{2^{\mu_{PDCCH}}}\right\rfloor+k+\left\lfloor\left(\frac{N_{slot,offset,PDCCH}^{CA}}{2^{\mu_{offset,PDCCH}}}-\frac{N_{slot,offset,SRS}^{CA}}{2^{\mu_{offset,SRS}}}\right)\cdot 2^{\mu_{SRS}}\right\rfloor$, if UE is configured with *ca-SlotOffset* for at least one of the triggered and triggering cell, $K_s=\left\lfloor n\cdot\frac{2^{\mu_{SRS}}}{2^{\mu_{PDCCH}}}\right\rfloor+k$, otherwise, and where
  - *k* is configured via higher layer parameter *slotOffset* for each aperiodic SRS resource in each triggered SRS resources set and is based on the subcarrier spacing of the triggered SRS transmission, μ_{SRS} and μ_{PDCCH} are the subcarrier spacing configurations for triggered SRS and PDCCH carrying the triggering command respectively;
  - $N_{\text{slot, offset, PDCCH}}^{\text{CA}}$ and $\mu_{\text{offset, PDCCH}}$ are the $N_{\text{slot, offset}}^{\text{CA}}$ and the μ_{offset}, respectively, which are determined by higher-layer configured *ca-SlotOffset* for the cell receiving the PDCCH, $N_{slot,offset,SRS}^{CA}$ and $\mu_{offset,SRS}$ are the $N_{slot,offset}^{CA}$ and the μ_{offset}, respectively, which are determined by higher-layer configured *ca-SlotOffset* for the cell transmitting the SRS, as defined in [4, TS 38.211] clause 4.5.

- if the UE is configured with the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos* containing the ID of a reference 'ssb-Index', 'ssb-IndexServing' or 'ssb-IndexNcell', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference SS/PBCH block, if the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos* contains the ID of a reference 'csi-RS-Index' or 'csi-RS-IndexServing', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference periodic CSI-RS or of the reference semi-persistent CSI-RS, or of the latest reference aperiodic CSI-RS. If the higher layer parameter *spatialRelationInfo* or *spatialRelationInfoPos* contains the ID of a reference 'srs' or 'srs-SpatialRelation', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the transmission of the reference periodic SRS or of the reference semi-persistent SRS or of the reference aperiodic SRS. When the SRS is configured by the higher layer parameter *SRS-PosResourceSet* and if the higher layer parameter *spatialRelationInfoPos* contains the ID of a reference 'dl-PRS', the UE shall transmit the target SRS resource with the same spatial domain transmission filter used for the reception of the reference DL PRS.

- when a UE receives an spatial relation update command, as described in clause 6.1.3.26 of [10, TS 38.321], for an SRS resource configured with the higher layer parameter *SRS-Resource*, and when the HARQ-ACK corresponding to the PDSCH carrying the update command is transmitted in slot *n*, the corresponding actions in [10, TS 38.321] and the UE assumptions on updating spatial relation for the SRS resource shall be applied for SRS transmission starting from the first slot that is after slot $n + 3N_{slot}^{subframe,\mu}$. The update command contains spatial relation assumptions provided by a list of references to reference signal IDs, one per element of the updated SRS resource set. Each ID in the list refers to a reference SS/PBCH block, NZP CSI-RS resource configured on serving cell indicated by *Resource Serving Cell ID* field in the update command if present, same serving cell as the SRS resource set otherwise, or SRS resource configured on serving cell and uplink bandwidth part indicated by *Resource Serving Cell ID* field and *Resource BWP ID* field in the update command if present, same serving cell and bandwidth part as the SRS resource set otherwise. When the UE is configured with the higher layer parameter *usage* in *SRS-ResourceSet* set to 'antennaSwitching', the UE shall not expect to be configured with different spatial relations for SRS resources in the same SRS resource set.

The UE is not expected to be configured with different time domain behavior for SRS resources in the same SRS resource set. The UE is also not expected to be configured with different time domain behavior between SRS resource and associated SRS resources set.

For operation in the same carrier, the UE is not expected to be configured on overlapping symbols with a SRS resource configured by the higher layer parameter *SRS-PosResource* and a SRS resource configured by the higher layer parameter *SRS-Resource* with *resourceType* of both SRS resources as 'periodic'.

For operation in the same carrier, the UE is not expected to be activated or triggered to transmit SRS on overlapping symbols with a SRS resource configured by the higher layer parameter *SRS-PosResource* and a SRS resource configured by the higher layer parameter *SRS-Resource* with *resourceType* of both SRS resources as 'semi-persistent' or 'aperiodic'.

For operations in the same carrier, the UE is not expected to be configured on overlapping symbols with more than one SRS resources configured by the higher layer parameter *SRS-PosResource* with *resourceType* of the SRS resources as 'periodic'.

For operations in the same carrier, the UE is not expected to be activated or triggered to transmit SRS on overlapping symbols with more than one SRS resources configured by the higher layer parameter *SRS-PosResource* with *resourceType* of the SRS resources as 'semi-persistent' or 'aperiodic'.

For intra-band and inter-band CA operations, a UE can simultaneously transmit more than one SRS resource configured by *SRS-PosResource* on different CCs, subject to UE's capability

For intra-band and inter-band CA operations, a UE can simultaneously transmit more than one SRS resource configured by *SRS-PosResource* and *SRS-Resource* on different CCs, subject to UE's capability.

The SRS request field [5, TS38.212] in DCI format 0_1, 1_1, 0_2 (if SRS request field is present), 1_2 (if SRS request field is present) indicates the triggered SRS resource set given in Table 7.3.1.1.2-24 of [5, TS 38.212]. The 2-bit SRS request field [5, TS38.212] in DCI format 2_3 indicates the triggered SRS resource set given in Clause 7.3 of [5, TS 38.212] if the UE is configured with higher layer parameter *srs-TPC-PDCCH-Group* set to 'typeB', or indicates the SRS transmission on a set of serving cells configured by higher layers if the UE is configured with higher layer parameter *srs-TPC-PDCCH-Group* set to 'typeA'.

For PUCCH and SRS on the same carrier, a UE shall not transmit SRS when semi-persistent or periodic SRS is configured in the same symbol(s) with PUCCH carrying only CSI report(s), or only L1-RSRP report(s), or only L1-SINR report(s). A UE shall not transmit SRS when semi-persistent or periodic SRS is configured or aperiodic SRS is triggered to be transmitted in the same symbol(s) with PUCCH carrying HARQ-ACK, link recovery request (as defined in clause 9.2.4 of [6, 38.213]) and/or SR. In the case that SRS is not transmitted due to overlap with PUCCH, only the SRS symbol(s) that overlap with PUCCH symbol(s) are dropped. PUCCH shall not be transmitted when aperiodic SRS is triggered to be transmitted to overlap in the same symbol with PUCCH carrying semi-persistent/periodic CSI report(s) or semi-persistent/periodic L1-RSRP report(s) only, or only L1-SINR report(s).

In case of intra-band carrier aggregation or in inter-band CA band combination if simultaneous SRS and PUCCH/PUSCH transmissions are not supported by UE, the UE is not expected to be configured with SRS from a carrier and PUSCH/UL DM-RS/UL PT-RS/PUCCH formats from a different carrier in the same symbol.

In case of intra-band carrier aggregation or in inter-band CA band combination if simultaneous SRS and PRACH transmissions are not supported by UE, the UE shall not transmit simultaneously SRS resource(s) from a carrier and PRACH from a different carrier.

In case a SRS resource with *resourceType* set as 'aperiodic' is triggered on the OFDM symbol(s) configured with periodic/semi-persistent SRS transmission, the UE shall transmit the aperiodic SRS resource and only the periodic/semi-persistent SRS symbol(s) overlapping within the symbol(s) are dropped, while the periodic/semi-persistent SRS symbol(s) that are not overlapped with the aperiodic SRS resource are transmitted. In case a SRS resource with *resourceType* set as 'semi-persistent' is triggered on the OFDM symbol(s) configured with periodic SRS transmission, the UE shall transmit the semi-persistent SRS resource and only the periodic SRS symbol(s) overlapping within the symbol(s) are dropped, while the periodic SRS symbol(s) that are not overlapped with the semi-persistent SRS resource are transmitted.

When the UE is configured with the higher layer parameter *usage* in *SRS-ResourceSet* set to 'antennaSwitching', and a guard period of Y symbols is configured according to Clause 6.2.1.2, the UE shall use the same priority rules as defined above during the guard period as if SRS was configured.

When a *spatialRelationInfo* is activated/updated for a semi-persistent or aperiodic SRS resource configured by the higher layer parameter *SRS-Resource* by a MAC CE for a set of CCs/BWPs, where the applicable list of CCs provided by higher layer parameter *simultaneousSpatial-UpdatedList1* or *simultaneousSpatial-UpdatedList2* is determined by the indicated CC in the MAC CE, the *spatialRelationInfo* is applied for the semi-persistent or aperiodic SRS resource(s) with the same SRS resource ID for all the BWPs in the determined CCs.

When the higher layer parameter *enableDefaultBeamPL-ForSRS* is set 'enabled', and if the higher layer parameter *spatialRelationInfo* for the SRS resource, except for the SRS resource with the higher layer parameter *usage* in SRS-ResourceSet set to 'beamManagement' or for the SRS resource with the higher layer parameter *usage* in SRS-ResourceSet set to 'nonCodebook' with configuration of *associatedCSI-RS* or for the SRS resource configured by the higher layer parameter *SRS-PosResourceSet*, is not configured in FR2 and if the UE is not configured with higher layer parameter(s) *pathlossReferenceRS*, and if the UE is not configured with different values of *coresetPoolIndex* in *ControlResourceSets*, and is not provided at least one TCI codepoint mapped with two TCI states, the UE shall transmit the target SRS resource in an active UL BWP of a CC,

- according to the spatial relation, if applicable, with a reference to the RS configured with *qcl-Type* set to 'typeD' corresponding to the QCL assumption of the CORESET with the lowest *controlResourceSetId* in the active DL BWP in the CC.

- according to the spatial relation, if applicable, with a reference to the RS configured with *qcl-Type* set to 'typeD' in the activated TCI state with the lowest ID applicable to PDSCH in the active DL BWP of the CC if the UE is not configured with any CORESET in the active DL BWP of the CC

6.2.1.1 UE SRS frequency hopping procedure

For a given SRS resource, the UE is configured with repetition factor R∈{1,2,4} by higher layer parameter *resourceMapping* in *SRS-Resource* where $R \leq N_s$. When frequency hopping within an SRS resource in each slot is not configured ($R=N_s$), each of the antenna ports of the SRS resource in each slot is mapped in all the N_s symbols to the same set of subcarriers in the same set of PRBs. When frequency hopping within an SRS resource in each slot is configured without repetition ($R=1$), according to the SRS hopping parameters B_{SRS}, C_{SRS} and b_{hop} defined in Clause 6.4.1.4 of [4, TS 38.211], each of the antenna ports of the SRS resource in each slot is mapped to different sets of subcarriers in each OFDM symbol, where the same transmission comb value is assumed for different sets of subcarriers. When both frequency hopping and repetition within an SRS resource in each slot are configured ($N_s=4, R=2$), each of the antenna ports of the SRS resource in each slot is mapped to the same set of subcarriers within each pair of R adjacent OFDM symbols, and frequency hopping across the two pairs is according to the SRS hopping parameters B_{SRS}, C_{SRS} and b_{hop}.

A UE may be configured $N_s = 2 \; or \; 4$ adjacent symbol aperiodic SRS resource with intra-slot frequency hopping within a bandwidth part, where the full hopping bandwidth is sounded with an equal-size subband across N_s symbols when frequency hopping is configured with $R=1$. A UE may be configured $N_s = 4$ adjacent symbols aperiodic SRS resource with intra-slot frequency hopping within a bandwidth part, where the full hopping bandwidth is sounded with an equal-size subband across two pairs of R adjacent OFDM symbols, when frequency hopping is configured with $R=2$. Each of the antenna ports of the SRS resource is mapped to the same set of subcarriers within each pair of R adjacent OFDM symbols of the resource.

A UE may be configured $N_s = 1$ symbol periodic or semi-persistent SRS resource with inter-slot hopping within a bandwidth part, where the SRS resource occupies the same symbol location in each slot. A UE may be configured $N_s = 2 \; or \; 4$ symbol periodic or semi-persistent SRS resource with intra-slot and inter-slot hopping within a bandwidth part, where the N-symbol SRS resource occupies the same symbol location(s) in each slot. For $N_s=4$, when frequency hopping is configured with $R=2$, intra-slot and inter-slot hopping is supported with each of the antenna ports of the SRS resource mapped to different sets of subcarriers across two pairs of R adjacent OFDM symbol(s) of the resource in each slot. Each of the antenna ports of the SRS resource is mapped to the same set of subcarriers within each pair of R adjacent OFDM symbols of the resource in each slot. For $N_s= R$, when frequency hopping is configured, inter-slot frequency hopping is supported with each of the antenna ports of the SRS resource mapped to the same set of subcarriers in R adjacent OFDM symbol(s) of the resource in each slot.

6.2.1.2 UE sounding procedure for DL CSI acquisition

When the UE is configured with the higher layer parameter *usage* in *SRS-ResourceSet* set as 'antennaSwitching', the UE may be configured with only one of the following configurations depending on the indicated UE capability *supportedSRS-TxPortSwitch* ('t1r2' for 1T2R, 't1r1-t1r2' for 1T=1R/1T2R, 't2r4' for 2T4R, 't1r4' for 1T4R, 't1r1-t1r2-t1r4' for 1T=1R/1T2R/1T4R, 't1r4-t2r4' for 1T4R/2T4R, 't1r1-t1r2-t2r2-t2r4' for 1T=1R/1T2R/2T=2R/2T4R, 't1r1-t1r2-t2r2-t1r4-t2r4' for 1T=1R/1T2R/2T=2R/1T4R/2T4R, 't1r1' for 1T=1R, 't2r2' for 2T=2R, 't1r1-t2r2' for 1T=1R/2T=2R, 't4r4' for 4T=4R, or 't1r1-t2r2-t4r4' for 1T=1R/2T=2R/4T=4R):

- For 1T2R, up to two SRS resource sets configured with a different value for the higher layer parameter *resourceType* in *SRS-ResourceSet* set, where each set has two SRS resources transmitted in different symbols, each SRS resource in a given set consisting of a single SRS port, and the SRS port of the second resource in the set is associated with a different UE antenna port than the SRS port of the first resource in the same set, or

- For 2T4R, up to two SRS resource sets configured with a different value for the higher layer parameter *resourceType* in *SRS-ResourceSet* set, where each SRS resource set has two SRS resources transmitted in different symbols, each SRS resource in a given set consisting of two SRS ports, and the SRS port pair of the second resource is associated with a different UE antenna port pair than the SRS port pair of the first resource, or

- For 1T4R, zero or one SRS resource set configured with higher layer parameter *resourceType* in *SRS-ResourceSet* set to 'periodic' or 'semi-persistent' with four SRS resources transmitted in different symbols, each SRS resource in a given set consisting of a single SRS port, and the SRS port of each resource is associated with a different UE antenna port, and

- For 1T4R, zero or two SRS resource sets each configured with higher layer parameter *resourceType* in *SRS-ResourceSet* set to 'aperiodic' and with a total of four SRS resources transmitted in different symbols of two different slots, and where the SRS port of each SRS resource in the given two sets is associated with a different UE antenna port. The two sets are each configured with two SRS resources, or one set is configured with one SRS resource and the other set is configured with three SRS resources. The UE shall expect that the two sets are both configured with the same values of the higher layer parameters *alpha*, *p0*, *pathlossReferenceRS*, and *srs-PowerControlAdjustmentStates* in *SRS-ResourceSet*. The UE shall expect that the value of the higher layer parameter *aperiodicSRS-ResourceTrigger* or the value of an entry in *AperiodicSRS-ResourceTriggerList* in each *SRS-ResourceSet* is the same, and the value of the higher layer parameter *slotOffset* in each *SRS-ResourceSet* is different. Or,

- For 1T=1R, or 2T=2R, or 4T=4R, up to two SRS resource sets each with one SRS resource, where the number of SRS ports for each resource is equal to 1, 2, or 4.

The UE is configured with a guard period of Y symbols, in which the UE does not transmit any other signal, in the case the SRS resources of a set are transmitted in the same slot. The guard period is in-between the SRS resources of the set.

The UE shall expect to be configured with the same number of SRS ports for all SRS resources in the SRS resource set(s) with higher layer parameter *usage* set as 'antennaSwitching'.

For 1T2R, 1T4R or 2T4R, the UE shall not expect to be configured or triggered with more than one SRS resource set with higher layer parameter *usage* set as 'antennaSwitching' in the same slot. For 1T=1R, 2T=2R or 4T=4R, the UE shall not expect to be configured or triggered with more than one SRS resource set with higher layer parameter *usage* set as 'antennaSwitching' in the same symbol.

The value of Y is defined by Table 6.2.1.2-1.

Table 6.2.1.2-1: The minimum guard period between two SRS resources of an SRS resource set for antenna switching

μ	$\Delta f = 2^{\mu} \cdot 15[\text{kHz}]$	***Y* [symbol]**
0	15	1
1	30	1
2	60	1
3	120	2

6.2.1.3 UE sounding procedure between component carriers

A UE can be configured with SRS resource(s) on a carrier c_1 with slot formats comprised of DL and UL symbols and not configured for PUSCH/PUCCH transmission. For carrier c_1, the UE is configured with higher layer parameter *srs-SwitchFromServCellIndex* and *srs-SwitchFromCarrier* the switching from carrier c_2 which is configured for PUSCH/PUCCH transmission. During SRS transmission on carrier c_1 (including any interruption due to uplink or downlink RF retuning time [11, TS 38.133] as defined by higher layer parameters *switchingTimeUL* and *switchingTimeDL* of *SRS-SwitchingTimeNR*), the UE temporarily suspends the uplink transmission on carrier c_2.

For an SRS transmission starting in symbol N_{c_1} of carrier c_1 and a conflicting transmission in carrier c_2 starting in symbol N_{c_2}, the UE shall apply the prioritization / dropping rules in the remainder of this clause taking into account:

- DCI(s) for which the time interval between the last symbol of PDCCH and N_{c_1} is at least N_2 symbols and an additional time duration $\mathrm{T}_{SRS_{CS}}$, and the time interval between the last symbol of PDCCH and N_{c_2} is at least N_2 symbols*;* and
- semi-persistent CSI reports or SRS considered active at least N_2 symbols and an additional time duration $\mathrm{T}_{SRS_{CS}}$ before N_{c_1}, and considered active at least N_2 symbols before N_{c_2}.

where $T_{SRS_{CS}} = \max\{switchingTimeUL, switchingTimeDL\}$, and the time interval unit of OFDM symbol is counted based on the smaller subcarrier spacing across c_1, c_2 and their corresponding scheduling cells.

For a carrier of a serving cell with slot formats comprised of DL and UL symbols, not configured for PUSCH/PUCCH transmission, the UE shall not transmit SRS whenever SRS transmission (including any interruption due to uplink or downlink RF retuning time [11, TS 38.133] as defined by higher layer parameters *switchingTimeUL* and *switchingTimeDL* of *SRS-SwitchingTimeNR)* on the carrier of the serving cell and PUSCH/PUCCH transmission carrying HARQ-ACK/positive SR/RI/CRI/SSBRI and/or PRACH happen to overlap in the same symbol and that can result in uplink transmissions beyond the UE's indicated uplink carrier aggregation capability included in [13, TS 38.306].

For a carrier of a serving cell with slot formats comprised of DL and UL symbols, not configured for PUSCH/PUCCH transmission, the UE shall not transmit a periodic/semi-persistent SRS whenever periodic/semi-persistent SRS transmission (including any interruption due to uplink or downlink RF retuning time [11, TS 38.133] as defined by higher layer parameters *switchingTimeUL* and *switchingTimeDL* of *SRS-SwitchingTimeNR)* on the carrier of the serving cell and PUSCH transmission carrying aperiodic CSI happen to overlap in the same symbol and that can result in uplink transmissions beyond the UE's indicated uplink carrier aggregation capability included in [13, TS 38.306].

For a carrier of a serving cell with slot formats comprised of DL and UL symbols, not configured for PUSCH/PUCCH transmission, the UE shall drop PUCCH/PUSCH transmission carrying periodic/semi-persistent CSI comprising only CQI/PMI/L1-RSRP/L1-SINR, and/or SRS transmission on another serving cell configured for PUSCH/PUCCH transmission whenever the transmission and SRS transmission (including any interruption due to uplink or downlink RF retuning time [11, TS 38.133] as defined by higher layer parameters *switchingTimeUL* and *switchingTimeDL* of *SRS-SwitchingTimeNR)* on the serving cell happen to overlap in the same symbol and that can result in uplink transmissions beyond the UE's indicated uplink carrier aggregation capability included in [13, TS 38.306].

For a carrier of a serving cell with slot formats comprised of DL and UL symbols, not configured for PUSCH/PUCCH transmission, the UE shall drop PUSCH transmission carrying aperiodic CSI comprising only CQI/PMI/L1-RSRP/L1-SINR whenever the transmission and aperiodic SRS transmission (including any interruption due to uplink or downlink RF retuning time [11, TS 38.133]) as defined by higher layer parameters *switchingTimeUL* and *switchingTimeDL* of *SRS-SwitchingTimeNR)* on the carrier of the serving cell happen to overlap in the same symbol and that can result in uplink transmissions beyond the UE's indicated uplink carrier aggregation capability included in [13, TS 38.306].

For an aperiodic SRS triggered in DCI format 2_3 and if the UE is configured with higher layer parameter *srs-TPC-PDCCH-Group* set to 'typeA', and given by *SRS-CarrierSwitching,* without PUSCH/PUCCH transmission, the order of the triggered SRS transmission on the serving cells follow the order of the serving cells in the indicated set of serving cells configured by higher layers, where the UE in each serving cell transmits the configured one or two SRS resource set(s) with higher layer parameter *usage* set to 'antennaSwitching' and higher layer parameter *resourceType* in *SRS-ResourceSet* set to 'aperiodic'.

For an aperiodic SRS triggered in DCI format 2_3 and if the UE is configured with higher layer parameter *srs-TPC-PDCCH-Group* set to 'typeB' without PUSCH/PUCCH transmission, the order of the triggered SRS transmission on the serving cells follow the order of the serving cells with aperiodic SRS triggered in the DCI, and the UE in each serving cell transmits the configured one or two SRS resource set(s) with higher layer parameter *usage* set to 'antennaSwitching' and higher layer parameter *resourceType* in *SRS-ResourceSet* set to 'aperiodic'.

If the UE is not configured for PUSCH/PUCCH transmission on carrier c_1 with slot formats comprised of DL and UL symbols, and if the UE is not capable of simultaneous reception and transmission on carrier c_1 and serving cell c_2, the UE is not expected to be configured or indicated with SRS resource(s) such that SRS transmission on carrier c_1 (including any interruption due to uplink or downlink RF retuning time [11, TS 38.133] as defined by higher layer parameters *switchingTimeUL* and *switchingTimeDL* of *SRS-SwitchingTimeNR*) would collide with the REs corresponding to the SS/PBCH blocks configured for the UE or the slots belonging to a control resource set indicated by *MIB* or *SIB1* on serving cell c_2.

For n-th ($n \geq 1$) aperiodic SRS transmission on a cell c, upon detection of a positive SRS request on a grant, the UE shall commence this SRS transmission on the configured symbol and slot provided

- it is no earlier than the summation of
  - the maximum time duration between the two durations spanned by N OFDM symbols of the numerology of cell c and the cell carrying the grant respectively, and
  - the UL or DL RF retuning time [11, TS 38.133] as defined by higher layer parameters *switchingTimeUL* and *switchingTimeDL* of *SRS-SwitchingTimeNR,*
- it does not collide with any previous SRS transmissions, or interruption due to UL or DL RF retuning time.

otherwise, n-th SRS transmission is dropped, where N is the reported capability as the minimum time interval in unit of symbols, between the DCI triggering and aperiodic SRS transmission.

In case of inter-band carrier aggregation, a UE can simultaneously transmit SRS and PUCCH/PUSCH across component carriers in different bands subject to the UE's capability.

In case of inter-band carrier aggregation, a UE can simultaneously transmit PRACH and SRS across component carriers in different bands subject to UE's capability.

6.2.1.4 UE sounding procedure for positioning purposes

When the SRS is configured by the higher layer parameter *SRS-PosResource* and if the higher layer parameter *spatialRelationInfoPos* is configured, it contains the ID of the configuration fields of a reference RS according to Clause 6.3.2 of [TS 38.331]. The reference RS can be an SRS configured by the higher layer parameter *SRS-Resource* or *SRS-PosResource*, CSI-RS, SS/PBCH block, or a DL PRS configured on a serving cell or a SS/PBCH block or a DL PRS configured on a non-serving cell.

The UE is not expected to transmit multiple SRS resources with different spatial relations in the same OFDM symbol.

If the UE is not configured with the higher layer parameter *spatialRelationInfoPos* the UE may use a fixed spatial domain transmission filter for transmissions of the SRS configured by the higher layer parameter *SRS-PosResource* across multiple SRS resources or it may use a different spatial domain transmission filter across multiple SRS resources.

The UE is only expected to transmit an SRS configured by the higher layer parameter *SRS-PosResource* within the active UL BWP of the UE.

When the configuration of SRS is done by the higher layer parameter *SRS-PosResource*, the UE can only be provided with a single RS source in *spatialRelationInfoPos* per SRS resource for positioning.

For operation on the same carrier, if an SRS configured by the higher parameter *SRS-PosResource* collides with a scheduled PUSCH, the SRS is dropped in the symbols where the collision occurs.

The UE does not expect to be configured with *SRS-PosResource* on a carrier of a serving cell with slot formats comprised of DL and UL symbols, not configured for PUSCH/PUCCH transmission.

6.2.2 UE DM-RS transmission procedure

The DM-RS transmission procedures for PUSCH scheduled by PDCCH with DCI format 0_1 described in this clause equally apply to PUSCH scheduled by PDCCH with DCI format 0_2, by applying the parameters of *dmrs-UplinkForPUSCH-MappingTypeA-DCI-0-2* and *dmrs-UplinkForPUSCH-MappingTypeB-DCI-0-2* instead of *dmrs-UplinkForPUSCH-MappingTypeA* and *dmrs-UplinkForPUSCH-MappingTypeB.*

When transmitted PUSCH is neither scheduled by DCI format 0_1/0_2 with CRC scrambled by C-RNTI, CS-RNTI, SP-CSI-RNTI or MCS-C-RNTI, nor corresponding to a configured grant, nor being a PUSCH for Type-2 random access procedure, the UE shall use single symbol front-loaded DM-RS of configuration type 1 on DM-RS port 0 and the remaining REs not used for DM-RS in the symbols are not used for any PUSCH transmission except for PUSCH with allocation duration of 2 or less OFDM symbols with transform precoding disabled, additional DM-RS can be transmitted according to the scheduling type and the PUSCH duration as specified in Table 6.4.1.1.3-3 of [4, TS38.211] for frequency hopping disabled and as specified in Table 6.4.1.1.3-6 of [4, TS38.211] for frequency hopping enabled, and

If frequency hopping is disabled:

- The UE shall assume *dmrs-AdditionalPosition* equals to 'pos2' and up to two additional DM-RS can be transmitted according to PUSCH duration, or

If frequency hopping is enabled:

- The UE shall assume *dmrs-AdditionalPosition* equals to 'pos1' and up to one additional DM-RS can be transmitted according to PUSCH duration.

When transmitted PUSCH is scheduled by activation DCI format 0_0 with CRC scrambled by CS-RNTI, the UE shall use single symbol front-loaded DM-RS of configuration type provided by higher layer parameter *dmrs-Type* in *DMRS-UplinkConfig* on DM-RS port 0 and the remaining REs not used for DM-RS in the symbols are not used for any PUSCH transmission except for PUSCH with allocation duration of 2 or less OFDM symbols with transform precoding disabled, and additional DM-RS with *dmrs-AdditionalPosition* from C*onfiguredGrantConfig* can be transmitted according to the scheduling type and the PUSCH duration as specified in Table 6.4.1.1.3-3 of [4, TS38.211] for frequency hopping disabled and as specified in Table 6.4.1.1.3-6 of [4, TS38.211] for frequency hopping enabled.

For the UE-specific reference signals generation as defined in Clause 6.4.1.1 of [4, TS 38.211], a UE can be configured by higher layers with one or two scrambling identity(s), $n_{ID}^{DMRS,i}$ i = 0,1 which are the same for both PUSCH mapping Type A and Type B.

When transmitted PUSCH is scheduled by DCI format 0_1 with CRC scrambled by C-RNTI, CS-RNTI, SP-CSI-RNTI or MCS-C-RNTI, or corresponding to a configured grant, or being a PUSCH for Type-2 random access procedure,

- the UE may be configured with higher layer parameter *dmrs-Type* in *DMRS-UplinkConfig,* and the configured DM-RS configuration type is used for transmitting PUSCH in as defined in Clause 6.4.1.1 of [4, TS 38.211].
- the UE may be configured with the maximum number of front-loaded DM-RS symbols for PUSCH by higher layer parameter *maxLength* in *DMRS-UplinkConfig,* or by higher layer parameter *msgA-MaxLength* in *msgA-DMRS-Config,*
  - if *maxLength* is not configured, single-symbol DM-RS can be scheduled for the UE by DCI or configured by the configured grant configuration, and the UE can be configured with a number of additional DM-RS for PUSCH by higher layer parameter *dmrs-AdditionalPosition,* which can be 'pos0', 'pos1', 'pos2', 'pos3'.
  - if *maxLength* is configured, either single-symbol DM-RS or double symbol DM-RS can be scheduled for the UE by DCI or configured by the configured grant configuration, and the UE can be configured with a number of additional DM-RS for PUSCH by higher layer parameter *dmrs-AdditionalPosition,* which can be 'pos0' or 'pos1'.
  - for msgA PUSCH for Type-2 random access procedure the UE can be configured with a number of additional DM-RS for PUSCH by higher layer parameter *msgA-DMRS-AdditionalPosition,* which can be 'pos0', 'pos1', 'pos2', 'pos3' for single-symbol DM-RS or 'pos0', 'pos1' for double-symbol DM-RS.

- and, the UE shall transmit a number of additional DM-RS as specified in Table 6.4.1.1.3-3 and Table 6.4.1.1.3-4 in -Clause 6.4.1.1.3 of [4, TS 38.211].

If a UE transmitting PUSCH scheduled by DCI format 0_2 is configured with the higher layer parameter *phaseTrackingRS* in *dmrs-UplinkForPUSCH-MappingTypeA-DCI-0-2* or *dmrs-UplinkForPUSCH-MappingTypeB-DCI-0-2*, or a UE transmitting PUSCH scheduled by DCI format 0_0 or DCI format 0_1 is configured with the higher layer parameter *phaseTrackingRS* in *dmrs-UplinkForPUSCH-MappingTypeA* or *dmrs-UplinkForPUSCH-MappingTypeB,* the UE may assume that the following configurations are not occurring simultaneously for the transmitted PUSCH

- any DM-RS ports among 4-7 or 6-11 for DM-RS configurations type 1 and type 2, respectively are scheduled for the UE and PT-RS is transmitted from the UE.

For PUSCH scheduled by DCI format 0_1, by activation DCI format 0_1 with CRC scrambled by CS-RNTI, or configured by configured grant Type 1 configuration, the UE shall assume the DM-RS CDM groups indicated in Tables 7.3.1.1.2-6 to 7.3.1.1.2-23 of Clause 7.3.1.1 of [5, TS38.212] are not used for data transmission, where "1", "2" and "3" for the number of DM-RS CDM group(s) correspond to CDM group 0, {0,1}, {0,1,2}, respectively.

For PUSCH scheduled by DCI format 0_0 or by activation DCI format 0_0 with CRC scrambled by CS-RNTI, the UE shall assume the number of DM-RS CDM groups without data is 1 which corresponds to CDM group 0 for the case of PUSCH with allocation duration of 2 or less OFDM symbols with transform precoding disabled, the UE shall assume that the number of DM-RS CDM groups without data is 3 which corresponds to CDM group {0,1,2} for the case of PUSCH scheduled by activation DCI format 0_0 and the *dmrs-Type* in *DMRS-UplinkConfig* equal to 'type2' and the PUSCH allocation duration being more than 2 OFDM symbols, and the UE shall assume that the number of DM-RS CDM groups without data is 2 which corresponds to CDM group {0,1} for all other cases.

For MsgA PUSCH transmission, if the UE is not configured with *msgA-PUSCH-DMRS-CDM-group,* the UE shall assume that 2 DM-RS CDM groups are configured. Otherwise, *msgA-PUSCH-DMRS-CDM-group* indicates which DM-RS CDM group to use from the set of {0,1}.

For MsgA PUSCH transmission, if the UE is not configured with *msgA-PUSCH-NrofPorts,* the UE shall assume that 4 ports are configured per DM-RS CDM group for double-symbol DM-RS. Otherwise, *msgA-PUSCH-NrofPorts* with value of 0 indicates the first port per DM-RS CDM group, while a value of 1 indicates the first two ports per DM-RS CDM group.

For uplink DM-RS with PUSCH, the UE may assume the ratio of PUSCH EPRE to DM-RS EPRE (β_{DMRS} [dB]) is given by Table 6.2.2-1 according to the number of DM-RS CDM groups without data. The DM-RS scaling factor β_{PUSCH}^{DMRS} specified in clause 6.4.1.1.3 of [4, TS 38.211] is given by $\beta_{PUSCH}^{DMRS} = 10^{-\frac{\beta_{\mathrm{DMRS}}}{20}}$.

Table 6.2.2-1: The ratio of PUSCH 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

For PUSCH repetition Type B, the DM-RS transmission procedure is applied for each actual repetition separately based on the allocation duration of the actual repetition. A UE is not expected to be indicated with an antenna port configuration that is invalid for the allocated duration of any actual repetition.

6.2.3 UE PT-RS transmission procedure

The procedures on PT-RS transmission described in this clause as well as clauses 6.2.3.1 and 6.2.3.2 apply to a UE PUSCH transmission scheduled by DCI format 0_2 if the higher layer parameter *phaseTrackingRS* in *dmrs-UplinkForPUSCH-MappingTypeA-DCI-0-2* or *dmrs-UplinkForPUSCH-MappingTypeB-DCI-0-2* is configured, to PUSCH transmissions scheduled by DCI format 0_0 or format 0_1 if the higher layer parameter *phaseTrackingRS* in *dmrs-UplinkForPUSCH-MappingTypeA* or *dmrs-UplinkForPUSCH-MappingTypeB* is configured and PUSCH transmissions corresponding to a configured grant if the higher layer parameter *phaseTrackingRS* in *cg-DMRS-Configuration* is configured. If a UE is not configured with the higher layer parameter *phaseTrackingRS* in the respective *DMRS-UplinkConfig,* the UE shall not transmit PT-RS. The PT-RS is only present on PUSCH scheduled by

PDCCH with CRC scrambled by MCS-C-RNTI, C-RNTI, CS-RNTI, SP-CSI-RNTI and on PUSCH corresponding to a configured grant. For PUSCH repetition Type B, the PT-RS transmission procedure is applied for each actual repetition separately based on the allocation duration of the actual repetition.

6.2.3.1 UE PT-RS transmission procedure when transform precoding is not enabled

When transform precoding is not enabled and if a UE is configured with the higher layer parameter *phaseTrackingRS* in *DMRS-UplinkConfig,*

- the higher layer parameters *timeDensity* and *frequencyDensity* in *PTRS-UplinkConfig* indicate the threshold values *ptrs-MCS*$_i$, i=1,2,3 and $N_{RB,i}$, i=0,1, as shown in Table 6.2.3.1-1 and Table 6.2.3.1-2, respectively.
- if either or both higher layer parameters *timeDensity* and/or *frequencyDensity* in *PTRS-UplinkConfig* are configured, the UE shall assume the PT-RS antenna ports' presence and pattern are a function of the corresponding scheduled MCS and scheduled bandwidth in a corresponding bandwidth part as shown in Table 6.2.3.1-1 and Table 6.2.3.1-2, respectively,
  - if the higher layer parameter *timeDensity* is not configured, the UE shall assume $L_{PT\text{-}RS}$ = 1.
  - if the higher layer parameter *frequencyDensity* is not configured, the UE shall assume $K_{PT\text{-}RS}$ = 2.
- if none of the higher layer parameters *timeDensity* and *frequencyDensity* in *PTRS-UplinkConfig* are configured, the UE shall assume $L_{PT\text{-}RS}$ = 1 and $K_{PT\text{-}RS}$ = 2.

Table 6.2.3.1-1: Time density of PT-RS as a function of scheduled MCS

Scheduled MCS	Time density(L_{PT-RS})
I_{MCS} < ptrs-MCS_1	PT-RS is not present
ptrs-MCS1 $\leq$ I_{MCS} < ptrs-MCS2	4
ptrs-MCS2 $\leq$ I_{MCS} < ptrs-MCS3	2
ptrs-MCS3 $\leq$ I_{MCS} < ptrs-MCS4	1

Table 6.2.3.1-2: Frequency density of PT-RS as a function of scheduled bandwidth

Scheduled bandwidth	Frequency density (K_{PT-RS})
N_{RB} < N_{RB0}	PT-RS is not present
N_{RB0} $\leq$ N_{RB} < N_{RB1}	2
N_{RB1} $\leq$ N_{RB}	4

The higher layer parameter *PTRS-UplinkConfig* provides the parameters *ptrs-MCS*$_i$, i=1,2,3 and with values in 0-29 when MCS Table 5.1.3.1-1 or Table 5.1.3.1-3 is used and 0-28 when MCS Table 5.1.3.1-2 is used, respectively. *ptrs-MCS4* is not explicitly configured by higher layers but assumed 29 when MCS Table 5.1.3.1-1 or Table 5.1.3.1-3 is used and 28 when MCS Table 5.1.3.1-2 is used. The higher layer parameter *PTRS-UplinkConfig* provides the parameters N_{RBi} i=0,1 with values in range 1-276.

If the higher layer parameter *PTRS-UplinkConfig* indicates that the time density thresholds *ptrs-MCS*$_i$ = *ptrs-MCS*$_{i+1}$, then the time density L_{PTRS} of the associated row where both these thresholds appear in Table 6.2.3.1-1 is disabled. If the higher layer parameter *frequencyDensity* in *PTRS-UplinkConfig* indicates that the frequency density thresholds $N_{RB,i}$ = $N_{RB,i+1}$, then the frequency density K_{PTRS} of the associated row where both these thresholds appear in Table 6.2.3.1-2 is disabled.

If either or both of the parameters PT-RS time density ($L_{PT\text{-}RS}$) and PT-RS frequency density ($K_{PT\text{-}RS}$), shown in Table 6.2.3.1-1 and Table 6.2.3.1-2, indicates that are configured as 'PT-RS not present', the UE shall assume that PT-RS is not present.

When a UE is scheduled to transmit PUSCH with allocation duration of 2 symbols or less, and if $L_{PT\text{-}RS}$ is set to 2 or 4, the UE shall not transmit PT-RS. When a UE is scheduled to transmit PUSCH with allocation duration of 4 symbols or less, and if $L_{PT\text{-}RS}$ is set to 4, the UE shall not transmit PT-RS.

When a UE is scheduled to transmit PUSCH for retransmission, if the UE is scheduled with $I_{MCS} > V$, where $V = 28$ for MCS Table 5.1.3.1-1 and MCS Table 5.1.3.1-3 and $V = 27$ for MCS Table 5.1.3.1-2, respectively, the MCS for PT-RS time-density determination is obtained from the DCI for the same transport block in the initial transmission, which is smaller than or equal to V.

The maximum number of configured PT-RS ports is given by the higher layer parameter *maxNrofPorts* in *PTRS-UplinkConfig*. The UE is not expected to be configured with a larger number of UL PT-RS ports than it has reported need for.

If a UE has reported the capability of supporting full-coherent UL transmission, the UE shall expect the number of UL PT-RS ports to be configured as one if UL-PTRS is configured.

For codebook or non-codebook based UL transmission, the association between UL PT-RS port(s) and DM-RS port(s) is signalled by *PTRS-DMRS association* field in DCI format 0_1 and DCI format 0_2. For a PUSCH corresponding to a configured grant Type 1 transmission, the UE may assume the association between UL PT-RS port(s) and DM-RS port(s) defined by value 0 in Table 7.3.1.1.2-25 or value "00" in Table 7.3.1.1.1.2-26 described in Clause 7.3.1 of [5, TS38.212].

For PUSCH scheduled by DCI format 0_0 or by activation DCI format 0_0, the UL PT-RS port is associated to DM-RS port 0.

For non-codebook based UL transmission, the actual number of UL PT-RS port(s) to transmit is determined based on SRI(s) in DCI format 0_1 and DCI format 0_2 or higher layer parameter *sri-ResourceIndicator* in *rrc-ConfiguredUplinkGrant*. A UE is configured with the PT-RS port index for each configured SRS resource by the higher layer parameter *ptrs-PortIndex* configured by *SRS-Config* if the UE is configured with the higher layer parameter *phaseTrackingRS in DMRS-UplinkConfig*. If the PT-RS port index associated with different SRIs are the same, the corresponding UL DM-RS ports are associated to the one UL PT-RS port.

For partial-coherent and non-coherent codebook-based UL transmission, the actual number of UL PT-RS port(s) is determined based on TPMI and/or number of layers which are indicated by '*Precoding information and number of layers'* field in DCI format 0_1 and DCI format 0_2 or configured by higher layer parameter *precodingAndNumberOfLayers*:

- if the UE is configured with the higher layer parameter *maxNrofPorts* in *PTRS-UplinkConfig* set to 'n2', the actual UL PT-RS port(s) and the associated transmission layer(s) are derived from indicated TPMI as:
- PUSCH antenna port 1000 and 1002 in indicated TPMI share PT-RS port 0, and PUSCH antenna port 1001 and 1003 in indicated TPMI share PT-RS port 1.
    - UL PT-RS port 0 is associated with the UL layer 'x' of layers which are transmitted with PUSCH antenna port 1000 and PUSCH antenna port 1002 in indicated TPMI, and UL PT-RS port 1 is associated with the UL layer 'y' of layers which are transmitted with PUSCH antenna port 1001 and PUSCH antenna port 1003 in indicated TPMI, where 'x' and/or 'y' are given by DCI parameter '*PTRS-DMRS association'* as shown in DCI format 0_1 and DCI format 0_2 described in Clause 7.3.1 of [5, TS38.212].

When the UE is scheduled with Q_p={1,2} PT-RS port(s) in uplink and the number of scheduled layers is n_{layer}^{PUSCH} ,

- If the UE is configured with higher layer parameter *ptrs-Power*, the PUSCH to PT-RS power ratio per layer per RE ρ_{PTRS}^{PUSCH} is given by $\rho_{PTRS}^{PUSCH} = -\alpha_{PTRS}^{PUSCH} [dB]$, where α_{PTRS}^{PUSCH} is shown in the Table 6.2.3.1-3 according to the higher layer parameter *ptrs-Power*, the PT-RS scaling factor β_{PTRS} specified in clause 6.4.1.2.2.1 of [4, TS 38.211] is given by $\beta_{PTRS} = 10^{-\frac{\rho_{PTRS}^{PUSCH}}{20}}$ and also on the '*Precoding Information and Number of Layers'* field in DCI.
- The UE shall assume *ptrs-Power* in *PTRS-UplinkConfig* is set to state "00" in Table 6.2.3.1-3 if not configured or in case of non-codebook based PUSCH.

Table 6.2.3.1-3: Factor related to PUSCH to PT-RS power ratio per layer per RE α_{PTRS}^{PUSCH}

		The number of PUSCH layers (n_{layer}^{PUSCH})		
	1	2	3	4

UL-PTRS-power / α_{PTRS}^{PUSCH}	All cases	Full coherent	Partial and non-coherent and non-codebook based	Full coherent	Partial and non-coherent and non-codebook based	Full coherent	Partial coherent	Non-coherent and non-codebook based
00	0	3	$3Q_p$-3	4.77	$3Q_p$-3	6	$3Q_p$	$3Q_p$-3
01	0	3	3	4.77	4.77	6	6	6
10	Reserved							
11	Reserved							

6.2.3.2 UE PT-RS transmission procedure when transform precoding is enabled

When transform precoding is enabled and if a UE is configured with the higher layer parameter *transformPrecoderEnabled* in *PTRS-UplinkConfig,*

- the UE shall be configured with the higher layer parameters *sampleDensity* and the UE shall assume the PT-RS antenna ports' presence and PT-RS group pattern are a function of the corresponding scheduled bandwidth in a corresponding bandwidth part, as shown in Table 6.2.3.2-1. The UE shall assume no PT-RS is present when the number of scheduled RBs is less than N_{RB0} if $N_{RB0} > 1$ or if the RNTI equals TC-RNTI.
- and the UE may be configured PT-RS time density $L_{PT\text{-}RS} = 2$ with the higher layer parameter *timeDensityTransformPrecoding*. Otherwise, the UE shall assume $L_{PT\text{-}RS} = 1$.
- if the higher layer parameter *sampleDensity* indicates that the sample density thresholds $N_{RB,i} = N_{RB,i+1}$, then the associated row where both these thresholds appear in Table 6.2.3.2-1 is disabled.

Table 6.2.3.2-1: PT-RS group pattern as a function of scheduled bandwidth

Scheduled bandwidth	Number of PT-RS groups	Number of samples per PT-RS group
$N_{RB0} \leq N_{RB} < N_{RB1}$	2	2
$N_{RB1} \leq N_{RB} < N_{RB2}$	2	4
$N_{RB2} \leq N_{RB} < N_{RB3}$	4	2
$N_{RB3} \leq N_{RB} < N_{RB4}$	4	4
$N_{RB4} \leq N_{RB}$	8	4

When transform precoding is enabled and if a UE is configured with the higher layer parameter *transformPrecoderEnabled* in *PTRS-UplinkConfig,* the PT-RS scaling factor β' specified in Clause 6.4.1.2.2.2 of [4, TS 38.211] is determined by the scheduled modulation order as shown in table 6.2.3.2-2.

Table 6.2.3.2-2: PT-RS scaling factor (β') when transform precoding enabled.

Scheduled modulation	PT-RS scaling factor (β')
π/2-BPSK	1
QPSK	1
16QAM	$3/\sqrt{5}$
64QAM	$7/\sqrt{21}$
256QAM	$15/\sqrt{85}$

6.3 UE PUSCH frequency hopping procedure

6.3.1 Frequency hopping for PUSCH repetition Type A

For PUSCH repetition Type A (as determined according to procedures defined in Clause 6.1.2.1 for scheduled PUSCH, or Clause 6.1.2.3 for configured PUSCH), a UE is configured for frequency hopping by the higher layer parameter *frequencyHoppingDCI-0-2* in *pusch-Config* for PUSCH transmission scheduled by DCI format 0_2, and by *frequencyHopping* provided in *pusch-Config* for PUSCH transmission scheduled by a DCI format other than 0_2, and by *frequencyHopping* provided in *configuredGrantConfig* for configured PUSCH transmission. One of two frequency hopping modes can be configured:

- Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission.
- Inter-slot frequency hopping, applicable to multi-slot PUSCH transmission.

In case of resource allocation type 2, the UE transmits PUSCH without frequency hopping.

In case of resource allocation type 1, whether or not transform precoding is enabled for PUSCH transmission, the UE may perform PUSCH frequency hopping, if the frequency hopping field in a corresponding detected DCI format or in a random access response UL grant is set to 1, or if for a Type 1 PUSCH transmission with a configured grant the higher layer parameter *frequencyHoppingOffset* is provided, otherwise no PUSCH frequency hopping is performed. When frequency hopping is enabled for PUSCH, the RE mapping is defined in clause 6.3.1.6 of [4, TS 38.211].

For a PUSCH scheduled by RAR UL grant, fallbackRAR UL grant, or by DCI format 0_0 with CRC scrambled by TC-RNTI, frequency offsets are obtained as described in clause 8.3 of [6, TS 38.213]. Otherwise, for a PUSCH scheduled by DCI format 0_0/0_1 or a PUSCH based on a Type2 configured UL grant activated by DCI format 0_0/0_1 and for resource allocation type 1, frequency offsets are configured by higher layer parameter *frequencyHoppingOffsetLists* in *pusch-Config*. For a PUSCH scheduled by DCI format 0_2 or a PUSCH based on a Type2 configured UL grant activated by DCI format 0_2 and for resource allocation type 1, frequency offsets are configured by higher layer parameter *frequencyHoppingOffsetListsDCI-0-2* in *pusch-Config.*

- When the size of the active BWP is less than 50 PRBs, one of two higher layer configured offsets is indicated in the UL grant.
- When the size of the active BWP is equal to or greater than 50 PRBs, one of four higher layer configured offsets is indicated in the UL grant.

For PUSCH based on a Type1 configured UL grant the frequency offset is provided by the higher layer parameter *frequencyHoppingOffset* in *rrc-ConfiguredUplinkGrant*.

For a MsgA PUSCH the frequency offset is provided by the higher layer parameter as described in [6, TS 38.213].

In case of intra-slot frequency hopping, the starting RB in each hop is given by:

$$\mathrm{RB}_{\mathrm{start}} = \begin{cases} \mathrm{RB}_{\mathrm{start}} & i=0 \\ \left(\mathrm{RB}_{\mathrm{start}} + \mathrm{RB}_{\mathrm{offset}}\right) \bmod N_{BWP}^{size} & i=1 \end{cases},$$

where i=0 and i=1 are the first hop and the second hop respectively, and $\mathrm{RB}_{\mathrm{start}}$ is the starting RB within the UL BWP, as calculated from the resource block assignment information of resource allocation type 1 (described in Clause 6.1.2.2.2) or as calculated from the resource assignment for MsgA PUSCH (described in [6, TS 38.213]) and $\mathrm{RB}_{\mathrm{offset}}$ is the frequency offset in RBs between the two frequency hops. The number of symbols in the first hop is given by $\left\lfloor N_{symb}^{PUSCH,s}/2 \right\rfloor$, the number of symbols in the second hop is given by $N_{symb}^{PUSCH,s} - \left\lfloor N_{symb}^{PUSCH,s}/2 \right\rfloor$, where $N_{symb}^{PUSCH,s}$ is the length of the PUSCH transmission in OFDM symbols in one slot.

In case of inter-slot frequency hopping, the starting RB during slot n_s^μ is given by:

$$\mathrm{RB}_{\mathrm{start}}\left(n_s^\mu\right) = \begin{cases} \mathrm{RB}_{\mathrm{start}} & n_s^\mu \bmod 2 = 0 \\ \left(\mathrm{RB}_{\mathrm{start}} + \mathrm{RB}_{\mathrm{offset}}\right) \bmod N_{BWP}^{size} & n_s^\mu \bmod 2 = 1 \end{cases},$$

where n_s^μ is the current slot number within a radio frame, where a multi-slot PUSCH transmission can take place, $\mathrm{RB}_{\mathrm{start}}$ is the starting RB within the UL BWP, as calculated from the resource block assignment information of resource allocation type 1 (described in Clause 6.1.2.2.2) and $\mathrm{RB}_{\mathrm{offset}}$ is the frequency offset in RBs between the two frequency hops.

6.3.2 Frequency hopping for PUSCH repetition Type B

For PUSCH repetition Type B (as determined according to procedures defined in Clause 6.1.2.1 for scheduled PUSCH, or Clause 6.1.2.3 for configured PUSCH), a UE is configured for frequency hopping by the higher layer parameter *frequencyHoppingDCI-0-2* in *pusch-Config* for PUSCH transmission scheduled by DCI format 0_2, by *frequencyHoppingDCI-0-1* provided in *pusch-Config* for PUSCH transmission scheduled by DCI format 0_1, and by *frequencyHoppingPUSCH-RepTypeB* provided in *rrc-ConfiguredUplinkGrant* for Type 1 configured PUSCH transmission. The frequency hopping mode for Type 2 configured PUSCH transmission follows the configuration of the activating DCI format. One of two frequency hopping modes can be configured:

- Inter-repetition frequency hopping
- Inter-slot frequency hopping

In case of resource allocation type 1, whether or not transform precoding is enabled for PUSCH transmission, the UE may perform PUSCH frequency hopping, if the frequency hopping field in a corresponding detected DCI format is set to 1, or if for a Type 1 PUSCH transmission with a configured grant the higher layer parameter *frequencyHoppingPUSCH-RepTypeB* is provided, otherwise no PUSCH frequency hopping is performed. When frequency hopping is enabled for PUSCH, the RE mapping is defined in clause 6.3.1.6 of [4, TS 38.211].

For a PUSCH scheduled by DCI format 0_1 or a PUSCH based on a Type 2 configured UL grant activated by DCI format 0_1 and for resource allocation type 1, frequency offsets are configured by higher layer parameter *frequencyHoppingOffsetLists* in *pusch-Config*. For a PUSCH scheduled by DCI format 0_2 or a PUSCH based on a Type 2 configured UL grant activated by DCI format 0_2 and for resource allocation type 1, frequency offsets are configured by higher layer parameter *frequencyHoppingOffsetListsDCI-0-2* in *pusch-Config*.

- When the size of the active BWP is less than 50 PRBs, one of two higher layer configured offsets is indicated in the UL grant.
- When the size of the active BWP is equal to or greater than 50 PRBs, one of four higher layer configured offsets is indicated in the UL grant.

For PUSCH based on a Type1 configured UL grant the frequency offset is provided by the higher layer parameter *frequencyHoppingOffset* in *rrc-ConfiguredUplinkGrant*.

In case of inter-repetition frequency hopping, the starting RB for an actual repetition within the *n*-th nominal repetition (as defined in Clause 6.1.2.1) is given by:

$$\mathrm{RB}_{\mathrm{start}}(n)=\begin{cases}\mathrm{RB}_{\mathrm{start}} & n \bmod 2=0\\ (\mathrm{RB}_{\mathrm{start}}+\mathrm{RB}_{\mathrm{offset}}) \bmod N_{BWP}^{size} & n \bmod 2=1\end{cases},$$

where $\mathrm{RB}_{\mathrm{start}}$ is the starting RB within the UL BWP, as calculated from the resource block assignment information of resource allocation type 1 (described in Clause 6.1.2.2.2) and $\mathrm{RB}_{\mathrm{offset}}$ is the frequency offset in RBs between the two frequency hops.

In case of inter-slot frequency hopping, the starting RB during slot n_s^μ follows that of inter-slot frequency hopping for PUSCH Repetition Type A in Clause 6.3.1.

6.4 UE PUSCH preparation procedure time

If the first uplink symbol in the PUSCH allocation for a transport block, including the DM-RS, as defined by the slot offset K_2 and the start S and length L of the PUSCH allocation indicated by '*Time domain resource assignment*' of the scheduling DCI and including the effect of the timing advance, is no earlier than at symbol L_2, where L_2 is defined as the next uplink symbol with its CP starting $T_{proc,2}=\max\left((N_2+d_{2,1}+d_2)(2048+144)\cdot\kappa 2^{-\mu}\cdot T_C+T_{ext}+T_{switch},d_{2,2}\right)$ after the end of the reception of the last symbol of the PDCCH carrying the DCI scheduling the PUSCH, then the UE shall transmit the transport block.

- N_2 is based on μ of Table 6.4-1 and Table 6.4-2 for UE processing capability 1 and 2 respectively, where μ corresponds to the one of (μ_{DL}, μ_{UL}) resulting with the largest $T_{proc,2}$, where the μ_{DL} corresponds to the subcarrier spacing of the downlink with which the PDCCH carrying the DCI scheduling the PUSCH was transmitted and μ_{UL} corresponds to the subcarrier spacing of the uplink channel with which the PUSCH is to be transmitted, and κ is defined in clause 4.1 of [4, TS 38.211].

- For operation with shared spectrum channel access, T_{ext} is calculated according to [4, TS 38.211], otherwise T_{ext} =0.
- If the first symbol of the PUSCH allocation consists of DM-RS only, then $d_{2,1} = 0$, otherwise $d_{2,1} = 1$.
- If the UE is configured with multiple active component carriers, the first uplink symbol in the PUSCH allocation further includes the effect of timing difference between component carriers as given in [11, TS 38.133].
- If the scheduling DCI triggered a switch of BWP, $d_{2,2}$ equals to the switching time as defined in [11, TS 38.133], otherwise $d_{2,2}$=0.
- If a PUSCH of a larger priority index would overlap with PUCCH of a smaller priority index, d_2 for the PUSCH of a larger priority is set as reported by the UE; otherwise $d_2 = 0$.
- For a UE that supports capability 2 on a given cell, the processing time according to UE processing capability 2 is applied if the high layer parameter *processingType2Enabled* in *PUSCH-ServingCellConfig* is configured for the cell and set to 'enable',
- If the PUSCH indicated by the DCI is overlapping with one or more PUCCH channels, then the transport block is multiplexed following the procedure in clause 9.2.5 of [6, TS 38.213], otherwise the transport block is transmitted on the PUSCH indicated by the DCI.
- If uplink switching gap is triggered as defined in clause 6.1.6, T_{switch} equals to the switching gap duration and for the UE configured with higher layer parameter *uplinkTxSwitchingOption* set to 'dualUL' for uplink carrier aggregation μ_{UL}=min($\mu_{UL,carrier1}$, $\mu_{UL,carrier2}$), otherwise $T_{switch} = 0$.

Otherwise the UE may ignore the scheduling DCI.

The value of $T_{proc,2}$ is used both in the case of normal and extended cyclic prefix.

Table 6.4-1: PUSCH preparation time for PUSCH timing capability 1

μ	PUSCH preparation time N_2 [symbols]
0	10
1	12
2	23
3	36

Table 6.4-2: PUSCH preparation time for PUSCH timing capability 2

μ	PUSCH preparation time N_2 [symbols]
0	5
1	5.5
2	11 for frequency range 1

7 UE procedures for transmitting and receiving on a carrier with intra-cell guard bands

For operation with shared spectrum channel access, when the UE is configured with any of *IntraCellGuardBandsPerSCS* for UL carrier and for DL carrier with SCS configuration μ, the UE is provided with $N_{\text{RB-set,x}} - 1$ intra-cell guard bands on a carrier with μ, each defined by start CRB and size in number of CRBs, $GB_{s,x}^{\text{start},\mu}$ and $GB_{s,x}^{\text{size},\mu}$, provided by higher layer parameters *startCRB* and *nrofCRBs*, respectively, where $s \in \{0,1,\dots,N_{\text{RB-set,x}} - 2\}$. The subscript *x* is set to DL and UL for the downlink and uplink, respectively. Where there is no risk of confusion, the subscript *x* can be dropped. The intra-cell guard bands separate $N_{\text{RB-set,x}}$ RB sets, each defined by start and end CRB, $RB_{s,x}^{\text{start},\mu}$ and $RB_{s,x}^{\text{end},\mu}$, respectively. The UE does not expect that *nrofCRBs* is configured with non-zero value smaller than the applicable intra-cell guard bands as specified in [8, TS 38.101-1] corresponding to μ and carrier size $N_{\text{grid,x}}^{\text{size},\mu}$. The UE determines the start and end CRB indices for $s \in \{0,1,\dots,N_{\text{RB-set},x} - 1\}$ as

$$RB_{s,x}^{\text{start},\mu} = N_{\text{grid},x}^{\text{start},\mu} + \begin{cases} 0 & s = 0 \\ GB_{s-1,x}^{\text{start},\mu} + GB_{s-1,x}^{\text{size},\mu} & \text{otherwise} \end{cases}$$

and

$$RB_{s,x}^{\text{end},\mu} = N_{\text{grid},x}^{\text{start},\mu} + \begin{cases} N_{\text{grid},x}^{\text{size},\mu} - 1 & s = N_{\text{RB-set},x} - 1 \\ GB_{s,x}^{\text{start},\mu} - 1 & \text{otherwise} \end{cases}$$

The RB set with index s consists of $RB_{s,x}^{\text{size},\mu}$ resource blocks where $RB_{s,x}^{\text{size},\mu} = RB_{s,x}^{\text{end},\mu} - RB_{s,x}^{\text{start},\mu} + 1$. When the UE is not configured with *IntraCellGuardBandsPerSCS* for μ, the UE determines the CRB indices for the intra-cell guard band(s), if any, and corresponding RB set(s) according to the nominal intra-cell guard band and RB set pattern as specified in [8, TS 38.101-1] corresponding to μ and carrier size $N_{\text{grid},x}^{\text{size},\mu}$. For either or both DL and UL, if the nominal intra-cell guard band and RB set pattern as specified in [8, TS 38.101-1] contains no intra-cell guard bands, the number of RB sets for the carrier is $N_{\text{RB-set},x} = 1$.

For a carrier with μ, the UE expects $N_{\text{BWP},i}^{\text{start},\mu} = RB_{s0,x}^{\text{start},\mu}$ and $N_{\text{BWP},i}^{\text{size},\mu} = RB_{s1,x}^{\text{end},\mu} - RB_{s0,x}^{\text{start},\mu} + 1$ where $0 \leq s0 \leq s1 \leq N_{\text{RB-set},x} - 1$ for a BWP *i* configured by *initialDownlinkBWP* or *BWP-Downlink* for the DL BWP, or *initialUplinkBWP* or *BWP-Uplink* for the UL BWP. Within the BWP *i*, RB sets are numbered in increasing order from 0 to $N_{\text{RB-set},x}^{\text{BWP}} - 1$ where $N_{\text{RB-set},x}^{\text{BWP}}$ is the number of RB sets contained in the BWP *i* and RB set 0 within the BWP *i* corresponds to RB set $s0$ in the carrier and RB set $N_{\text{RB-set},x}^{\text{BWP}} - 1$ within the BWP *i* corresponds to RB set $s1$ in the carrier.

When a UE is provided with *nrofCRBs* = 0 for all intra-cell guard band(s) on a carrier with μ, the UE is indicated that no intra-cell guard-bands are configured for the carrier and expects $N_{RB-set,x} > 1$. For $\mu = 0$, the UE expects the number of RBs within a RB set is between 100 and 110. For $\mu = 1$, the UE expects the number of RBs within a RB set is between 50 and 55 except for at most one RB set which may contain 56 RBs.

8 Physical sidelink shared channel related procedures

A UE can be configured by higher layers with one or more sidelink resource pools. A sidelink resource pool can be for transmission of PSSCH, as described in Clause 8.1, or for reception of PSSCH, as described in Clause 8.3 and can be associated with either sidelink resource allocation mode 1 or sidelink resource allocation mode 2.

In the frequency domain, a sidelink resource pool consists of *sl-NumSubchannel* contiguous sub-channels. A sub-channel consists of *sl-SubchannelSize* contiguous PRBs, where *sl-NumSubchannel* and *sl-SubchannelSize* are higher layer parameters.

The set of slots that may belong to a sidelink resource pool is denoted by $(t_0^{SL}, t_1^{SL}, \cdots, t_{T_{max}-1}^{SL})$ where

- $0 \leq t_i^{SL} < 10240 \times 2^{\mu}, 0 \leq i < T_{max}$,
- the slot index is relative to slot#0 of the radio frame corresponding to SFN 0 of the serving cell or DFN 0,
- the set includes all the slots except the following slots,
  - N_{S_SSB} slots in which S-SS/PSBCH block (S-SSB) is configured,
  - N_{nonSL} slots in each of which at least one of *Y-th*, *(Y+1)-th*, …, *(Y+X-1)-th* OFDM symbols are not semi-statically configured as UL as per the higher layer parameter *tdd-UL-DL-ConfigurationCommon-r16* of the serving cell if provided or *sl-TDD-Configuration-r16* if provided or *sl-TDD-Config-r16* of the received PSBCH if provided, where *Y* and *X* are set by the higher layer parameters *sl-StartSymbol* and *sl-LengthSymbols*, respectively.
  - The reserved slots which are determined by the following steps.
    1) the remaining slots excluding N_{S_SSB} slots and N_{nonSL} slots from the set of all the slots are denoted by $(l_0, l_1, \cdots, l_{(10240\times 2^{\mu} - N_{S_{SSB}} - N_{nonSL} - 1)})$ arranged in increasing order of slot index.

2) a slot l_r $(0 \le r < 10240 \times 2^{\mu} - N_{S_{SSB}} - N_{nonSL})$ belongs to the reserved slots if $r = \left\lfloor \frac{m \cdot (10240 \times 2^{\mu} - N_{S_{SSB}} - N_{nonSL})}{N_{reserved}} \right\rfloor$, here $m = 0,1,\cdots,N_{reserved} - 1$ and $N_{reserved} = \left(10240 \times 2^{\mu} - N_{S_{SSB}} - N_{nonSL}\right)\ mod\ L_{bitmap}$ where L_{bitmap} denotes the length of bitmap configured by higher layers.

- The slots in the set are arranged in increasing order of slot index.

The UE determines the set of slots assigned to a sidelink resource pool as follows:

- a bitmap $\left(b_0, b_1, \ldots, b_{L_{bitmap}-1}\right)$ associated with the resource pool is used where L_{bitmap} the length of the bitmap is configured by higher layers.

- a slot t_k^{SL} $(0 \le k < 10240 \times 2^{\mu} - N_{S_{SSB}} - N_{nonSL} - N_{reserved})$ belongs to the set if $b_{k'} = 1$ where $k' = k\ mod\ L_{bitmap}$.

- The slots in the set are re-indexed such that the subscripts *i* of the remaining slots t'^{SL}_i are successive {0, 1, …, $T'_{max} - 1$} where T'_{max} is the number of the slots remaining in the set.

The UE determines the set of resource blocks assigned to a sidelink resource pool as follows:

- The resource block pool consists of N_{PRB} PRBs.

- The sub-channel *m* for $m = 0,1,\cdots,numSubchannel - 1$ consists of a set of $n_{subCHsize}$ contiguous resource blocks with the physical resource block number $n_{PRB} = n_{subCHRBstart} + m \cdot n_{subCHsize} + j$ for $j = 0,1,\cdots,n_{subCHsize} - 1$, where $n_{subCHRBstart}$ and $n_{subCHsize}$ are given by higher layer parameters *sl-StartRB-Subchannel* and *sl-SubchannelSize*, respectively

A UE is not expected to use the last N_{PRB} mod $n_{subCHsize}$ PRBs in the resource pool.

8.1 UE procedure for transmitting the physical sidelink shared channel

Each PSSCH transmission is associated with an PSCCH transmission.

That PSCCH transmission carries the 1st stage of the SCI associated with the PSSCH transmission; the 2nd stage of the associated SCI is carried within the resource of the PSSCH.

If the UE transmits SCI format 1-A on PSCCH according to a PSCCH resource configuration in slot *n* and PSCCH resource *m*, then for the associated PSSCH transmission in the same slot

- one transport block is transmitted with up to two layers;

- The number of layers (υ) is determined according to the '*Number of DMRS port'* field in the SCI;

- The set of consecutive symbols within the slot for transmission of the PSSCH is determined according to clause 8.1.2.1;

- The set of contiguous resource blocks for transmission of the PSSCH is determined according to clause 8.1.2.2;

Transform precoding is not supported for PSSCH transmission.

Only wideband precoding is supported for PSSCH transmission.

The DM-RS antenna ports in Clause 8.4.1.1.2 of [4, TS38.211] are determined according to the ordering of DM-RS port(s) given by Tables 8.3.1.1-3 in Clause 8.3.1.1 of [5, TS 38.212].

The UE shall set the contents of the SCI format 2-A as follows:

- the UE shall set value of the *'HARQ process number'* field as indicated by higher layers.

- the UE shall set value of the '*NDI*' field as indicated by higher layers.

- the UE shall set value of the '*Redundancy version*' field as indicated by higher layers.

- the UE shall set value of the '*Source ID*' field as indicated by higher layers.
- the UE shall set value of the '*Destination ID*' field as indicated by higher layers.
- the UE shall set value of the '*HARQ feedback enabled/disabled indicator*' field as indicated by higher layers.
- the UE shall set value of the '*Cast type indicator*' field as indicated by higher layers.
- the UE shall set value of the '*CSI request*' field as indicated by higher layers.

The UE shall set the contents of the SCI formats 2-B as follows:

- the UE shall set value of the '*HARQ process number*' field as indicated by higher layers.
- the UE shall set value of the '*NDI*' field as indicated by higher layers.
- the UE shall set value of the '*Redundancy version*' field as indicated by higher layers.
- the UE shall set value of the '*Source ID*' field as indicated by higher layers.
- the UE shall set value of the '*Destination ID*' field as indicated by higher layers.
- the UE shall set value of the '*HARQ feedback enabled/disabled indicator*' field as indicated by higher layers.
- the UE shall set value of the '*Zone ID*' field as indicated by higher layers.
- the UE shall set the '*Communication range requirement*' field as indicated by higher layers.

8.1.1 Transmission schemes

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

PSSCH transmission is performed with up to two antenna ports, with antenna ports 1000-1001 as defined in clause 8.2.4 of [4, TS 38.211].

8.1.2 Resource allocation

In sidelink resource allocation mode 1:

- for PSSCH and PSCCH transmission, dynamic grant, configured grant type 1 and configured grant type 2 are supported. The configured grant Type 2 sidelink transmission is semi-persistently scheduled by a SL grant in a valid activation DCI according to Clause 10.2A of [6, TS 38.213].

8.1.2.1 Resource allocation in time domain

The UE shall transmit the PSSCH in the same slot as the associated PSCCH.

The minimum resource allocation unit in the time domain is a slot.

The UE shall transmit the PSSCH in consecutive symbols within the slot, subject to the following restrictions:

- The UE shall not transmit PSSCH in symbols which are not configured for sidelink. A symbol is configured for sidelink, according to higher layer parameters *startSLsymbols* and *lengthSLsymbols*, where *startSLsymbols* is the symbol index of the first symbol of *lengthSLsymbols* consecutive symbols configured for sidelink.
- Within the slot, PSSCH resource allocation starts at symbol *startSLsymbols+1*.
- The UE shall not transmit PSSCH in symbols which are configured for use by PSFCH, if PSFCH is configured in this slot.
- The UE shall not transmit PSSCH in the last symbol configured for sidelink.
- The UE shall not transmit PSSCH in the symbol immediately preceding the symbols which are configured for use by PSFCH, if PSFCH is configured in this slot.

In sidelink resource allocation mode 1:

- For sidelink dynamic grant, the PSSCH transmission is scheduled by a DCI format 3_0.
- For sidelink configured grant type 2, the configured grant is activated by a DCI format 3_0.
- For sidelink dynamic grant and sidelink configured grant type 2:
  - The "Time gap" field value *m* of the DCI format 3_0 provides an index *m* + 1 into a slot offset table. That table is given by higher layer parameter *sl-DCI-ToSL-Trans* and the table value at index *m* + 1 will be referred to as slot offset K_{SL}.
  - The slot of the first sidelink transmission scheduled by the DCI is the first SL slot of the corresponding resource pool that starts not earlier than $T_{\mathrm{DL}} - \frac{T_{\mathrm{TA}}}{2} + K_{SL} \times T_{\mathrm{slot}}$, where T_{DL} is the starting time of the downlink slot carrying the corresponding DCI, T_{TA} is the timing advance value corresponding to the TAG of the serving cell on which the DCI is received and K_{SL} is the slot offset between the slot of the DCI and the first sidelink transmission scheduled by DCI and T_{slot} is the SL slot duration.
  - The "Configuration index" field of the DCI format 3_0, if provided and not reserved, indicates the index of the sidelink configured type 2.
- For sidelink configured grant type 1:
  - The slot of the first sidelink transmissions follows the higher layer configuration according to [10, TS 38.321].

8.1.2.2 Resource allocation in frequency domain

The resource allocation unit in the frequency domain is the sub-channel.

The sub-channel assignment for sidelink transmission is determined using the "Frequency resource assignment" field in the associated SCI.

The lowest sub-channel for sidelink transmission is the sub-channel on which the lowest PRB of the associated PSCCH is transmitted.

If a PSSCH scheduled by a PSCCH would overlap with resources containing the PSCCH, the resources corresponding to a union of the PSCCH that scheduled the PSSCH and associated PSCCH DM-RS are not available for the PSSCH.

8.1.3 Modulation order, target code rate, redundancy version and transport block size determination

The redundancy version is given by the "Redundancy version" field in SCI format 2-A or 2-B.

8.1.3.1 Modulation order and target code rate determination

I_{MCS} is given by the '*Modulation and coding scheme*' field in SCI format 1-A.

The MCS table is determined as follows: Table 5.1.3.1-1 is used if no additional MCS table is configured by higher layer parameter *sl-MCS-Table*; otherwise an MCS table is determined according to Table 8.1.3.1-1 or Table 8.1.3.1-2 and '*MCS table indicator*' field in SCI format 1-A.

Table 8.1.3.1-1: Mapping of one bit of MCS table indicator to MCS table

MCS table indicator	MCS table
'0'	Table 5.1.3.1-1
'1'	1st table provided by higher layer parameter *sl-Additional-MCS-Table*

Table 8.1.3.1-2: Mapping of two bits of MCS table indicator to MCS table

MCS table indicator	MCS table
'00'	Table 5.1.3.1-1
'01'	1st table provided by higher layer parameter *sl-Additional-MCS-Table*
'10'	2nd table provided by higher layer parameter *sl-Additional-MCS-Table*
'11'	reserved

The UE shall use I_{MCS} and the MCS table determined according to the previous step to determine the modulation order (Q_m) and Target code rate (R) used in the physical sidelink shared channel.

8.1.3.2 Transport block size determination

For the PSSCH assigned by SCI, if Table 5.1.3.1-2 is used and $0 \le I_{MCS} \le 27$, or a table other than Table 5.1.3.1-2 is used and $0 \le I_{MCS} \le 28$, the UE shall first determine the TBS as specified below:

The UE shall first determine the number of REs (N_{RE}) within the slot.

- A UE first determines the number of REs allocated for PSSCH within a PRB (N'_{RE}) by $N'_{RE} = N_{sc}^{RB}\left(N_{symb}^{sh} - N_{symb}^{PSFCH}\right) - N_{oh}^{PRB} - N_{RE}^{DMRS}$, where
  - $N_{sc}^{RB} = 12$ is the number of subcarriers in a physical resource block,
  - N_{symb}^{sh} = *sl-LengthSymbols* -2, where *sl-LengthSymbols* is the number of sidelink symbols within the slot provided by higher layers,
  - N_{symb}^{PSFCH} = 3 if '*PSFCH overhead indication'* field of SCI format 1-A indicates "1", and N_{symb}^{PSFCH} = 0 otherwise, if higher layer parameter *sl-PSFCH-Period* is 2 or 4. If higher layer parameter *sl-PSFCH-Period* is 0, $N_{symb}^{PSFCH} = 0$. If higher layer parameter *sl-PSFCH-Period* is 1, $N_{symb}^{PSFCH} = 3$.
  - N_{oh}^{PRB} is the overhead given by higher layer parameter *sl-X-Overhead*,
  - N_{RE}^{DMRS} is given by Table 8.1.3.2-1 according to higher layer parameter *sl-PSSCH-DMRS-TimePattern.*

Table 8.1.3.2-1: N_{RE}^{DMRS} according to higher layer parameter *sl-PSSCH-DMRS-TimePatternList*

sl-PSSCH-DMRS-TimePatternList	N_{RE}^{DMRS}
{2}	12
{3}	18
{4}	24
{2,3}	15
{2,4}	18
{3,4}	21
{2,3,4}	18

- A UE determines the total number of REs allocated for PSSCH (N_{RE}) by $N_{RE} = N'_{RE} \cdot n_{PRB} - N_{RE}^{SCI,1} - N_{RE}^{SCI,2}$, where
  - n_{PRB} is the total number of allocated PRBs for the PSSCH,
  - $N_{RE}^{SCI,1}$ is the total number of REs occupied by the PSCCH and PSCCH DM-RS.
  - $N_{RE}^{SCI,2}$ is the number of coded modulation symbols generated for 2nd-stage SCI transmission (prior to duplication for the 2nd layer, if present) according to Clause 8.4.4 of [5, TS 38.212], with the assumption of $\gamma = 0$.

The UE determines TBS according to Steps 2), 3), and 4) in clause 5.1.3.2.

A UE is not expected to receive an SCI indicating $28 \leq I_{MCS} \leq 31$ if Table 5.1.3.1-2 is used, or $29 \leq I_{MCS} \leq 31$ otherwise.

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

In resource allocation mode 2, the higher layer can request the UE to determine a subset of resources from which the higher layer will select resources for PSSCH/PSCCH transmission. To trigger this procedure, in slot *n*, the higher layer provides the following parameters for this PSSCH/PSCCH transmission:

- the resource pool from which the resources are to be reported;
- L1 priority, $prio_{TX}$;
- the remaining packet delay budget;
- the number of sub-channels to be used for the PSSCH/PSCCH transmission in a slot, L_{subCH};
- optionally, the resource reservation interval, $P_{\text{rsvp\_TX}}$, in units of msec.
- if the higher layer requests the UE to determine a subset of resources from which the higher layer will select resources for PSSCH/PSCCH transmission as part of re-evaluation or pre-emption procedure, the higher layer provides a set of resources $(r_0, r_1, r_2, \ldots)$ which may be subject to re-evaluation and a set of resources $(r'_0, r'_1, r'_2, \ldots)$ which may be subject to pre-emption.
  - it is up to UE implementation to determine the subset of resources as requested by higher layers before or after the slot r''_i - T_3, where r''_i is the slot with the smallest slot index among $(r_0, r_1, r_2, \ldots)$ and $(r'_0, r'_1, r'_2, \ldots)$, and T_3 is equal to $T^{SL}_{proc,1}$, where $T^{SL}_{proc,1}$ is defined in slots in Table 8.1.4-2 where μ_{SL} is the SCS configuration of the SL BWP.

The following higher layer parameters affect this procedure:

- *sl-SelectionWindowList*: internal parameter T_{2min} is set to the corresponding value from higher layer parameter *sl-SelectionWindowList* for the given value of $prio_{TX}$.
- *sl-Thres-RSRP-List*: this higher layer parameter provides an RSRP threshold for each combination $(p_i,\ p_j)$, where p_i is the value of the priority field in a received SCI format 1-A and p_{j} is the priority of the transmission of the UE selecting resources; for a given invocation of this procedure, $p_{\text{j}} = prio_{TX}$.
- *sl-RS-ForSensing* selects if the UE uses the PSSCH-RSRP or PSCCH-RSRP measurement, as defined in clause 8.4.2.1.
- *sl-ResourceReservePeriodList*
- *sl-SensingWindow*: internal parameter T_0 is defined as the number of slots corresponding to *sl-SensingWindow* msec
- *sl-TxPercentageList*: internal parameter X for a given $prio_{TX}$ is defined as *sl-TxPercentageList ($prio_{TX}$)* converted from percentage to ratio
- *sl-PreemptionEnable*: if *sl-PreemptionEnable* is provided, and if it is not equal to 'enabled', internal parameter $prio_{pre}$ is set to the higher layer provided parameter *sl-PreemptionEnable*

The resource reservation interval, $P_{\text{rsvp\_TX}}$, if provided, is converted from units of msec to units of logical slots, resulting in $P'_{\text{rsvp\_TX}}$ according to clause 8.1.7.

Notation:

$(t'^{SL}_0, t'^{SL}_1, t'^{SL}_2, \ldots)$ denotes the set of slots which belongs to the sidelink resource pool and is defined in Clause 8.

The following steps are used:

1) A candidate single-slot resource for transmission $R_{x,y}$ is defined as a set of L_{subCH} contiguous sub-channels with sub-channel $x+j$ in slot t'^{SL}_{y} where $j = 0, \ldots, L_{\text{subCH}} - 1$. The UE shall assume that any set of L_{subCH} contiguous sub-channels included in the corresponding resource pool within the time interval $[n + T_1, n + T_2]$ correspond to one candidate single-slot resource, where

   - selection of T_1 is up to UE implementation under $0 \le T_1 \le T^{SL}_{proc,1}$, where $T^{SL}_{proc,1}$ is defined in slots in Table 8.1.4-2 where μ_{SL} is the SCS configuration of the SL BWP;

   - if T_{2min} is shorter than the remaining packet delay budget (in slots) then T_2 is up to UE implementation subject to $T_{2min} \le T_2 \le$ remaining packet delay budget (in slots); otherwise T_2 is set to the remaining packet delay budget (in slots).

   The total number of candidate single-slot resources is denoted by M_{total}.

2) The sensing window is defined by the range of slots $[n - T_0, n - T^{SL}_{proc,0})$ where T_0 is defined above and $T^{SL}_{proc,0}$ is defined in slots in Table 8.1.4-1 where μ_{SL} is the SCS configuration of the SL BWP. The UE shall monitor slots which belongs to a sidelink resource pool within the sensing window except for those in which its own transmissions occur. The UE shall perform the behaviour in the following steps based on PSCCH decoded and RSRP measured in these slots.

3) The internal parameter $Th(p_i, p_j)$ is set to the corresponding value of RSRP threshold indicated by the *i*-th field in *sl-Thres-RSRP-List*, where $i = p_i + (p_j - 1) * 8$.

4) The set S_A is initialized to the set of all the candidate single-slot resources.

5) The UE shall exclude any candidate single-slot resource $R_{x,y}$ from the set S_A if it meets all the following conditions:

   - the UE has not monitored slot t'^{SL}_{m} in Step 2.

   - for any periodicity value allowed by the higher layer parameter *sl-ResourceReservePeriodList* and a hypothetical SCI format 1-A received in slot t'^{SL}_{m} with '*Resource reservation period*' field set to that periodicity value and indicating all subchannels of the resource pool in this slot, condition c in step 6 would be met.

5a) If the number of candidate single-slot resources $R_{x,y}$ remaining in the set S_A is smaller than $X \cdot M_{total}$, the set S_A is initialized to the set of all the candidate single-slot resources as in step 4.

6) The UE shall exclude any candidate single-slot resource $R_{x,y}$ from the set S_A if it meets all the following conditions:

   a) the UE receives an SCI format 1-A in slot t'^{SL}_{m}, and '*Resource reservation period'* field, if present, and '*Priority*' field in the received SCI format 1-A indicate the values $P_{\text{rsvp\_RX}}$ and $prio_{RX}$, respectively according to Clause 16.4 in [6, TS 38.213];

   b) the RSRP measurement performed, according to clause 8.4.2.1 for the received SCI format 1-A, is higher than $Th(prio_{RX}, prio_{TX})$;

   c) the SCI format received in slot t'^{SL}_{m} or the same SCI format which, if and only if the '*Resource reservation period*' field is present in the received SCI format 1-A, is assumed to be received in slot(s) $t'^{SL}_{m+q\times P'_{rsvp\_RX}}$ determines according to clause 8.1.5 the set of resource blocks and slots which overlaps with $R_{x,y+j\times P'_{rsvp\_TX}}$ for q=1, 2, …, Q and j=0, 1, …, $C_{resel} - 1$. Here, P'_{rsvp_RX} is $P_{\text{rsvp\_RX}}$ converted to units of logical slots according to clause 8.1.7, $Q = \left\lceil \frac{T_{scal}}{P_{rsvp\_RX}} \right\rceil$ if $P_{rsvp\_RX} < T_{scal}$ and $n' - m \le P'_{rsvp\_RX}$, where $t'^{SL}_{n'} = n$ if slot n belongs to the set $(t'^{SL}_{0}, t'^{SL}_{1}, \ldots, t'^{SL}_{T'_{max}-1})$, otherwise slot $t'^{SL}_{n'}$ is the first slot after slot n belonging to the set $(t'^{SL}_{0}, t'^{SL}_{1}, \ldots, t'^{SL}_{T'_{max}-1})$; otherwise $Q = 1$. T_{scal} is set to selection window size T_2 converted to units of msec.

7) If the number of candidate single-slot resources remaining in the set S_A is smaller than $X \cdot M_{\text{total}}$, then $Th(p_i, p_j)$ is increased by 3 dB for each priority value $Th(p_i, p_j)$ and the procedure continues with step 4.

The UE shall report set S_A to higher layers.

If a resource r_i from the set $(r_0, r_1, r_2, ...)$ is not a member of S_A, then the UE shall report re-evaluation of the resource r_i to higher layers.

If a resource r_i' from the set $(r_0', r_1', r_2', ...)$ meets the conditions below then the UE shall report pre-emption of the resource r_i' to higher layers

- r_i' is not a member of S_A, and
- r_i' meets the conditions for exclusion in step 6, with $Th(prio_{RX}, prio_{TX})$ set to the final threshold after executing steps 1)-7), i.e. including all necessary increments for reaching $X \cdot M_{\text{total}}$, and
- the associated priority $prio_{RX}$, satisfies one of the following conditions:
  - *sl-PreemptionEnable* is provided and is equal to 'enabled' and $prio_{TX} > prio_{RX}$
  - *sl-PreemptionEnable* is provided and is not equal to 'enabled', and $prio_{RX} < prio_{pre}$ and $prio_{TX} > prio_{RX}$

Table 8.1.4-1: $T_{proc,0}^{SL}$ depending on sub-carrier spacing

μ_{SL}	$T_{proc,0}^{SL}$ [slots]
0	1
1	1
2	2
3	4

Table 8.1.4-2: $T_{proc,1}^{SL}$ depending on sub-carrier spacing

μ_{SL}	$T_{proc,1}^{SL}$ [slots]
0	3
1	5
2	9
3	17

8.1.5 UE procedure for determining slots and resource blocks for PSSCH transmission associated with an SCI format 1-A

The set of slots and resource blocks for PSSCH transmission is determined by the resource used for the PSCCH transmission containing the associated SCI format 1-A, and fields '*Frequency resource assignment*', '*Time resource assignment*' of the associated SCI format 1-A as described below.

'*Time resource assignment*' carries logical slot offset indication of N = 1 or 2 actual resources when *sl-MaxNumPerReserve* is 2, and N = 1 or 2 or 3 actual resources when *sl_MaxNumPerReserve* is 3, in a form of time RIV (TRIV) field which is determined as follows:

if $N = 1$

$TRIV = 0$

elseif $N = 2$

$TRIV = t_1$

else

if $(t_2 - t_1 - 1) \leq 15$

$TRIV = 30(t_2 - t_1 - 1) + t_1 + 31$

else

$TRIV = 30(31 - t_2 + t_1) + 62 - t_1$

end if

end if

where the first resource is in the slot where SCI format 1-A was received, and t_i denotes i-th resource time offset in logical slots of a resource pool with respect to the first resource where for N = 2, $1 \leq t_1 \leq 31$; and for N = 3, $1 \leq t_1 \leq 30$, $t_1 < t_2 \leq 31$.

The starting sub-channel $n_{subCH,0}^{start}$ of the first resource is determined according to clause 8.1.2.2. The number of contiguously allocated sub-channels for each of the N resources $L_{subCH} \geq 1$ and the starting sub-channel indexes of resources indicated by the received SCI format 1-A, except the resource in the slot where SCI format 1-A was received, are determined from "Frequency resource assignment" which is equal to a frequency RIV (FRIV) where.

If *sl-MaxNumPerReserve* is 2 then

$$FRIV = n_{subCH,1}^{start} + \sum_{i=1}^{L_{\text{subCH}}-1} \left(N_{\text{subchannel}}^{SL} + 1 - i\right)$$

If *sl-MaxNumPerReserve* is 3 then

$$FRIV = n_{subCH,1}^{start} + n_{subCH,2}^{start} \cdot \left(N_{\text{subchannel}}^{SL} + 1 - L_{\text{subCH}}\right) + \sum_{i=1}^{L_{\text{subCH}}-1} \left(N_{\text{subchannel}}^{SL} + 1 - i\right)^2$$

where

- $n_{subCH,1}^{start}$ denotes the starting sub-channel index for the second resource
- $n_{subCH,2}^{start}$ denotes the starting sub-channel index for the third resource
- $N_{subchannel}^{SL}$ is the number of sub-channels in a resource pool provided according to the higher layer parameter *sl-NumSubchannel*

If TRIV indicates $N <$ *sl-MaxNumPerReserve,* the starting sub-channel indexes corresponding to *sl-MaxNumPerReserve* minus N last resources are not used.

The number of slots in one set of the time and frequency resources for transmission opportunities of PSSCH is given by C_{resel} where C_{resel}= 10*SL_RESOURCE_RESELECTION_COUNTER [10, TS 38.321] if configured else C_{resel} is set to 1.

If a set of sub-channels in slot t'^{SL}_m is determined as the time and frequency resource for PSSCH transmission corresponding to the selected sidelink grant (described in [10, TS 38.321]), the same set of sub-channels in slots $t'^{SL}_{m+j\times P'_{rsvp\_TX}}$ are also determined for PSSCH transmissions corresponding to the same sidelink grant where j=1, 2,..., $C_{resel} - 1$, $P_{\text{rsvp\_TX}}$, if provided, is converted from units of msec to units of logical slots, resulting in $P'_{\text{rsvp\_TX}}$ according to clause 8.1.7, and $\left(t'^{SL}_0, t'^{SL}_1, t'^{SL}_2, \ldots\right)$ is determined by Clause 8. Here, $P_{\text{rsvp\_TX}}$ is the resource reservation interval indicated by higher layers.

8.1.6 Sidelink congestion control in sidelink resource allocation mode 2

If a UE is configured with higher layer parameter *sl-CR-Limit* and transmits PSSCH in slot *n*, the UE shall ensure the following limits for any priority value k;

$$\sum_{i \geq k} CR(i) \leq CR_{Limit}(k)$$

where $CR(i)$ is the CR evaluated in slot *n-N* for the PSSCH transmissions with '*Priority*' field in the SCI set to *i*, and $CR_{Limit}(k)$ corresponds to the high layer parameter *sl-CR-Limit* that is associated with the priority value *k* and the CBR range which includes the CBR measured in slot *n-N*, where *N* is the congestion control processing time.

The congestion control processing time N is based on μ of Table 8.1.6-1 and Table 8.1.6-2 for UE processing capability 1 and 2 respectively, where μ corresponds to the subcarrier spacing of the sidelink channel with which the PSSCH is to be transmitted. A UE shall only apply a single processing time capability in sidelink congestion control.

Table 8.1.6-1: Congestion control processing time for processing timing capability 1

μ	Congestion control processing time N [slots]
0	2
1	2
2	4
3	8

Table 8.1.6-2: Congestion control processing time for processing timing capability 2

μ	Congestion control processing time N [slots]
0	2
1	4
2	8
3	16

It is up to UE implementation how to meet the above limits, including dropping the transmissions in slot *n*.

8.1.7 UE procedure for determining the number of logical slots for a reservation period

A given resource reservation period P_{rsvp} in milliseconds is converted to a period P'_{rsvp} in logical slots as:

$$P'_{\text{rsvp}} = \left\lceil \frac{T'_{max}}{10240\ \ ms} \times P_{\text{rsvp}} \right\rceil$$

where T'_{max} is the number of slots that belong to a resource pool as defined in Clause 8.

8.2 UE procedure for transmitting sidelink reference signals

8.2.1 CSI-RS transmission procedure

A UE transmits sidelink CSI-RS within a unicast PSSCH transmission if the following conditions hold:

- CSI reporting is enabled by higher layer parameter *sl-CSI-Acquisition*; and
- the '*CSI request*' field in the corresponding SCI format 2-A is set to 1.

The following parameters for CSI-RS transmission are configured for each CSI-RS configuration:

- *sl-CSI-RS-FirstSymbol* indicates the first OFDM symbol in a PRB used for SL CSI-RS
- *sl-CSI-RS-FreqAllocation* indicates the number of antenna ports and the frequency domain allocation for SL CSI-RS.

When the UE is configured with Q_p={1,2} CSI-RS port(s) in sidelink and the number of scheduled layers is n_{layer}^{PSSCH},

- The CSI-RS scaling factor β_{CSIRS} specified in clause 8.4.1.5.3 of [4, TS 38.211] is given by $\beta_{\text{CSIRS}} = \beta_{\text{DMRS}}^{\text{PSSCH}} \cdot \sqrt{\frac{n_{layer}^{PSSCH}}{Q_p}}$ where $\beta_{\text{DMRS}}^{\text{PSSCH}}$ is the scaling factor for the corresponding PSSCH specified in clause 8.3.1.5 of [4, TS 38.211].

8.2.2 PSSCH DM-RS transmission procedure

The UE selects the DM-RS time domain pattern out of the patterns configured using the higher layer parameter *sl-PSSCH-DMRS-TimePatternList* for the resource pool on which the PSSCH is to be transmitted. If more than one DM-RS time domain pattern is configured, the selected pattern is indicated by the '*DMRS pattern*' field in the SCI format 1-A associated with the PSSCH transmission.

If PSSCH DM-RS and PSCCH are mapped to the same OFDM symbol, then this mapping within a single sub-channel is only supported if higher layer parameter *sl-SubchannelSize* >= 20, i.e. the sub-channel size is at least 20 PRBs.

When a sub-channel size is less than 20 PRBs and the size of PSCCH is less than the sub-channel size, a UE is not expected to choose a PSSCH DM-RS pattern to be transmitted in the same OFDM symbol with PSCCH.

8.2.3 PT-RS transmission procedure

Transmission of PT-RS is only supported in frequency range 2.

The UE PT-RS transmission procedure specified in clause 6.2.3.1 applies for derivation of the PT-RS parameters $L_{PT\text{-}RS}$ and, $K_{PT\text{-}RS}$ and for determination of PT-RS presence, with the following changes:

- *timeDensity* and *frequencyDensity* in *PTRS-UplinkConfig* are replaced by *sl-PTRS-TimeDensity* and *sl-PTRS-FreqDensity* in *SL-PTRS-Config* respectively, and *SL-PTRS-Config* is (pre)configured per resource pool;

- the number of antenna ports is the same as the number of PSSCH DM-RS antenna ports and the association between a PT-RS antenna port and a PSSCH DM-RS antenna port is fixed.

8.3 UE procedure for receiving the physical sidelink shared channel

For sidelink resource allocation mode 1, a UE upon detection of SCI format 1-A on PSCCH can decode PSSCH according to the detected SCI formats 2-A and 2-B, and associated PSSCH resource configuration configured by higher layers. The UE is not required to decode more than one PSCCH at each PSCCH resource candidate.

For sidelink resource allocation mode 2, a UE upon detection of SCI format 1-A on PSCCH can decode PSSCH according to the detected SCI formats 2-A and 2-B, and associated PSSCH resource configuration configured by higher layers. The UE is not required to decode more than one PSCCH at each PSCCH resource candidate.

A UE is required to decode neither the corresponding SCI formats 2-A and 2-B nor the PSSCH associated with an SCI format 1-A if the SCI format 1-A indicates an MCS table that the UE does not support.

8.4 UE procedure for receiving reference signals

8.4.1 CSI-RS reception procedure

The CSI-RS defined in Clause 8.4.1.5 of [4, TS 38.211] may be used for CSI computation.

8.4.2 DM-RS reception procedure for RSRP computation

8.4.2.1 RSRP for resource selection in sidelink resource allocation mode 2

In sidelink resource allocation mode 2, the UE measures RSRP for resource selection as follows:

- PSSCH-RSRP over the DM-RS resource elements for the PSSCH according to the received SCI format 1-A if higher layer parameter *sl-RS-ForSensing* is set to 'pssch', and

- PSCCH-RSRP over the DM-RS resource elements for the PSCCH carrying to the received SCI format 1-A if higher layer parameter *sl-RS-ForSensing* is set to 'pscch'.

8.4.3 PT-RS reception procedure

Reception of PT-RS is only supported in frequency range 2.

The UE PT-RS reception procedure specified in clause 5.1.6.3 applies for derivation of the PT-RS parameters $L_{PT\text{-}RS}$ and $K_{PT\text{-}RS}$ and for determination of PT-RS presence, with the following changes:

- *timeDensity* and f*requencyDensity* in *PTRS-DownlinkConfig* are replaced by *sl-PTRS-TimeDensity* and *sl-PTRS-FreqDensity* in *SL-PTRS-Config* respectively, and *SL-PTRS-Config* is (pre)configured per resource pool;
- the number of antenna ports is the same as the number of PSSCH DM-RS antenna ports and the association between a PT-RS antenna port and a PSSCH DM-RS antenna port is fixed.

8.5 UE procedure for reporting channel state information (CSI)

8.5.1 Channel state information framework

CSI consists of Channel Quality Indicator (CQI) and Rank Indicator (RI). The CQI and RI are always reported together.

8.5.1.1 Reporting configurations

The UE shall calculate CSI parameters (if reported) assuming the following dependencies between CSI parameters (if reported)

- CQI shall be calculated conditioned on the reported RI

The CSI reporting can be aperiodic (using [10, TS 38.321]). Table 8.5.1.1-1 shows the supported combinations of CSI reporting configurations and CSI-RS configurations and how the CSI reporting is triggered for CSI-RS configuration. Aperiodic CSI-RS is configured and triggered/activated as described in Clause 8.5.1.2.

Table 8.5.1.1-1 Triggering/Activation of CSI reporting for the possible CSI-RS Configurations.

CSI-RS Configuration	Aperiodic CSI Reporting
Aperiodic CSI-RS	Triggered by SCI.

For CSI reporting, wideband CQI reporting is supported. A wideband CQI is reported for a single codeword for the entire CSI reporting band.

8.5.1.2 Triggering of sidelink CSI reports

The CSI-triggering UE is not allowed to trigger another aperiodic CSI report for the same UE before the last slot of the expected reception or completion of the ongoing aperiodic CSI report associated with the SCI format 2-A with the '*CSI request*' field set to 1, where the last slot of the expected reception of the ongoing aperiodic CSI report is given by [10, TS38.321].

An aperiodic CSI report is triggered by an SCI format 2-A with the '*CSI request*' field set to 1.

A UE is not expected to transmit a sidelink CSI-RS and a sidelink PT-RS which overlap.

8.5.2 Channel state information

8.5.2.1 CSI reporting quantities

8.5.2.1.1 Channel quality indicator (CQI)

The UE shall derive CQI as specified in clause 5.2.2.1, with the following changes

- PDSCH replaced by PSSCH
- uplink slot replaced by sidelink slot
- downlink physical resource blocks replaced by sidelink physical resource blocks
- Transport Block Size determination according to Clause 8.1.3.2
- CSI reference resource according to the Clause 8.5.2.3
- interference measurements are not supported

- sub-band differential CQI is not supported
- cqi-Table is determined as follows
  - cqi-Table = 'table1' if Table 5.1.3.1-1 is determined as the MCS table according to Clause 8.1.3.1 of [6, 38.214],
  - cqi-Table = 'table2' if Table 5.1.3.1-2 is determined as the MCS table according to Clause 8.1.3.1 of [6, 38.214],
  - cqi-Table = 'table3' if Table 5.1.3.1-3 is determined as the MCS table according to Clause 8.1.3.1 of [6, 38.214]

8.5.2.2 Reference signal (CSI-RS)

The UE can be configured with one CSI-RS pattern as indicated by the higher layer parameters *sl-CSI-RS-FreqAllocation, sl-OneAntennaPort, sl-CSI-RS-FirstSymbol* in *SL-CSI-RS-Config.*

Parameters for which the UE shall assume non-zero transmission power for CSI-RS are configured according to clause 8.2.1.

A UE is not expected to be configured such that a CSI-RS and the corresponding PSCCH can be mapped to the same resource element. A UE is not expected to receive sidelink CSI-RS and PSSCH DM-RS, nor CSI-RS and 2nd-stage SCI, on the same symbol.

Sidelink CSI-RS shall be transmitted according to [4, TS 38.211] in the resource blocks used for the PSSCH associated with the SCI format 2-A triggering a report.

8.5.2.3 CSI reference resource definition

The CSI reference resource in sidelink is defined as follows:

- In the frequency domain, the CSI reference resource is defined by the group of sidelink physical resource blocks containing the sidelink CSI-RS to which the derived CSI relates.
- In the time domain, the CSI reference resource for a CSI reporting in sidelink slot n is defined by a single sidelink slot n_{CSI_ref} where n_{CSI_ref} is the same sidelink slot as the corresponding CSI request.

If configured to report CQI index and RI index, in the CSI reference resource, the UE shall assume the following for the purpose of deriving the CQI index and RI index:

- The reference resource uses the CP length and subcarrier spacing configured for the SL BWP.
- Redundancy Version 0.
- PSCCH occupies 2 OFDM symbols.
- The number of PSSCH and DM-RS symbols is equal to *sl-LenghSymbols*–2.
- Assume no REs allocated for sidelink CSI-RS.
- Assume no REs allocated SCI format 2-A or SCI format 2-B.
- Assume the same number of DM-RS symbols as the smallest one configured by the higher layer parameter *sl-PSSCH-DMRS-TimePatternList.*
- Assume no REs allocated for sidelink PT-RS.
- Assume sidelink CSI-RS RE power is the same as PSSCH RE power.
- The PSSCH transmission scheme where the UE may assume that PSSCH transmission would be performed with up to 2 transmission layers as defined in Clause 8.3.1.4 of [4, TS 38.211]. For CQI calculation, the UE should assume that PSSCH signals on antenna ports in the set [1000,…, 1000+ν-1] for ν layers would result in signals equivalent to corresponding symbols transmitted on antenna ports [3000,…, 3000+P-1], as given by

$$\begin{bmatrix} y^{(3000)}(i) \\ \cdots \\ y^{(3000+P-1)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \cdots \\ x^{(\nu-1)}(i) \end{bmatrix}$$

where $x(i) = \left[x^{(0)}(i) .. x^{(\nu-1)}(i)\right]^T$ is a vector of PSSCH symbols from the layer mapping defined in Clause 8.3.1.4 of [4, TS 38.211], $P \in [1,2]$ is the number of CSI-RS ports. If only one CSI-RS port is configured, *W(i)* is 1. Otherwise, *W(i)* is the identity matrix.

8.5.3 CSI reporting

The UE can be configured with one CSI reporting latency bound as indicated by the higher layer parameter *sl-LatencyBound-CSI-Report*. CSI reporting is aperiodic and is described in [10, TS 38.321].

8.6 UE PSSCH preparation procedure time

For sidelink dynamic grant and for SL configured grant type 2 activation, if the first sidelink symbol in the sidelink allocation for a PSSCH for a transport block and the associated PSCCH, including the DM-RS and the duplicated symbol, as defined by the slot offset K_{SL} of the scheduling DCI for dynamic grant or the activating DCI for SL configured grant type 2, is no earlier than at symbol L, where L is defined as the next sidelink symbol with its CP starting $T_{proc} = (N_2 + d_{2,1})(2048 + 144) \cdot \kappa 2^{-\mu} \cdot T_C$ after the end of the reception of the last symbol of the PDCCH carrying the DCI scheduling the sidelink transmissions for dynamic grant or activating the SL configured grant type 2, then the UE shall transmit the PSSCH and the associated PSCCH.

- N_2 is based on μ of Table 8.6-1, where μ corresponds to the one of (μ_{DL}, μ_{SL}) resulting with the largest T_{proc}, where the μ_{DL} corresponds to the subcarrier spacing of the downlink with which the PDCCH carrying the DCI scheduling the PSSCH for dynamic grant or activating the SL configured grant type 2 was transmitted and μ_{SL} corresponds to the subcarrier spacing of the sidelink channel with which the PSSCH and the associated PSCCH are to be transmitted, and κ is defined in Clause 4.1 of [4, TS 38.211].

- $d_{2,1} = 1$.

Otherwise the UE may ignore the scheduling DCI for dynamic grant or the activating DCI for SL configured grant type 2.

The value of T_{proc} is used both in the case of normal and extended cyclic prefix.

Table 8.6-1: PSSCH preparation time

μ	PSSCH preparation time N_2 [symbols]
0	10
1	12
2	23
3	36

For sidelink resource allocation mode 1, the UE does not expect that the first sidelink symbol in the sidelink allocation for a PSSCH for retransmission of a transport block and the associated PSCCH, including the DM-RS and the duplicated symbol as defined by the "Time resource assignment" field of the corresponding DCI for dynamic grant or for SL configured grant type 2, or by *sl-TimeResourceCG-Type1* for configured grant type 1 starts earlier than at symbol L where L is defined as the next sidelink symbol with its CP starting $T_{prep} + \delta$ after the end of the last symbol of the PSFCH occasion corresponding to the most recent transmission of PSSCH for the same transport block, where T_{prep} is defined in Clause 16.5 of [6, TS 38.213] and $\delta = 5 \cdot 10^{-4}$ s. Otherwise the UE may skip the retransmission of the PSSCH and the transmsission of the corresponding PSCCH.

Annex A (informative): Change history

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2017-05	RAN1#89	R1-1708892	-	-	-	Draft skeleton	0.0.0
2017-07	AH_1706	R1-1712016				Inclusion of agreements up to and including RAN1#AH2	0.0.1
2017-08	AH_1706	R1-1714234				Inclusion of agreements up to and including RAN1#AH2	0.0.2
2017-08	RAN1#90	R1-1714596				Updated editor's version	0.0.3
2017-08	RAN1#90	R1-1714626				Updated editor's version	0.0.4
2017-08	RAN1#90	R1-1715077				Endorsed version by RAN1#90	0.1.0
2017-08	RAN1#90	R1-1715324				Inclusion of agreements up to and including RAN1#90	0.1.1
2017-08	RAN1#90	R1-1715331				Updated editor's version	0.1.2
2017-09	RAN#77	RP-172001				For information to plenary	1.0.0
2017-09	AH_1709	R1-1716930				Inclusion of agreements up to and including RAN1#AH3	1.0.1
2017-10	RAN1#90 bis	R1-1718808				Updated editor's version	1.0.2
2017-10	RAN1#90 bis	R1-1718819				Endorsed version by RAN1#90bis	1.1.0
2017-10	RAN1#90 bis	R1-1719227				Inclusion of agreements up to and including RAN1#90bis	1.1.1
2017-11	RAN1#90 bis	R1-1720113				Inclusion of agreements up to and including RAN1#90bis	1.1.2
2017-11	RAN1#90 bis	R1-1720114				Inclusion of agreements up to and including RAN1#90bis	1.1.3
2017-11	RAN1#90 bis	R1-1721051				Endorsed version	1.2.0
2017-12	RAN1#91	R1-1721344				Inclusion of agreements up to and including RAN1#91	1.3.0
2017-12	RAN#78	RP-172416				Endorsed version for approval by plenary	2.0.0
2017-12	RAN#78					Approved by plenary – Rel-15 spec under change control	15.0.0
2018-03	RAN#79	RP-180200	0001		F	CR capturing the Jan18 ad-hoc and RAN1#92 meeting agreements	15.1.0
2018-06	RAN#80	RP-181172	0002	1	F	CR to 38.214 capturing the RAN1#92bis and RAN1#93 meeting agreements	15.2.0
2018-06	RAN#80	RP-181257	0003	-	B	CR to 38.214 capturing the RAN1#92bis and RAN1#93 meeting agreements related to URLLC	15.2.0
2018-06	RAN#80	RP-181172	0004	-	F	CR to 38.214: maintenance according to agreed Rel 15 features	15.2.0
2018-09	RAN#81	RP-181789	0005	-	F	CR to 38.214 capturing the RAN1#94 meeting agreements	15.3.0
2018-12	RAN#82	RP-182523	0006	2	F	Combined CR of all essential corrections to 38.214 from RAN1#94bis and RAN1#95	15.4.0
2019-03	RAN#83	RP-190632	0007	3	F	Correction to aperiodic CSI-RS triggering with different numerology between PDCCH and CSI-RS	15.5.0
2019-03	RAN#83	RP-190450	0009	-	F	Correction on CSI-RS configuration in 38.214	15.5.0
2019-03	RAN#83	RP-190450	0010	-	F	Correction on uplink resource allocation type 1	15.5.0
2019-03	RAN#83	RP-190450	0011	-	F	Correction on determination of the resource allocation table for PUSCH with SP CSI	15.5.0
2019-03	RAN#83	RP-190450	0012	-	F	Correction on PUSCH resource allocation	15.5.0
2019-03	RAN#83	RP-190450	0013	-	F	Change Request for alignment of frequency domain resource allocation with 38.213 for a PUSCH transmission scheduled by a RAR UL grant	15.5.0
2019-03	RAN#83	RP-190450	0014	-	F	CR on sequential PDSCH and PUSCH scheduling	15.5.0
2019-03	RAN#83	RP-190450	0015	-	F	CR on out of HARQ order with multiple PDSCHs within one slot	15.5.0
2019-03	RAN#83	RP-190450	0016	-	F	Correction to LBRM restriction	15.5.0
2019-03	RAN#83	RP-190450	0017	-	F	CR on PDSCH beam indication	15.5.0
2019-03	RAN#83	RP-190450	0018	-	F	Correction on TCI indication for multi-slot PDSCH	15.5.0
2019-03	RAN#83	RP-190450	0019	-	F	Clarifications on CSI reporting on PUSCH	15.5.0
2019-03	RAN#83	RP-190450	0020	-	F	QCL properties of Msg4 in CONNECTED Mode	15.5.0
2019-03	RAN#83	RP-190450	0022	1	F	CR on dynamic grant overriding configured grant	15.5.0
2019-03	RAN#83	RP-190450	0023	-	F	Correction on PUSCH with configured grant	15.5.0
2019-03	RAN#83	RP-190450	0024	-	F	Corrections to 38.214	15.5.0
2019-03	RAN#83	RP-190425	0025	1	F	CR on QCL assumption for receiving PDSCH for RAR	15.5.0
2019-06	RAN#84	RP-191552	0035	-	F	Removal of "Correction to aperiodic CSI-RS triggering with different numerology between PDCCH and CSI-RS"	15.6.0
2019-06	RAN#84	RP-191284	0026	-	F	Corrections on non-codebook based UL transmission to TS 38.214	15.6.0
2019-06	RAN#84	RP-191284	0027	-	F	CR on UE procedure for PDSCH and PUSCH	15.6.0
2019-06	RAN#84	RP-191284	0028	-	F	Correction on configured scheduling PUSCH repetition with dynamic SFI	15.6.0
2019-06	RAN#84	RP-191284	0029	-	F	CR on rate matching for PDSCH scheduled by DCI format 1_0	15.6.0
2019-06	RAN#84	RP-191284	0030	-	F	Clarification on CG transmission opportunities	15.6.0
2019-06	RAN#84	RP-191284	0031	5	F	Corrections to 38.214 including alignment of terminology across specifications	15.6.0
2019-06	RAN#84	RP-191284	0032	-	F	CR to 38.214 clarifying calculation of DataRate and DataRateCC	15.6.0
2019-06	RAN#84	RP-191284	0033	-	F	Correction on PUSCH retransmission for a serving cell configured with two uplinks	15.6.0

2019-06	RAN#84	RP-191284	0034	-	F	Corrections to 38.214 regarding the MAC CE activation/deactivation timing in mixed numerology scenario	15.6.0
2019-09	RAN#85	RP-191943	0037	-	F	Correction on UE receiving PDSCH procedure in FR2	15.7.0
2019-09	RAN#85	RP-191943	0038	-	F	Correction on slot aggregation	15.7.0
2019-09	RAN#85	RP-191943	0039	-	F	CR on grant-based PDSCH overlapping with SPS PDSCH	15.7.0
2019-09	RAN#85	RP-191943	0040	-	F	Correction on the resource mapping of PDSCH in TS 38.214	15.7.0
2019-09	RAN#85	RP-191943	0041	1	F	Corrections to 38.214 including alignment of terminology across specifications in RAN1#98	15.7.0
2019-09	RAN#85	RP-191943	0042	-	F	Clarification of PUSCH with SP-CSI overlapping with PUSCH with data	15.7.0
2019-12	RAN#86	RP-192627	0045	-	F	Correction on resource allocation for uplink transmission with configured grant Type 1	15.8.0
2019-12	RAN#86	RP-192627	0046	-	F	Clarification to the dynamically scheduled PDSCH collision with SPS-PDSCH	15.8.0
2019-12	RAN#86	RP-192627	0047	-	F	Correction on rate-matching for LTE-CRS-toMatchAround	15.8.0
2019-12	RAN#86	RP-192627	0048	-	F	Correction on timing for MAC CE applicability in 38.214	15.8.0
2019-12	RAN#86	RP-192627	0049	-	F	Corrections to 38.214 including alignment of terminology across specifications in RAN1#98bis and RAN1#99	15.8.0
2019-12	RAN#86	RP-192634	0043	1	B	Introduction of UE behaviour for SRS measurements for CLI	16.0.0
2019-12	RAN#86	RP-192635	0050	-	B	Introduction of two-step RACH	16.0.0
2019-12	RAN#86	RP-192636	0051	-	B	Introduction of NR - U	16.0.0
2019-12	RAN#86	RP-192637	0052	-	B	Introduction of integrated access and backhaul for NR	16.0.0
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2019-12	RAN#86	RP-192639	0054	-	B	Introduction of NR URLLC support	16.0.0
2019-12	RAN#86	RP-192641	0055	-	B	Introduction of NR enhanced MIMO	16.0.0
2019-12	RAN#86	RP-192642	0056	-	B	Introduction of cross-slot scheduling restriction	16.0.0
2019-12	RAN#86	RP-192643	0057	-	B	Introduction of NR positioning support	16.0.0
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2019-12	RAN#86	RP-192646	0061	-	B	Behaviour for triggered with a CSI report for non-active BWP	16.0.0
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2020-03	RAN#87-e	RP-200187	0069	-	F	Corrections on NR V2X	16.1.0
2020-03	RAN#87-e	RP-200483	0070	1	F	Corrections on Cross-carrier Scheduling with Different Numerologies	16.1.0
2020-03	RAN#87-e	RP-200188	0071	-	F	Corrections on NR URLLC support	16.1.0
2020-03	RAN#87-e	RP-200190	0072	-	F	Corrections on NR enhanced MIMO	16.1.0
2020-03	RAN#87-e	RP-200189	0073	-	F	Corrections on Industrial IoT	16.1.0
2020-03	RAN#87-e	RP-200191	0074	-	F	Corrections of cross-slot scheduling restriction and CSI/L1-RSRP measurement outside active time	16.1.0
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2020-06	RAN#88-e	RP-200683	0080	-	A	CR on CSI reporting for BWP size < 24 PRBs	16.2.0

2020-06	RAN#88-e	RP-200683	0082	-	A	CR on 38.214 PDSCH resource mapping	16.2.0
2020-06	RAN#88-e	RP-200683	0084	-	A	CR to 38.214 clarification on resource and port occupation of duplicate CSI-RS resources	16.2.0
2020-06	RAN#88-e	RP-200693	0085	1	F	Corrections of cross-slot scheduling restriction	16.2.0
2020-06	RAN#88-e	RP-200686	0086	1	F	Correction of two-step RACH	16.2.0
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2020-06	RAN#88-e	RP-200691	0088	1	F	Corrections on Industrial IoT	16.2.0
2020-06	RAN#88-e	RP-200694	0089	1	F	Corrections of NR positioning support	16.2.0
2020-06	RAN#88-e	RP-200687	0090	1	F	Corrections on NR - U	16.2.0
2020-06	RAN#88-e	RP-200689	0091	1	F	Corrections on NR V2X	16.2.0
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2020-06	RAN#88-e	RP-200692	0093	1	F	Corrections on NR enhanced MIMO	16.2.0
2020-06	RAN#88-e	RP-200685	0094	-	F	Correction on SRS-RSRP reception procedure for CLI	16.2.0
2020-06	RAN#88-e	RP-200683	0097	-	A	CR on SRS for 38.214	16.2.0
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2020-06	RAN#88-e	RP-200683	0101	-	A	Correction for SP-CSI reporting on PUSCH	16.2.0
2020-06	RAN#88-e	RP-200683	0103	-	A	CR on port and CSI-RS resource counting	16.2.0
2020-06	RAN#88-e	RP-200705	0106	-	B	Introduction of switched uplink operation	16.2.0
2020-06	RAN#88-e	RP-200697	0107	-	F	Correction on aperiodic CSI-RS triggering with beam switching timing of 224 and 336 and on CSI reporting	16.2.0
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2020-09	RAN#89-e	RP-201803	0111	-	A	CR on Measurement Restriction for L1-RSRP	16.3.0
2020-09	RAN#89-e	RP-201803	0113	-	A	Correction on sounding procedure between component carriers	16.3.0
2020-09	RAN#89-e	RP-201803	0115	-	A	Clarification on which UE capability component indicates the number of supported simultaneous CSI calculations N_{CPU}	16.3.0
2020-09	RAN#89-e	RP-201814	0116	-	F	Corrections to PDSCH PRB bundling notation (Rel-15 origin)	16.3.0
2020-09	RAN#89-e	RP-201804	0117	-	F	CR on 2-step RACH for 38.214	16.3.0
2020-09	RAN#89-e	RP-201813	0118	-	F	Corrections on Cross-carrier Scheduling with Different Numerologies	16.3.0
2020-09	RAN#89-e	RP-201809	0120	-	F	Correction on SRS carrier switching	16.3.0
2020-09	RAN#89-e	RP-201814	0121	-	F	Correction on aperiodic CSI-RS triggering with beam switching timing of 224 and 336	16.3.0
2020-09	RAN#89-e	RP-201814	0122	-	B	Introduction of flexible TRS bandwidth for BWP of 52 RBs	16.3.0
2020-09	RAN#89-e	RP-201814	0123	-	F	Correction on 38.214 for PUSCH with UL skipping (Note: CR was not implementable because "not based on the latest version of the specification")	16.3.0
2020-09	RAN#89-e	RP-201810	0124	-	F	RRM measurements when drx-onDurationTimer does not start	16.3.0
2020-09	RAN#89-e	RP-201820	0125	-	F	Correction on uplink Tx switching	16.3.0
2020-09	RAN#89-e	RP-201807	0126	1	F	Corrections on 5G V2X sidelink features	16.3.0
2020-09	RAN#89-e	RP-201809	0127	-	F	Corrections to MIMO enhancements	16.3.0

2020-09	RAN#89-e	RP-201811	0128	-	F	Corrections to NR positioning support	16.3.0
2020-09	RAN#89-e	RP-201805	0129	-	F	Corrections to NR-based access to unlicensed spectrum	16.3.0
2020-09	RAN#89-e	RP-201808	0130	-	F	Corrections on NR URLLC support	16.3.0
2020-12	RAN#90-e	RP-202385	0131	-	F	Corrections for default TCI state of AP CSI-RS in multi-TRP	16.4.0
2020-12	RAN#90-e	RP-202390	0132	-	F	Correction on beam switch timing for aperiodic TRS	16.4.0
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2020-12	RAN#90-e	RP-202390	0134	-	F	38.214 CR (Rel-16, F, Rel-15 originating) to fix configurable xOverhead values for TBS determination	16.4.0
2020-12	RAN#90-e	RP-202385	0135	-	F	Corrections for the issue of PDCCH and PDSCH colliding in multi-TRP	16.4.0
2020-12	RAN#90-e	RP-202385	0136	-	F	Correction on TCI state codepoint mapping for DCI format 1_2	16.4.0
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2020-12	RAN#90-e	RP-202390	0138	-	F	Correction to beam switch timing	16.4.0
2020-12	RAN#90-e	RP-202385	0139	-	F	CR on Interference Measurement Resource for L1-SINR	16.4.0
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2020-12	RAN#90-e	RP-202383	0142	-	F	Introduction of the preparation time for SL retransmissions in Mode 1	16.4.0
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2020-12	RAN#90-e	RP-202385	0146	-	F	CR on Measurement Restriction for L1-SINR	16.4.0
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2020-12	RAN#90-e	RP-202387	0148	-	F	CR on DL PRS resource prioritization for UE measurements	16.4.0
2020-12	RAN#90-e	RP-202387	0149	-	F	CR on the configuration of spatial relation for the SRS for positioning	16.4.0
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2020-12	RAN#90-e	RP-202387	0152	-	F	CR for parameter name alignment and reference corrections in PRS reception procedure	16.4.0
2020-12	RAN#90-e	RP-202389	0153	-	F	Corrections for A-CSI triggering with unaligned CA	16.4.0
2020-12	RAN#90-e	RP-202398	0154	-	F	Alignment of RRC parameter names for 38.214	16.4.0
2021-03	RAN#91-e	RP-210047	0156	-	A	Correction on MCS values for PT-RS time density determination in TS 38.214	16.5.0
2021-03	RAN#91-e	RP-210048	0157	-	F	CR on DMRS configuration for MsgA in 38.214	16.5.0
2021-03	RAN#91-e	RP-210049	0158	-	F	Correction on joint configuration of semi-static repetitions and multi-pusch scheduling	16.5.0
2021-03	RAN#91-e	RP-210055	0159	-	F	Correction on UE sounding procedure	16.5.0
2021-03	RAN#91-e	RP-210052	0160	-	F	CR on Default TCI state of Scheme 3 and Scheme 4	16.5.0
2021-03	RAN#91-e	RP-210052	0161	-	F	CR on multi-TRP	16.5.0
2021-03	RAN#91-e	RP-210052	0162	-	F	CR on PDSCH QCL	16.5.0
2021-03	RAN#91-e	RP-210052	0163	-	F	CR on L1-SINR based beam measurement	16.5.0
2021-03	RAN#91-e	RP-210050	0164	-	F	Corrections related to the sidelink resource reservation period	16.5.0

2021-03	RAN#91-e	RP-210050	0165	-	F	Correction to pre-emption condition for Mode-2 resource allocation	16.5.0
2021-03	RAN#91-e	RP-210051	0166	-	F	Correction on Part 2 CSI dropping for UCI multiplexing on PUSCH repetition Type B	16.5.0
2021-03	RAN#91-e	RP-210058	0167	-	F	Correction on uplink Tx switching	16.5.0
2021-03	RAN#91-e	RP-210053	0168	1	F	CR for the configuration of semi-persistent SRS	16.5.0
2021-03	RAN#91-e	RP-210053	0169	1	F	CR for the configuration of DL-PRS as the spatial relation of periodic and semi-persistent positioning SRS	16.5.0
2021-03	RAN#91-e	RP-210053	0170	1	F	CR for the configuration of SRS for positioning in SRS carrier switching	16.5.0
2021-03	RAN#91-e	RP-210053	0171	1	F	CR on DL PRS resource indication in activation command for semi-persistent SRS for positioning and amount of DL PRS resource sets per TRP	16.5.0
2021-03	RAN#91-e	RP-210053	0172	1	F	CR on timestamp reference in NR positioning measurement report	16.5.0
2021-03	RAN#91-e	RP-210053	0173	1	F	CR on measurement gap configuration for NR positioning	16.5.0
2021-03	RAN#91-e	RP-210054	0175	-	F	Additional timing delay for applying QCL relation on the PDSCH with cross-carrier scheduling with different SCS.	16.5.0
2021-03	RAN#91-e	RP-210051	0176	-	F	Correction on PDSCH resource mapping with RE symbol level granularity	16.5.0
2021-03	RAN#91-e	RP-210051	0177	-	F	Active time duration of NZP CSI-RS resource	16.5.0
2021-03	RAN#91-e	RP-210059	0178	-	F	Editorial corrections for 38.214	16.5.0
2021-03	RAN#91-e	RP-210309	0123	2	F	Correction on 38.214 for PUSCH with UL skipping in Rel-16	16.5.0
2021-06	RAN#92-e	RP-211237	0179	-	F	Correction on out-of-order HARQ operation in 38.214	16.6.0
2021-06	RAN#92-e	RP-211239	0180	-	F	38.214 CR on CSI request constraint per slot	16.6.0
2021-06	RAN#92-e	RP-211240	0181	-	F	Timelines for SRS carrier switching	16.6.0
2021-06	RAN#92-e	RP-211238	0182	1	F	Correction to the DL PRS reception procedure for PRS cell determination	16.6.0
2021-06	RAN#92-e	RP-211235	0183	1	F	Correction to sidelink resource identification procedure avoiding infinite loop issue	16.6.0
2021-06	RAN#92-e	RP-211234	0184	-	F	Correction on averaging CSI-RS for measuring CSI across DL bursts	16.6.0
2021-06	RAN#92-e	RP-211233	0186	1	A	Rel-15 editorial corrections for TS 38.214 (mirrored to Rel-16)	16.6.0
2021-06	RAN#92-e	RP-211243	0187	1	F	Rel-16 editorial corrections for TS 38.214	16.6.0
2021-06	RAN#92-e	RP-211236	0188	-	F	Correction on DMRS reception and transmission procedure in TS 38.214	16.6.0
2021-06	RAN#92-e	RP-211237	0189	-	F	Correction on simultaneous multi-CC spatial relation update for SRS	16.6.0
2021-06	RAN#92-e	RP-211237	0190	-	F	Correction on enabling configuration of time restriction over L1-SINR measurement	16.6.0
2021-06	RAN#92-e	RP-211237	0191	-	F	Corrections on RRC names and interpretation for Multi-TRP	16.6.0
2021-06	RAN#92-e	RP-211251	0192	-	F	Correction of UE Power Saving	16.6.0
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2021-06	RAN#92-e	RP-211233	0196	-	A	Clarification on back-to-back PUSCHs scheduling restriction	16.6.0
2021-06	RAN#92-e	RP-211235	0197	-	F	Corrections for transmitting sidelink reference signals in TS 38.214	16.6.0
2021-06	RAN#92-e	RP-211238	0198	-	F	CR on DL PRS periodicity and muting repetition factor	16.6.0

2021-06	RAN#92-e	RP-211238	0199	-	F	CR on measurement gap request inside of the active DL BWP for DL PRS measurements	16.6.0
2021-06	RAN#92-e	RP-211239	0200	-	F	38.214 CR on unaligned frame boundary CA with A-CSI-RS transmission and CSI reference resource definition	16.6.0
2021-06	RAN#92-e	RP-211238	0201	1	F	CR on SCS values for DL PRS	16.6.0
2021-06	RAN#92-e	RP-211238	0202	1	F	CR on correction to DL PRS processing priority order	16.6.0
2021-06	RAN#92-e	RP-211236	0203	-	F	Correction on SRS resource set configuration in TS 38.214	16.6.0
2021-09	RAN#93-e	RP-211847	0204	-	F	Correction to PDSCH rate matching for SPS	16.7.0
2021-09	RAN#93-e	RP-211844	0205	-	F	CR on sum data rate for tdmSchemeA and fdmSchemeB	16.7.0
2021-09	RAN#93-e	RP-211842	0206	1	F	Correction on procedure for transmitting the physical sidelink shared channel	16.7.0
2021-09	RAN#93-e	RP-211843	0207	-	F	Correction on invalid symbol determination for PUSCH repetition Type B	16.7.0
2021-09	RAN#93-e	RP-211846	0208	-	F	Correction on cross-carrier scheduling and cross-carrier CSI-RS triggering	16.7.0
2021-09	RAN#93-e	RP-211845	0209	-	F	CR on terminology correction to cell for positioning	16.7.0
2021-09	RAN#93-e	RP-211845	0210	-	F	CR on alignment with RAN4 on DL PRS processing	16.7.0
2021-09	RAN#93-e	RP-211841	0212	-	A	CR to 38.214 clarification on coefficients packing order for Type II CSI	16.7.0
2021-09	RAN#93-e	RP-211841	0214	-	A	Clarification on back-to-back PUSCHs scheduling restriction	16.7.0
2021-09	RAN#93-e	RP-211850	0215	-	F	Rel-16 editorial corrections for TS 38.214	16.7.0