**3GPP TSG-RAN WG1 Meeting #113R1-23xxxxx**

**Incheon, Korea, May 22 – 26, 2023**

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| *CR-Form-v12.2* | | | | | | | | |
| **DRAFT CHANGE REQUEST** | | | | | | | | |
|  | | | | | | | | |
|  | **38.211** | **CR** | **xxxx** | **rev** | **-** | **Current version:** | **17.4.0** |  |
|  | | | | | | | | |
| *For* [***HE******LP***](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* | | | | | | | | |
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| ***Proposed change affects:*** | UICC apps |  | ME | **X** | Radio Access Network | **X** | Core Network |  |

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| ***Title:*** | Introduction of MIMO evolution for downlink and uplink | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Source to WG:*** | Ericsson | | | | | | | | | |
| ***Source to TSG:*** |  | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Work item code:*** | NR\_MIMO\_evo\_DL\_UL-Core | | | | |  | ***Date:*** | | | 2023-06-04 |
|  |  | | | |  | |  | | |  |
| ***Category:*** | B |  | | | | | ***Release:*** | | | Rel-18 |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) … Rel-16 (Release 16) Rel-17 (Release 17) Rel-18 (Release 18) Rel-19 (Release 19)* | |
|  |  | | | | | | | | | |
| ***Reason for change:*** | | Introduction of MIMO evolution for downlink and uplink | | | | | | | | |
|  | |  | | | | | | | | |
| ***Summary of change:*** | | Defining enhanced DM-RS, SRS, and uplink precoding . | | | | | | | | |
|  | |  | | | | | | | | |
| ***Consequences if not approved:*** | | Incomplete support for MIMO evolution. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Clauses affected:*** | |  | | | | | | | | |
|  | |  | | | | | | | | |
|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | |  |  | Other core specifications | | | | TS/TR ... CR ... | | |
| ***affected:*** | |  |  | Test specifications | | | | TS/TR ... CR ... | | |
| ***(show related CRs)*** | |  |  | O&M Specifications | | | | TS/TR ... CR ... | | |
|  | |  | | | | | | | | |
| ***Other comments:*** | |  | | | | | | | | |
|  | |  | | | | | | | | |
| ***This CR's revision history:*** | |  | | | | | | | | |

### 6.3.1 Physical uplink shared channel

#### 6.3.1.1 Scrambling

Up to two codewords can be transmitted. In case of single-codeword transmission, .

For each codeword, the block of bits , where is the number of bits in codeword transmitted on the physical channel, shall be scrambled prior to modulation, resulting in a block of scrambled bits according to the following pseudo code

Set *i* = 0

while

if  // UCI placeholder bits



else

if  // UCI placeholder bits



else



end if

end if

*i* = *i* + 1

end while

where x and y are tags defined in [4, TS 38.212] and where the scrambling sequence is given by clause 5.2.1. The scrambling sequence generator shall be initialized with

where

-  equals the higher-layer parameter *dataScramblingIdentityPUSCH* if configured and the RNTI equals the C-RNTI, MCS-C-RNTI, SP-CSI-RNTI or CS-RNTI, and the transmission is not scheduled using DCI format 0\_0 in a common search space;

- equals the higher-layer parameter *msgA-DataScramblingIndex* if configured and the PUSCH transmission is triggered by a Type-2 random access procedure as described in clause 8.1A of [5, TS 38.213];

-  otherwise

- is the index of the random-access preamble transmitted for msgA as described in clause 5.1.3A of [11, TS 38.321]

and where  equals the RA-RNTI for msgA and otherwise corresponds to the RNTI associated with the PUSCH transmission as described in clause 6.1 of [6, TS 38.214] and clause 8.3 of [5, TS 38.213].

#### 6.3.1.2 Modulation

For each codeword , the block of scrambled bits shall be modulated as described in clause 5.1 using one of the modulation schemes in Table 6.3.1.2-1, resulting in a block of complex-valued modulation symbols .

Table 6.3.1.2-1: Supported modulation schemes.

|  |  |  |  |
| --- | --- | --- | --- |
| **Transform precoding disabled** | | **Transform precoding enabled** | |
| **Modulation scheme** | **Modulation order** | **Modulation scheme** | **Modulation order** |
|  |  | π/2-BPSK | 1 |
| QPSK | 2 | QPSK | 2 |
| 16QAM | 4 | 16QAM | 4 |
| 64QAM | 6 | 64QAM | 6 |
| 256QAM | 8 | 256QAM | 8 |

#### 6.3.1.3 Layer mapping

The complex-valued modulation symbols for each of the codewords to be transmitted shall be mapped onto up to four layers according to Table 7.3.1.3-1. Complex-valued modulation symbols for codeword shall be mapped onto the layers , where is the number of layers and is the number of modulation symbols per layer.

#### 6.3.1.5 Precoding

The block of vectors ,  shall be precoded according to



where , . The set of antenna ports  shall be determined according to the procedure in [6, TS 38.214].

For non-codebook-based transmission, the precoding matrix equals the identity matrix.

For codebook-based transmission, the precoding matrix is given by for single-layer transmission on a single antenna port, otherwise by Tables 6.3.1.5-1 to 6.3.1.5-24 with the TPMI index obtained from the DCI scheduling the uplink transmission or the higher layer parameters according to the procedure in [6, TS 38.214].

When the higher-layer parameter *txConfig* is not configured, the precoding matrix .

Table 6.3.1.5-1: Precoding matrix  for single-layer transmission using two antenna ports.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | | | | | |
| 0 – 5 |  |  |  |  |  |  | - | - |

Table 6.3.1.5-2: Precoding matrix  for single-layer transmission using four antenna ports with transform precoding enabled.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | | | | | |
| 0 – 7 |  |  |  |  |  |  |  |  |
| 8 – 15 |  |  |  |  |  |  |  |  |
| 16 – 23 |  |  |  |  |  |  |  |  |
| 24 – 27 |  |  |  |  | - | - | - | - |

Table 6.3.1.5-3: Precoding matrix  for single-layer transmission using four antenna ports with transform precoding disabled.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | | | | | |
| 0 – 7 |  |  |  |  |  |  |  |  |
| 8 – 15 |  |  |  |  |  |  |  |  |
| 16 – 23 |  |  |  |  |  |  |  |  |
| 24 – 27 |  |  |  |  | - | - | - | - |

Table 6.3.1.5-4: Precoding matrix  for two-layer transmission using two antenna ports with transform precoding disabled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | |
| 0 – 2 |  |  |  |  |

Table 6.3.1.5-5: Precoding matrix  for two-layer transmission using four antenna ports with transform precoding disabled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | |
| 0 – 3 |  |  |  |  |
| 4 – 7 |  |  |  |  |
| 8 – 11 |  |  |  |  |
| 12 – 15 |  |  |  |  |
| 16 – 19 |  |  |  |  |
| 20 – 21 |  |  | - | - |

Table 6.3.1.5-6: Precoding matrix  for three-layer transmission using four antenna ports with transform precoding disabled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | |
| 0 – 3 |  |  |  |  |
| 4 – 6 |  |  |  | - |

Table 6.3.1.5-7: Precoding matrix  for four-layer transmission using four antenna ports with transform precoding disabled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | |
| 0 – 3 |  |  |  |  |
| 4 |  | - | - | - |

Table 6.3.1.5-8: Precoding matrix type A with 8 antenna groups for single-layer transmission using eight antenna ports. Up to 8 layers are supported with transform precoding disabled and up to one layer with transform precoding enabled.

|  |  |
| --- | --- |
| TPMI index |  |
| 1 – 255 | where column of W, , is has an element 1 on the row corresponding to the port on which layer is to be transmitted, and element 0 in all other rows, ,  and TPMI index = , where if a layer is to be transmitted on port and otherwise |

Table 6.3.1.5-9: Precoding matrix type B with one antenna group for single-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | | | | | |
| 0 – 7 |  |  |  |  |  |  |  |  |
| 8 – 15 |  |  |  |  |  |  |  |  |

Table 6.3.1.5-10: Precoding matrix type B with one antenna group for two-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | | | | | |
| 0 – 7 |  |  |  |  |  |  |  |  |
| 8 – 15 |  |  |  |  |  |  |  |  |
| 16 – 23 |  |  |  |  |  |  |  |  |
| 24 – 31 |  |  |  |  |  |  |  |  |

Table 6.3.1.5-11: Precoding matrix type B with one antenna group for three-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | |
| 0 – 3 |  |  |  |  |
| 4 – 7 |  |  |  |  |
| 8 – 11 |  |  |  |  |
| 12 – 15 |  |  |  |  |
| 16 – 19 |  |  |  |  |
| 20 – 23 |  |  |  |  |

Table 6.3.1.5-12: Precoding matrix type B with one antenna group for four-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | |
| 0 – 3 |  |  |  |  |
| 4 – 7 |  |  |  |  |
| 8 – 11 |  |  |  |  |
| 12 – 15 |  |  |  |  |
| 16 – 19 |  |  |  |  |
| 20 – 23 |  |  |  |  |

Table 6.3.1.5-13: Precoding matrix type B with one antenna group for five-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |
| --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | |
| 0 – 1 |  |  |
| 2 – 3 |  |  |
| 4 – 5 |  |  |
| 6 – 7 |  |  |

Table 6.3.1.5-14: Precoding matrix type B with one antenna group for six-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |
| --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | |
| 0 – 1 |  |  |
| 2 – 3 |  |  |
| 4 – 5 |  |  |
| 6 – 7 |  |  |

Table 6.3.1.5-15: Precoding matrix type B with one antenna group for seven-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |
| --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | |
| 0 – 1 |  |  |
| 2 – 3 |  |  |

Table 6.3.1.5-16: Precoding matrix type B with one antenna group for eight-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |
| --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | |
| 0 – 1 |  |  |
| 2 – 3 |  |  |

Table 6.3.1.5-17: Precoding matrix type C with one antenna group for single-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | | | | | |
| 0 – 7 |  |  |  |  |  |  |  |  |
| 8 – 15 |  |  |  |  |  |  |  |  |

Table 6.3.1.5-18: Precoding matrix type C with one antenna group for two-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | | | | | |
| 0 – 7 |  |  |  |  |  |  |  |  |
| 8 – 15 |  |  |  |  |  |  |  |  |
| 16 – 23 |  |  |  |  |  |  |  |  |
| 24 – 31 |  |  |  |  |  |  |  |  |

Table 6.3.1.5-19: Precoding matrix type C with one antenna group for three-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | |
| 0 – 3 |  |  |  |  |
| 4 – 7 |  |  |  |  |
| 8 – 11 |  |  |  |  |
| 12 – 15 |  |  |  |  |
| 16 – 19 |  |  |  |  |
| 20 – 23 |  |  |  |  |

Table 6.3.1.5-20: Precoding matrix type C with one antenna group for four-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | | | |
| 0 – 3 |  |  |  |  |
| 4 – 7 |  |  |  |  |
| 8 – 11 |  |  |  |  |
| 12 – 15 |  |  |  |  |
| 16 – 19 |  |  |  |  |
| 20 – 23 |  |  |  |  |

Table 6.3.1.5-21: Precoding matrix type C with one antenna group for five-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |
| --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | |
| 0 – 1 |  |  |
| 2 – 3 |  |  |
| 4 – 5 |  |  |
| 6 – 7 |  |  |

Table 6.3.1.5-22: Precoding matrix type C with one antenna group for six-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |
| --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | |
| 0 – 1 |  |  |
| 2 – 3 |  |  |
| 4 – 5 |  |  |
| 6 – 7 |  |  |

Table 6.3.1.5-23: Precoding matrix type C with one antenna group for seven-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |
| --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | |
| 0 – 1 |  |  |
| 2 – 3 |  |  |
| 4 – 5 |  |  |
| 6 – 7 |  |  |

Table 6.3.1.5-24: Precoding matrix type C with one antenna group for eight-layer transmission using eight antenna ports with transform precoding disabled.

|  |  |  |
| --- | --- | --- |
| TPMI index | (ordered from left to right in increasing order of TPMI index) | |
| 0 – 1 |  |  |
| 2 – 3 |  |  |
| 4 – 5 |  |  |
| 6 – 7 |  |  |

##### 6.4.1.1.3 Precoding and mapping to physical resources

The sequence  shall be mapped to the intermediate quantity according to

- if transform precoding is not enabled,

- if transform precoding is enabled

where , , and are given by Tables 6.4.1.1.3-1 and 6.4.1.1.3-2 and the configuration type is given by the higher-layer parameter *DMRS-UplinkConfig*, and both and correspond to . The intermediate quantity if Δ corresponds to any other antenna ports than*.*

The intermediate quantity shall be precoded, multiplied with the amplitude scaling factor  in order to conform to the transmit power specified in [6, TS 38.214], and mapped to physical resources according to

where

- the precoding matrix is given by clause 6.3.1.5,

- the set of antenna ports  is given by clause 6.3.1.5, and

- the set of antenna ports  is given by [6, TS 38.214];

and the following conditions are fulfilled:

- the resource elements are within the common resource blocks allocated for PUSCH transmission.

The reference point for is

- subcarrier 0 in common resource block 0 if transform precoding is not enabled, and

- subcarrier 0 of the lowest-numbered resource block of the scheduled PUSCH allocation if transform precoding is enabled.

The reference point for and the position  of the first DM-RS symbol depends on the mapping type:

- for PUSCH mapping type A:

-  is defined relative to the start of the slot if frequency hopping is disabled and relative to the start of each hop in case frequency hopping is enabled

-  is given by the higher-layer parameter *dmrs-TypeA-Position*

- for PUSCH mapping type B:

-  is defined relative to the start of the scheduled PUSCH resources if frequency hopping is disabled and relative to the start of each hop in case frequency hopping is enabled

- 

The position(s) of the DM-RS symbols is given by  and duration where

- is the duration between the first OFDM symbol of the slot and the last OFDM symbol of the scheduled PUSCH resources in the slot for PUSCH mapping type A according to Tables 6.4.1.1.3-3 and 6.4.1.1.3-4 if intra-slot frequency hopping is not used, or

- is the duration of scheduled PUSCH resources for PUSCH mapping type B according to Tables 6.4.1.1.3-3 and 6.4.1.1.3-4 if intra-slot frequency hopping is not used, or

- is the duration per hop according to Table 6.4.1.1.3-6 if intra-slot frequency hopping is used.

- if the higher-layer parameter *maxLength* in *DMRS-UplinkConfig* is not configured, or for a msgA transmission *msgA-MaxLength* in *msgA-DMRS-Config* is not configured, the tables shall be used according to single-symbol DM-RS

- if the higher-layer parameter *maxLength* in *DMRS-UplinkConfig* is equal to 'len2', the associated DCI or configured grant configuration determines whether single-symbol or double-symbol DM-RS shall be used

- if the higher-layer parameter *msgA-MaxLength* in *msgA-DMRS-Config* is equal to 'len2', double-symbol DM-RS shall be used

- if the higher-layer parameter *dmrs-AdditionalPosition* is not set to 'pos0' and intra-slot frequency hopping is enabled according to clause 7.3.1.1.2 in [4, TS 38.212] and by higher layer, Tables 6.4.1.1.3-6 shall be used assuming *dmrs-AdditionalPosition* is equal to 'pos1' for each hop.

For PUSCH mapping type A,

- the case *dmrs-AdditionalPosition* is equal to 'pos3' is only supported when *dmrs-TypeA-Position* is equal to 'pos2';

- symbols in Table 6.4.1.1.3-4 is only applicable when *dmrs-TypeA-Position* is equal to 'pos2'.

For msgA transmitted using PUSCH mapping type A,

- the case *msgA-DMRS-AdditionalPosition* is equal to 'pos3' is only supported when *dmrs-TypeA-Position* is equal to 'pos2';

- *'dmrs-AdditionalPosition*' in Tables 6.4.1.1.3-3 to 6.4.1.1.3-6 shall be replaced by *msgA-DMRS-AdditionalPosition;*

- only PUSCH DM-RS configuration type 1 is supported;

- only DM-RS patterns with are supported.

For msgA transmitted using PUSCH mapping type B,

- '*dmrs-AdditionalPosition*' in Tables 6.4.1.1.3-3 to 6.4.1.1.3-6 shall be replaced by *msgA-DMRS-AdditionalPosition*;

- only PUSCH DM-RS configuration type 1 is supported;

- only DM-RS patterns with are supported.

The frequency-domain index , the time-domain index , and the supported antenna ports are given by Table 6.4.1.1.3-5.

Table 6.4.1.1.3-1: Parameters for PUSCH DM-RS configuration type 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | CDM group |  |  |  |
| 0 | 0 | 0 |  |  |
| 1 | 0 | 0 |  |  |
| 2 | 1 | 1 |  |  |
| 3 | 1 | 1 |  |  |
| 4 | 0 | 0 |  |  |
| 5 | 0 | 0 |  |  |
| 6 | 1 | 1 |  |  |
| 7 | 1 | 1 |  |  |
| 8 | 0 | 0 |  |  |
| 9 | 0 | 0 |  |  |
| 10 | 1 | 1 |  |  |
| 11 | 1 | 1 |  |  |
| 12 | 0 | 0 |  |  |
| 13 | 0 | 0 |  |  |
| 14 | 1 | 1 |  |  |
| 15 | 1 | 1 |  |  |

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Table 6.4.1.1.3-2: Parameters for PUSCH DM-RS configuration type 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | CDM group |  |  |  |
| 0 | 0 | 0 |  |  |
| 1 | 0 | 0 |  |  |
| 2 | 1 | 2 |  |  |
| 3 | 1 | 2 |  |  |
| 4 | 2 | 4 |  |  |
| 5 | 2 | 4 |  |  |
| 6 | 0 | 0 |  |  |
| 7 | 0 | 0 |  |  |
| 8 | 1 | 2 |  |  |
| 9 | 1 | 2 |  |  |
| 10 | 2 | 4 |  |  |
| 11 | 2 | 4 |  |  |
| 12 | 0 | 0 |  |  |
| 13 | 0 | 0 |  |  |
| 14 | 1 | 2 |  |  |
| 15 | 1 | 2 |  |  |
| 16 | 2 | 4 |  |  |
| 17 | 2 | 4 |  |  |
| 18 | 0 | 0 |  |  |
| 19 | 0 | 0 |  |  |
| 20 | 1 | 2 |  |  |
| 21 | 1 | 2 |  |  |
| 22 | 2 | 4 |  |  |
| 23 | 2 | 4 |  |  |

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Table 6.4.1.1.3-3: PUSCH DM-RS positions  within a slot for single-symbol DM-RS and intra-slot frequency hopping disabled.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| in symbols | DM-RS positions | | | | | | | |
| PUSCH mapping type A | | | | PUSCH mapping type B | | | |
| *dmrs-AdditionalPosition* | | | | *dmrs-AdditionalPosition* | | | |
| *pos0* | *pos1* | *pos2* | *pos3* | *pos0* | *pos1* | *pos2* | *pos3* |
| <4 | - | - | - | - |  |  |  |  |
| 4 |  |  |  |  |  |  |  |  |
| 5 |  |  |  |  |  | , 4 | , 4 | , 4 |
| 6 |  |  |  |  |  | , 4 | , 4 | , 4 |
| 7 |  |  |  |  |  | , 4 | , 4 | , 4 |
| 8 |  | , 7 | , 7 | , 7 |  | , 6 | , 3, 6 | , 3, 6 |
| 9 |  | , 7 | , 7 | , 7 |  | , 6 | , 3, 6 | , 3, 6 |
| 10 |  | , 9 | , 6, 9 | , 6, 9 |  | , 8 | , 4, 8 | , 3, 6, 9 |
| 11 |  | , 9 | , 6, 9 | , 6, 9 |  | , 8 | , 4, 8 | , 3, 6, 9 |
| 12 |  | , 9 | , 6, 9 | , 5, 8, 11 |  | , 10 | , 5, 10 | , 3, 6, 9 |
| 13 |  | , 11 | , 7, 11 | , 5, 8, 11 |  | , 10 | , 5, 10 | , 3, 6, 9 |
| 14 |  | , 11 | , 7, 11 | , 5, 8, 11 |  | , 10 | , 5, 10 | , 3, 6, 9 |

Table 6.4.1.1.3-4: PUSCH DM-RS positions  within a slot for double-symbol DM-RS and intra-slot frequency hopping disabled.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **in symbols** | **DM-RS positions** | | | | | | | |
| **PUSCH mapping type A** | | | | **PUSCH mapping type B** | | | |
| ***dmrs-AdditionalPosition*** | | | | ***dmrs-AdditionalPosition*** | | | |
| ***pos0*** | ***pos1*** | ***pos2*** | ***pos3*** | ***pos0*** | ***pos1*** | ***pos2*** | ***pos3*** |
| <4 | - | - |  |  | - | - |  |  |
| 4 |  |  |  |  | - | - |  |  |
| 5 |  |  |  |  |  |  |  |  |
| 6 |  |  |  |  |  |  |  |  |
| 7 |  |  |  |  |  |  |  |  |
| 8 |  |  |  |  |  | , 5 |  |  |
| 9 |  |  |  |  |  | , 5 |  |  |
| 10 |  | , 8 |  |  |  | , 7 |  |  |
| 11 |  | , 8 |  |  |  | , 7 |  |  |
| 12 |  | , 8 |  |  |  | , 9 |  |  |
| 13 |  | , 10 |  |  |  | , 9 |  |  |
| 14 |  | , 10 |  |  |  | , 9 |  |  |

Table 6.4.1.1.3-5: PUSCH DM-RS frequency index and time index .

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| DM-RS multiplexing | DM-RS duration |  |  | Supported antenna ports | |
| Configuration type 1 | Configuration type 2 |
| Basic | single-symbol DM-RS | 0, 1 | 0 | 0 – 3 | 0 – 5 |
| double-symbol DM-RS | 0, 1 | 0, 1 | 0 – 7 | 0 – 11 |
| Enhanced | single-symbol DM-RS | 0, 1, 2, 3 | 0 | 0 – 7 | 0 – 11 |
| double-symbol DM-RS | 0, 1, 2, 3 | 0, 1 | 0 – 15 | 0 – 23 |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  | |
|  |  |
|  |  |  |  |
|  |  |  |  |

Table 6.4.1.1.3-6: PUSCH DM-RS positions  within a slot for single-symbol DM-RS and intra-slot frequency hopping enabled.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **in symbols** | **DM-RS positions** | | | | | | | | | | | |
| **PUSCH mapping type A** | | | | | | | | **PUSCH mapping type B** | | | |
|  | | | |  | | | |
| ***dmrs-AdditionalPosition*** | | | | ***dmrs-AdditionalPosition*** | | | | ***dmrs-AdditionalPosition*** | | | |
| ***pos0*** | | ***pos1*** | | ***pos0*** | | ***pos1*** | | ***pos0*** | | ***pos1*** | |
| **1st hop** | **2nd hop** | **1st hop** | **2nd hop** | **1st hop** | **2nd hop** | **1st hop** | **2nd hop** | **1st hop** | **2nd hop** | **1st hop** | **2nd hop** |
| ≤3 | - | - | - | - | - | - | - | - | 0 | 0 |  | 0 |
| 4 | 2 | 0 | 2 | 0 | 3 | 0 | 3 | 0 | 0 | 0 |  | 0 |
| 5, 6 | 2 | 0 | 2 | 0, 4 | 3 | 0 | 3 | 0, 4 | 0 | 0 |  | 0, 4 |
| 7 | 2 | 0 | 2, 6 | 0, 4 | 3 | 0 | 3 | 0, 4 | 0 | 0 |  | 0, 4 |

##### 6.4.1.2.2 Mapping to physical resources

###### 6.4.1.2.2.1 Precoding and mapping to physical resources if transform precoding is not enabled

The UE shall transmit phase-tracking reference signals only in the resource blocks used for the PUSCH, and only if the procedure in [6, TS 38.214] indicates that phase-tracking reference signals are being used.

The PUSCH PT-RS shall be mapped to resource elements according to

when all the following conditions are fulfilled

-  is within the OFDM symbols allocated for the PUSCH transmission

- resource element  is not used for DM-RS

-  and correspond to

The quantities and are given by Tables 6.4.1.1.3-1 and 6.4.1.1.3-2, the configuration type is given by the higher-layer parameter *dmrs-Type* in the *DMRS-UplinkConfig* IE, and the precoding matrix is given by clause 6.3.1.5*.* The quantity  is an amplitude scaling factor to conform with the transmit power specified in clause 6.2.2 of [6, TS 38.214].

The set of time indices  defined relative to the start of the PUSCH allocation is defined by

1. set and 

2. if any symbol in the interval overlaps with a symbol used for DM-RS according to clause 6.4.1.1.3

- set

- set  to the symbol index of the DM-RS symbol in case of a single-symbol DM-RS or to the symbol index of the second DM-RS symbol in case of a double-symbol DM-RS

- repeat from step 2 as long as  is inside the PUSCH allocation

3. add  to the set of time indices for PT-RS

4. increment  by one

5. repeat from step 2 above as long as  is inside the PUSCH allocation

where  is defined in Table 6.2.3.1-1 of [6, TS 38.214].

For the purpose of PT-RS mapping, the resource blocks allocated for PUSCH transmission are numbered from 0 to  from the lowest scheduled resource block to the highest. The corresponding subcarriers in this set of resource blocks are numbered in increasing order starting from the lowest frequency from 0 to . The subcarriers to which the PT-RS shall be mapped are given by



where

- 

-  is given by Table 6.4.1.2.2.1-1 for the DM-RS port associated with the PT-RS port according to clause 6.2.3 in [6, TS 38.214]. If the higher-layer parameter *resourceElementOffset* in *PTRS-UplinkConfig* is not configured, the column corresponding to 'offset00' shall be used.

- is the RNTI associated with the DCI scheduling the transmission using C-RNTI, CS-RNTI, MCS-C-RNTI, SP-CSI-RNTI, or is the CS-RNTI in case of configured grant

-  is the number of resource blocks scheduled

- is given by [6, TS 38.214].

Table 6.4.1.2.2.1-1: The parameter  .

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DM-RS antenna port |  | | | | | | | |
| DM-RS Configuration type 1 | | | | DM-RS Configuration type 2 | | | |
| *resourceElementOffset* | | | | *resourceElementOffset* | | | |
| offset00 | offset01 | offset10 | offset11 | offset00 | offset01 | offset10 | offset11 |
| 0 | 0 | 2 | 6 | 8 | 0 | 1 | 6 | 7 |
| 1 | 2 | 4 | 8 | 10 | 1 | 6 | 7 | 0 |
| 2 | 1 | 3 | 7 | 9 | 2 | 3 | 8 | 9 |
| 3 | 3 | 5 | 9 | 11 | 3 | 8 | 9 | 2 |
| 4 | - | - | - | - | 4 | 5 | 10 | 11 |
| 5 | - | - | - | - | 5 | 10 | 11 | 4 |
| 8 | 4 | 6 | 10 | 0 | - | - | - | - |
| 9 | 6 | 8 | 0 | 2 | - | - | - | - |
| 10 | 5 | 7 | 11 | 1 | - | - | - | - |
| 11 | 7 | 9 | 1 | 3 | - | - | - | - |
| 12 | - | - | - | - | 6 | 7 | 0 | 1 |
| 13 | - | - | - | - | 7 | 0 | 1 | 6 |
| 14 | - | - | - | - | 8 | 9 | 2 | 3 |
| 15 | - | - | - | - | 9 | 2 | 3 | 8 |
| 16 | - | - | - | - | 10 | 11 | 4 | 5 |
| 17 | - | - | - | - | 11 | 4 | 5 | 10 |

#### 6.4.1.4 Sounding reference signal

##### 6.4.1.4.1 SRS resource

An SRS resource is configured by the *SRS-Resource* IE or the *SRS-PosResource* IE and consists of

- antenna ports , where the number of antenna ports is given by the higher layer parameter *nrofSRS-Ports* if configured, otherwise , and when the SRS resource is in a SRS resource set with higher-layer parameter *usage* in *SRS-ResourceSet* not set to 'nonCodebook', or determined according to [6, TS 38.214] when the SRS resource is in a SRS resource set with higher-layer parameter *usage* in *SRS-ResourceSet* set to 'nonCodebook'

- consecutive OFDM symbols given by the field *nrofSymbols* contained in the higher layer parameter *resourceMapping*

- , the starting position in the time domain given by  where the offset counts symbols backwards from the end of the slot and is given by the field *startPosition* contained in the higher layer parameter *resourceMapping* and

- , the frequency-domain starting position of the sounding reference signal

##### 6.4.1.4.2 Sequence generation

The sounding reference signal sequence for an SRS resource shall be generated according to

where is given by clause 6.4.1.4.3, is given by clause 5.2.2 with and the transmission comb number is contained in the higher-layer parameter *transmissionComb*.

The quantity is given by

- if the higher-layer parameter XXX\_TDM is configured

- otherwise

The cyclic shift for antenna port if the higher-layer parameter XXX\_TDM is not configured is given as

,

where is contained in the higher layer parameter *transmissionComb*. The maximum number of cyclic shifts is given by Table 6.4.1.4.2-1.

The sequence group and the sequence number in clause 5.2.2 depends on the higher-layer parameter *groupOrSequenceHopping* in the *SRS-Resource* IE or the *SRS-PosResource* IE*.* The SRS sequence identity is given by the higher layer parameter *sequenceId* in the *SRS-Resource* IE, in which case , or the *SRS-PosResource-r16* IE, in which case . The quantity is the OFDM symbol number within the SRS resource.

- if *groupOrSequenceHopping* equals 'neither', neither group, nor sequence hopping shall be used and



- if *groupOrSequenceHopping* equals 'groupHopping', group hopping but not sequence hopping shall be used and



where the pseudo-random sequence is defined by clause 5.2.1 and shall be initialized with at the beginning of each radio frame.

- if *groupOrSequenceHopping* equals 'sequenceHopping', sequence hopping but not group hopping shall be used and



where the pseudo-random sequence is defined by clause 5.2.1 and shall be initialized with at the beginning of each radio frame.

Table 6.4.1.4.2-1: Maximum number of cyclic shifts as a function of .

|  |  |
| --- | --- |
|  |  |
| 2 | 8 |
| 4 | 12 |
| 8 | 6 |

##### 6.4.1.4.3 Mapping to physical resources

When SRS is transmitted on a given SRS resource, the sequence for each OFDM symbol and for each of the antenna ports of the SRS resource shall be multiplied with the amplitude scaling factor  in order to conform to the transmit power specified in [5, 38.213] and mapped in sequence starting with  to resource elements  in a slot for each of the antenna ports  according to

where if the higher-layer parameter XXX\_TDM is configured, otherwise .

The length of the sounding reference signal sequence is given by

where is given by a selected row of Table 6.4.1.4.3-1 with  where  is given by the field *b-SRS* contained in the higher-layer parameter *freqHopping* if configured, otherwise . The row of the table is selected according to the index  given by the field *c-SRS* contained in the higher-layer parameter *freqHopping*. The quantity is given by the higher-layer parameter *FreqScalingFactor* if configured, otherwise . When *FreqScalingFactor* is configured, the UE expects the length of the SRS sequence to be a multiple of 6.

The frequency-domain starting position is defined by

where

and

- is given by the higher-layer parameter *StartRBIndex* if configured, otherwise ;

- is given by Table 6.4.1.4.3-3 with

if the higher-layer parameter *EnableStartRBHopping* is configured, otherwise .

If  the reference point for is subcarrier 0 in common resource block 0, otherwise the reference point is the lowest subcarrier of the BWP.

If the SRS is configured by the IE *SRS-PosResource*, the quantity is given by Table 6.4.1.4.3-2, otherwise .

The frequency domain shift value adjusts the SRS allocation with respect to the reference point grid and is contained in the higher-layer parameter *freqDomainShift* in the *SRS-Resource* IE or the *SRS-PosResource* IE. The transmission comb offset is contained in the higher-layer parameter *transmissionComb* in the *SRS-Resource* IE or the *SRS-PosResource* IE and is a frequency position index.

Frequency hopping of the sounding reference signal is configured by the parameter , given by the field *b-hop* contained in the higher-layer parameter *freqHopping* if configured, otherwise .

If , frequency hopping is disabled and the frequency position index remains constant (unless re-configured) and is defined by



for all OFDM symbols of the SRS resource. The quantity  is given by the higher-layer parameter *freqDomainPosition* if configured, otherwise , and the values of and for are given by the selected row of Table 6.4.1.4.3-1 corresponding to the configured value of .

If , frequency hopping is enabled and the frequency position indices are defined by

where is given by Table 6.4.1.4.3-1,



and where regardless of the value of . The quantity counts the number of SRS transmissions. For the case of an SRS resource configured as aperiodic by the higher-layer parameter *resourceType*, it is given by within the slot in which the symbol SRS resource is transmitted. The quantity is the repetition factor given by the field *repetitionFactor* if configured, otherwise .

For the case of an SRS resource configured as periodic or semi-persistent by the higher-layer parameter *resourceType*, the SRS counter is given by

for slots that satisfy . The periodicity  in slots and slot offset  are given in clause 6.4.1.4.4.

Table 6.4.1.4.3-1: SRS bandwidth configuration.

|  |  | |  | |  | |  | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |
| 0 | 4 | 1 | 4 | 1 | 4 | 1 | 4 | 1 |
| 1 | 8 | 1 | 4 | 2 | 4 | 1 | 4 | 1 |
| 2 | 12 | 1 | 4 | 3 | 4 | 1 | 4 | 1 |
| 3 | 16 | 1 | 4 | 4 | 4 | 1 | 4 | 1 |
| 4 | 16 | 1 | 8 | 2 | 4 | 2 | 4 | 1 |
| 5 | 20 | 1 | 4 | 5 | 4 | 1 | 4 | 1 |
| 6 | 24 | 1 | 4 | 6 | 4 | 1 | 4 | 1 |
| 7 | 24 | 1 | 12 | 2 | 4 | 3 | 4 | 1 |
| 8 | 28 | 1 | 4 | 7 | 4 | 1 | 4 | 1 |
| 9 | 32 | 1 | 16 | 2 | 8 | 2 | 4 | 2 |
| 10 | 36 | 1 | 12 | 3 | 4 | 3 | 4 | 1 |
| 11 | 40 | 1 | 20 | 2 | 4 | 5 | 4 | 1 |
| 12 | 48 | 1 | 16 | 3 | 8 | 2 | 4 | 2 |
| 13 | 48 | 1 | 24 | 2 | 12 | 2 | 4 | 3 |
| 14 | 52 | 1 | 4 | 13 | 4 | 1 | 4 | 1 |
| 15 | 56 | 1 | 28 | 2 | 4 | 7 | 4 | 1 |
| 16 | 60 | 1 | 20 | 3 | 4 | 5 | 4 | 1 |
| 17 | 64 | 1 | 32 | 2 | 16 | 2 | 4 | 4 |
| 18 | 72 | 1 | 24 | 3 | 12 | 2 | 4 | 3 |
| 19 | 72 | 1 | 36 | 2 | 12 | 3 | 4 | 3 |
| 20 | 76 | 1 | 4 | 19 | 4 | 1 | 4 | 1 |
| 21 | 80 | 1 | 40 | 2 | 20 | 2 | 4 | 5 |
| 22 | 88 | 1 | 44 | 2 | 4 | 11 | 4 | 1 |
| 23 | 96 | 1 | 32 | 3 | 16 | 2 | 4 | 4 |
| 24 | 96 | 1 | 48 | 2 | 24 | 2 | 4 | 6 |
| 25 | 104 | 1 | 52 | 2 | 4 | 13 | 4 | 1 |
| 26 | 112 | 1 | 56 | 2 | 28 | 2 | 4 | 7 |
| 27 | 120 | 1 | 60 | 2 | 20 | 3 | 4 | 5 |
| 28 | 120 | 1 | 40 | 3 | 8 | 5 | 4 | 2 |
| 29 | 120 | 1 | 24 | 5 | 12 | 2 | 4 | 3 |
| 30 | 128 | 1 | 64 | 2 | 32 | 2 | 4 | 8 |
| 31 | 128 | 1 | 64 | 2 | 16 | 4 | 4 | 4 |
| 32 | 128 | 1 | 16 | 8 | 8 | 2 | 4 | 2 |
| 33 | 132 | 1 | 44 | 3 | 4 | 11 | 4 | 1 |
| 34 | 136 | 1 | 68 | 2 | 4 | 17 | 4 | 1 |
| 35 | 144 | 1 | 72 | 2 | 36 | 2 | 4 | 9 |
| 36 | 144 | 1 | 48 | 3 | 24 | 2 | 12 | 2 |
| 37 | 144 | 1 | 48 | 3 | 16 | 3 | 4 | 4 |
| 38 | 144 | 1 | 16 | 9 | 8 | 2 | 4 | 2 |
| 39 | 152 | 1 | 76 | 2 | 4 | 19 | 4 | 1 |
| 40 | 160 | 1 | 80 | 2 | 40 | 2 | 4 | 10 |
| 41 | 160 | 1 | 80 | 2 | 20 | 4 | 4 | 5 |
| 42 | 160 | 1 | 32 | 5 | 16 | 2 | 4 | 4 |
| 43 | 168 | 1 | 84 | 2 | 28 | 3 | 4 | 7 |
| 44 | 176 | 1 | 88 | 2 | 44 | 2 | 4 | 11 |
| 45 | 184 | 1 | 92 | 2 | 4 | 23 | 4 | 1 |
| 46 | 192 | 1 | 96 | 2 | 48 | 2 | 4 | 12 |
| 47 | 192 | 1 | 96 | 2 | 24 | 4 | 4 | 6 |
| 48 | 192 | 1 | 64 | 3 | 16 | 4 | 4 | 4 |
| 49 | 192 | 1 | 24 | 8 | 8 | 3 | 4 | 2 |
| 50 | 208 | 1 | 104 | 2 | 52 | 2 | 4 | 13 |
| 51 | 216 | 1 | 108 | 2 | 36 | 3 | 4 | 9 |
| 52 | 224 | 1 | 112 | 2 | 56 | 2 | 4 | 14 |
| 53 | 240 | 1 | 120 | 2 | 60 | 2 | 4 | 15 |
| 54 | 240 | 1 | 80 | 3 | 20 | 4 | 4 | 5 |
| 55 | 240 | 1 | 48 | 5 | 16 | 3 | 8 | 2 |
| 56 | 240 | 1 | 24 | 10 | 12 | 2 | 4 | 3 |
| 57 | 256 | 1 | 128 | 2 | 64 | 2 | 4 | 16 |
| 58 | 256 | 1 | 128 | 2 | 32 | 4 | 4 | 8 |
| 59 | 256 | 1 | 16 | 16 | 8 | 2 | 4 | 2 |
| 60 | 264 | 1 | 132 | 2 | 44 | 3 | 4 | 11 |
| 61 | 272 | 1 | 136 | 2 | 68 | 2 | 4 | 17 |
| 62 | 272 | 1 | 68 | 4 | 4 | 17 | 4 | 1 |
| 63 | 272 | 1 | 16 | 17 | 8 | 2 | 4 | 2 |

Table 6.4.1.4.3-2: The offset for SRS as a function of and .

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | | | | |
|  |  |  |  |  |
| 2 | 0 | 0,1 | 0,1,0,1 | - | - |
| 4 | - | 0, 2 | 0, 2, 1, 3 | 0, 2, 1, 3, 0, 2, 1, 3 | 0, 2, 1, 3, 0, 2, 1, 3, 0, 2, 1, 3 |
| 8 | - | - | 0, 4, 2, 6 | 0, 4, 2, 6, 1, 5, 3, 7 | 0, 4, 2, 6, 1, 5, 3, 7, 0, 4, 2, 6 |

Table 6.4.1.4.3-3: The quantity as a function of .

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | | |
|  |  |  |  |
| 0 | 0 | 0 | 0 |
| 1 | - | 1 | 2 |
| 2 | - | - | 1 |
| 3 | - | - | 3 |

##### 6.4.1.4.4 Sounding reference signal slot configuration

For an SRS resource configured as periodic or semi-persistent by the higher-layer parameter *resourceType*, a periodicity  (in slots) and slot offset  are configured according to the higher-layer parameter *periodicityAndOffset-p* or *periodicityAndOffset-sp* in the *SRS-Resource* IE, or *periodicityAndOffset-p* or *periodicityAndOffset-sp* in the *SRS-PosResource* IE. Candidate slots in which the configured SRS resource may be used for SRS transmission are the slots satisfying



SRS is transmitted as described in clause 6.2.1 of [6, TS 38.214].

##### 7.4.1.1.2 Mapping to physical resources

The UE shall assume the PDSCH DM-RS being mapped to physical resources according to configuration type 1 or configuration type 2 as given by the higher-layer parameter *dmrs-Type*.

The UE shall assume the sequence  is scaled by a factor  to conform with the transmission power specified in [6, TS 38.214] and mapped to resource elements according to

where , , and are given by Tables 7.4.1.1.2-1 and 7.4.1.1.2-2 and the following conditions are fulfilled:

- the resource elements are within the common resource blocks allocated for PDSCH transmission

The reference point for  is

- subcarrier 0 of the lowest-numbered resource block in CORESET 0 if the corresponding PDCCH is associated with CORESET 0 and Type0-PDCCH common search space and is addressed to SI-RNTI;

- otherwise, subcarrier 0 in common resource block 0

The reference point for  and the position  of the first DM-RS symbol depends on the mapping type:

- for PDSCH mapping type A:

-  is defined relative to the start of the slot

- if the higher-layer parameter *dmrs-TypeA-Position* is equal to 'pos3' and  otherwise

- for PDSCH mapping type B:

-  is defined relative to the start of the scheduled PDSCH resources

- 

The position(s) of the DM-RS symbols is given by  and duration where

- for PDSCH mapping type A, is the duration between the first OFDM symbol of the slot and the last OFDM symbol of the scheduled PDSCH resources in the slot

- for PDSCH mapping type B, is the duration of the scheduled PDSCH resources

and according to Tables 7.4.1.1.2-3 and 7.4.1.1.2-4.

For PDSCH mapping type A

- the case *dmrs-AdditionalPosition* equals to 'pos3' is only supported when *dmrs-TypeA-Position* is equal to 'pos2';

- and symbols in Tables 7.4.1.1.2-3 and 7.4.1.1.2-4 respectively is only applicable when *dmrs-TypeA-Position* is equal to 'pos2';

- single-symbol DM-RS, except if all of the following conditions are fulfilled in which case :

- the higher-layer parameter *lte-CRS-ToMatchAround*, *lte-CRS-PatternList1*, or *lte-CRS-PatternList2* is configured; and

*-* the higher-layer parameter *dmrs-AdditionalPosition* is equal to 'pos1' and ; and

*-* the UE has indicated it is capable of *additionalDMRS-DL-Alt*

For PDSCH mapping type B

- if the PDSCH duration  OFDM symbols for normal cyclic prefix or OFDM symbols for extended cyclic prefix, and the front-loaded DM-RS of the PDSCH allocation collides with resources reserved for a search space set associated with a CORESET,  shall be incremented such that the first DM-RS symbol occurs immediately after the CORESET and until no collision with any CORESET occurs, and

- if the PDSCH duration is 2 symbols, the UE is not expected to receive a DM-RS symbol beyond the second symbol;

- if the PDSCH duration is 5 symbols and if one additional single-symbol DMRS is configured, the UE only expects the additional DM-RS to be transmitted on the 5th symbol when the front-loaded DM-RS symbol is in the 1st symbol of the PDSCH duration, otherwise the UE should expect that the additional DM-RS is not transmitted;

- if the PDSCH duration is 7 symbols for normal cyclic prefix or 6 symbols for extended cyclic prefix:

- if one additional single-symbol DM-RS is configured, the UE only expects the additional DM-RS to be transmitted on the 5th or 6th symbol when the front-loaded DM-RS symbol is in the 1st or 2nd symbol, respectively, of the PDSCH duration, otherwise the UE should expect that the additional DM-RS is not transmitted;

- if the PDSCH duration OFDM symbols, the UE is not expected to receive the front-loaded DM-RS beyond the 4th symbol;

- if the PDSCH duration is 12 or 13 symbols, the UE is not expected to receive DM-RS mapped to symbol 12 or later in the slot;

- for all values of the PDSCH duration other than 2, 5, and 7 symbols, the UE is not expected to receive DM-RS beyond the :th symbol;

- if the PDSCH duration is less than or equal to 4 OFDM symbols, only single-symbol DM-RS is supported.

- if the higher-layer parameter *lte-CRS-ToMatchAround*, *lte-CRS-PatternList1*, or *lte-CRS-PatternList2* is configured, the PDSCH duration symbols for normal cyclic prefix, the subcarrier spacing configuration , single-symbol DM-RS is configured, and at least one PDSCH DM-RS symbol in the PDSCH allocation collides with a symbol containing resource elements as indicated by the higher-layer parameter *lte-CRS-ToMatchAround*, *lte-CRS-PatternList1*, or *lte-CRS-PatternList2*, then shall be incremented by one in all slots.

The frequency-domain index , the time-domain index , and the supported antenna ports are given by Table 7.4.1.1.2-5 where

- single-symbol DM-RS is used if the higher-layer parameter *maxLength* in the *DMRS-DownlinkConfig* IE is not configured

- single-symbol or double-symbol DM-RS is determined by the associated DCI if the higher-layer parameter *maxLength* in the *DMRS-DownlinkConfig* IE is equal to 'len2'.

- basic or enhanced DM-RS multiplexing is controlled by the higher-layer parameter XXX

In absence of CSI-RS configuration, and unless otherwise configured, the UE may assume PDSCH DM-RS and SS/PBCH block to be quasi co-located with respect to Doppler shift, Doppler spread, average delay, delay spread, and, when applicable, spatial Rx parameters. Unless specified otherwise, the UE may assume that the PDSCH DM-RS within the same CDM group are quasi co-located with respect to Doppler shift, Doppler spread, average delay, delay spread, and spatial Rx (when applicable). The UE may assume that DMRS ports associated with a TCI state as described in clause 5.1.6.2 of [6, TS 38.214] of a PDSCH are QCL with QCL Type A, Type D (when applicable) and average gain.

The UE may assume that no DM-RS collides with the SS/PBCH block.

Table 7.4.1.1.2-1: Parameters for PDSCH DM-RS configuration type 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | CDM group |  |  |  |
| 1000 | 0 | 0 |  |  |
| 1001 | 0 | 0 |  |  |
| 1002 | 1 | 1 |  |  |
| 1003 | 1 | 1 |  |  |
| 1004 | 0 | 0 |  |  |
| 1005 | 0 | 0 |  |  |
| 1006 | 1 | 1 |  |  |
| 1007 | 1 | 1 |  |  |
| 1008 | 0 | 0 |  |  |
| 1009 | 0 | 0 |  |  |
| 1010 | 1 | 1 |  |  |
| 1011 | 1 | 1 |  |  |
| 1012 | 0 | 0 |  |  |
| 1013 | 0 | 0 |  |  |
| 1014 | 1 | 1 |  |  |
| 1015 | 1 | 1 |  |  |



Table 7.4.1.1.2-2: Parameters for PDSCH DM-RS configuration type 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | CDM group |  |  |  |
| 0 | 0 | 0 |  |  |
| 1 | 0 | 0 |  |  |
| 2 | 1 | 2 |  |  |
| 3 | 1 | 2 |  |  |
| 4 | 2 | 4 |  |  |
| 5 | 2 | 4 |  |  |
| 6 | 0 | 0 |  |  |
| 7 | 0 | 0 |  |  |
| 8 | 1 | 2 |  |  |
| 9 | 1 | 2 |  |  |
| 10 | 2 | 4 |  |  |
| 11 | 2 | 4 |  |  |
| 12 | 0 | 0 |  |  |
| 13 | 0 | 0 |  |  |
| 14 | 1 | 2 |  |  |
| 15 | 1 | 2 |  |  |
| 16 | 2 | 4 |  |  |
| 17 | 2 | 4 |  |  |
| 18 | 0 | 0 |  |  |
| 19 | 0 | 0 |  |  |
| 20 | 1 | 2 |  |  |
| 21 | 1 | 2 |  |  |
| 22 | 2 | 4 |  |  |
| 23 | 2 | 4 |  |  |



Table 7.4.1.1.2-3: PDSCH DM-RS positions  for single-symbol DM-RS.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **in symbols** | **DM-RS positions** | | | | | | | |
| **PDSCH mapping type A** | | | | **PDSCH mapping type B** | | | |
| ***dmrs-AdditionalPosition*** | | | | ***dmrs-AdditionalPosition*** | | | |
| ***pos0*** | ***pos1*** | ***pos2*** | ***pos3*** | ***pos0*** | ***pos1*** | ***pos2*** | ***pos3*** |
| 2 | - | - | - | - |  |  |  |  |
| 3 |  |  |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |  |  |
| 6 |  |  |  |  |  |  |  |  |
| 7 |  |  |  |  |  |  |  |  |
| 8 |  | , 7 | , 7 | , 7 |  |  |  |  |
| 9 |  | , 7 | , 7 | , 7 |  |  |  |  |
| 10 |  | , 9 | , 6, 9 | , 6, 9 |  |  |  |  |
| 11 |  | , 9 | , 6, 9 | , 6, 9 |  |  |  |  |
| 12 |  | , 9 | , 6, 9 | , 5, 8, 11 |  |  |  |  |
| 13 |  | , | , 7, 11 | , 5, 8, 11 |  |  |  |  |
| 14 |  | , | , 7, 11 | , 5, 8, 11 | - | - | - | - |

Table 7.4.1.1.2-4: PDSCH DM-RS positions  for double-symbol DM-RS.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **in symbols** | **DM-RS positions** | | | | | |
| **PDSCH mapping type A** | | | **PDSCH mapping type B** | | |
| ***dmrs-AdditionalPosition*** | | | ***dmrs-AdditionalPosition*** | | |
| ***pos0*** | ***pos1*** | ***pos2*** | ***pos0*** | ***pos1*** | ***pos2*** |
| <4 |  |  |  | - | - |  |
| 4 |  |  |  | - | - |  |
| 5 |  |  |  |  |  |  |
| 6 |  |  |  |  |  |  |
| 7 |  |  |  |  |  |  |
| 8 |  |  |  |  |  |  |
| 9 |  |  |  |  |  |  |
| 10 |  | , 8 |  |  |  |  |
| 11 |  | , 8 |  |  |  |  |
| 12 |  | , 8 |  |  |  |  |
| 13 |  | , 10 |  |  |  |  |
| 14 |  | , 10 |  | - | - |  |

Table 7.4.1.1.2-5: PDSCH DM-RS frequency index , time index , and antenna ports .

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| DM-RS multiplexing | DM-RS duration |  |  | Supported antenna ports | |
| Configuration type 1 | Configuration type 2 |
| Basic | single-symbol DM-RS | 0, 1 | 0 | 1000 – 1003 | 1000 – 1005 |
| double-symbol DM-RS | 0, 1 | 0, 1 | 1000 – 1007 | 1000 – 1011 |
| Enhanced | single-symbol DM-RS | 0, 1, 2, 3 | 0 | 1000 – 1007 | 1000 – 1011 |
| double-symbol DM-RS | 0, 1, 2, 3 | 0, 1 | 1000 – 1015 | 1000 – 1023 |



##### 7.4.1.2.2 Mapping to physical resources

The UE shall assume phase-tracking reference signals being present only in the resource blocks used for the PDSCH, and only if the procedure in [6, TS 38.214] indicates phase-tracking reference signals being used.

If present, the UE shall assume the PDSCH PT-RS is scaled by a factor to conform with the transmission power specified in clause 4.1 of [6, TS 38.214] and mapped to resource elements according to

when all the following conditions are fulfilled

-  is within the OFDM symbols allocated for the PDSCH transmission

- resource element is not used for DM-RS, non-zero-power CSI-RS (except for those configured for mobility measurements or with *resourceType* in corresponding *CSI-ResourceConfig* configured as 'aperiodic'), zero-power CSI-RS, SS/PBCH block, a detected PDCCH according to clause 5.1.4.1 of [6, TS38.214], or is declared as 'not available' by clause 5.1.4 of [6, TS 38.214]

The set of time indices  defined relative to the start of the PDSCH allocation is defined by

1. set and 

2. if any symbol in the interval overlaps with a symbol used for DM-RS according to clause 7.4.1.1.2

- set

- set  to the symbol index of the DM-RS symbol in case of a single-symbol DM-RS and to the symbol index of the second DM-RS symbol in case of a double-symbol DM-RS

- repeat from step 2 as long as is inside the PDSCH allocation

3. add to the set of time indices for PT-RS

4. increment  by one

5. repeat from step 2 above as long as is inside the PDSCH allocation

where .

For the purpose of PT-RS mapping, the resource blocks allocated for PDSCH transmission are numbered from 0 to  from the lowest scheduled resource block to the highest. The corresponding subcarriers in this set of resource blocks are numbered in increasing order starting from the lowest frequency from 0 to . The subcarriers to which the UE shall assume the PT-RS is mapped are given by



where

-

-  is given by Table 7.4.1.2.2-1 for the DM-RS port associated with the PT-RS port according to clause 5.1.6.3 in [6, TS 38.214]. If the higher-layer parameter *resourceElementOffset* in the *PTRS-DownlinkConfig* IE is not configured, the column corresponding to 'offset00' shall be used.

-  is the RNTI associated with the DCI scheduling the transmission

-  is the number of resource blocks scheduled

- is given by [6, TS 38.214].

Table 7.4.1.2.2-1: The parameter .

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DM-RS antenna port |  | | | | | | | |
| DM-RS Configuration type 1 | | | | DM-RS Configuration type 2 | | | |
| *resourceElementOffset* | | | | *resourceElementOffset* | | | |
| offset00 | offset01 | offset10 | offset11 | offset00 | offset01 | offset10 | offset11 |
| 1000 | 0 | 2 | 6 | 8 | 0 | 1 | 6 | 7 |
| 1001 | 2 | 4 | 8 | 10 | 1 | 6 | 7 | 0 |
| 1002 | 1 | 3 | 7 | 9 | 2 | 3 | 8 | 9 |
| 1003 | 3 | 5 | 9 | 11 | 3 | 8 | 9 | 2 |
| 1004 | - | - | - | - | 4 | 5 | 10 | 11 |
| 1005 | - | - | - | - | 5 | 10 | 11 | 4 |
| 1008 | 4 | 6 | 10 | 0 | - | - | - | - |
| 1009 | 6 | 8 | 0 | 2 | - | - | - | - |
| 1010 | 5 | 7 | 11 | 1 | - | - | - | - |
| 1011 | 7 | 9 | 1 | 3 | - | - | - | - |
| 1012 | - | - | - | - | 6 | 7 | 0 | 1 |
| 1013 | - | - | - | - | 7 | 0 | 1 | 6 |
| 1014 | - | - | - | - | 8 | 9 | 2 | 3 |
| 1015 | - | - | - | - | 9 | 2 | 3 | 8 |
| 1016 | - | - | - | - | 10 | 11 | 4 | 5 |
| 1017 | - | - | - | - | 11 | 4 | 5 | 10 |