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CHANGE REQUEST

38.214	**CR**	**0026**	**rev**	**-**	**Current version:**	**16.7.0**

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Proposed change affects:	UICC apps		ME	X	Radio Access Network	X	Core Network

Title:	Introduction of DL 1024QAM for NR FR1		
Source to WG: ***Source to TSG:***	Nokia		
Work item code:	NR_DL1024QAM_FR1-Core	***Date:***	2021-12-08
Category:	**B**	***Release:***	Rel-17
	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.		*Use one of the following releases:* *Rel-8 (Release 8)* *Rel-9 (Release 9)* *Rel-10 (Release 10)* *Rel-11 (Release 11)* *…* *Rel-15 (Release 15)* *Rel-16 (Release 16)* *Rel-17 (Release 17)* *Rel-18 (Release 18)*

Reason for change:	Introduction of DL 1024QAM for NR FR1
Summary of change:	Introduction of 1024QAM related procedures in modulation order and target code rate determination, TBS determination, PT-RS operation, CQI
Consequences if not approved:	Incomplete support of DL 1024QAM for NR FR1

Clauses affected:	5.1.3, 5.1.3.1, 5.1.3.2, 5.1.6.3, 5.2.2.1			
	Y	**N**		
Other specs affected:	**X**		Other core specifications	TS 38.211, TS 38.212
(show related CRs)		**X**	Test specifications	TS/TR ... CR ...
		X	O&M Specifications	TS/TR ... CR ...
Other comments:				
This CR's revision history:				

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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 ith 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 ith 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, and W = 26 for MCS table 5.1.3.1-4, 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, $V_{j,m} = C' \cdot \left\lfloor \frac{A}{C} \right\rfloor$
  - 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]
- $DataRateCC$ [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-Table-r17* given by *PDSCH-Config* is set to 'qam1024', 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 5.1.3.1-4 to determine the modulation order (Q_m) and Target code rate (R) used in the physical downlink shared channel.

elseif *mcs-TableDCI-1-2-r17* given by *PDSCH-Config* is set to 'qam1024', 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 5.1.3.1-4 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-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-Table-r17* given by *PDSCH-Config* is set to 'qam1024',

- 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 5.1.3.1-4 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-r17* given by *PDSCH-Config* is set to 'qam1024',

- 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 5.1.3.1-4 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	

Table 5.1.3.1-4: MCS index table 4 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	449	0.8770
3	4	378	1.4766
4	4	490	1.9141
5	4	616	2.4063
6	6	466	2.7305
7	6	517	3.0293
8	6	567	3.3223
9	6	616	3.6094
10	6	666	3.9023
11	6	719	4.2129
12	6	772	4.5234
13	6	822	4.8164
14	6	873	5.1152
15	8	682.5	5.3320
16	8	711	5.5547
17	8	754	5.8906
18	8	797	6.2266
19	8	841	6.5703
20	8	885	6.9141
21	8	916.5	7.1602
22	8	948	7.4063
23	10	805.5	7.8662
24	10	853	8.3301
25	10	900.5	8.7939
26	10	948	9.2578
27	2	reserved	
28	4	reserved	
29	6	reserved	
30	8	reserved	
31	10	reserved	

<omitted text>

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 $0 \le I_{MCS} \le 27$, else if Table 5.1.3.1-4 used and $0 \le I_{MCS} \le 26$ or a table other than Table 5.1.3.1-2 and Table 5.1.3.1-4 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 $N'_{RE} = N_{sc}^{RB} \cdot N_{symb}^{sh} - N_{DMRS}^{PRB} - N_{oh}^{PRB}$, where $N_{sc}^{RB} = 12$ is the number of subcarriers in a physical resource block, N_{symb}^{sh} is the number of symbols of the PDSCH allocation within the slot, N_{DMRS}^{PRB} 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_{oh}^{PRB} 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_{oh}^{PRB} 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 $N_{\inf o} = N_{RE} \cdot R \cdot Q_m \cdot \upsilon$.

If $N_{\inf o} \le 3824$

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 $N_{\inf o} \le 3824$, TBS is determined as follows

- quantized intermediate number of information bits $N_{\inf o}^{'} = \max\left(24, 2^n \cdot \left\lfloor \frac{N_{\inf o}}{2^n} \right\rfloor\right)$, where $n = \max\left(3, \left\lfloor \log_2\left(N_{\inf o}\right)\right\rfloor - 6\right)$.
- use Table 5.1.3.2-1 find the closest TBS that is not less than $N_{\inf o}^{'}$.

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 if Table 5.1.3.1-4 is used and $27 \le I_{MCS} \le 31$,

- the TBS is assumed to be as determined from the DCI transported in the latest PDCCH for the same transport block using $0 \le I_{MCS} \le 26$. If there is no PDCCH for the same transport block using $0 \le I_{MCS} \le 26$, 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 $N'_{RE} = N_{sc}^{RB} \cdot N_{symb}^{sh} - N_{DMRS}^{PRB} - N_{oh}^{PRB}$, where N_{symb}^{sh} 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.

<omitted text>

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 $ptrs\text{-}MCS_i$, 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 scheduled MCS from Table 5.1.3.1-4 is smaller than 3, 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, and 0-27 when MCS Table 5.1.3.1-4 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 and 27 when MCS Table 5.1.3.1-4 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 ($L_{PT\text{-}RS}$) and PT-RS frequency density ($K_{PT\text{-}RS}$), 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 $L_{PT\text{-}RS}$ 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 $L_{PT\text{-}RS}$ 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, and V=26 for MCS Table 5.1.3.1-4 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.

<omitted text>

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. The CQI indices and their interpretations are given in Table 5.2.2.1-5 for reporting CQI based on QPSK, 16QAM, 64QAM, 256QAM and 1024 QAM.

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 if the higher layer parameter *cqi-Table* in *CSI-ReportConfig* configures ‘table4-r17’ (corresponding to Table 5.2.2.1-5)
  - 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

Table 5.2.2.1-5: 4-bit CQI Table 4

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	193	0.377
3	QPSK	449	0.877
4	16QAM	378	1.4766
5	16QAM	616	2.4063
6	64QAM	567	3.3223
7	64QAM	666	3.9023
8	64QAM	772	4.5234
9	64QAM	873	5.1152
10	256QAM	711	5.5547
11	256QAM	797	6.2266
12	256QAM	885	6.9141
13	256QAM	948	7.4063
14	1024QAM	853	8.3301
15	1024QAM	948	9.2578

<omitted text>