The channel quality bits in Table 5.2.2.6.3-1, Table 5.2.2.6.3-2, Table 5.2.2.6.3-2A, Table 5.2.2.6.3-2B, Table 5.2.2.6.3-2C, Table 5.2.2.6.3-2D, Table 5.2.2.6.3-2E, Table 5.2.2.6.3-2F, Table 5.2.2.6.3-2G, Table 5.2.2.6.3-2H, Table 5.2.2.6.3-2I, Table 5.2.2.6.3-3B, and Table 5.2.2.6.3-3D form the bit sequence $o_0, o_1, o_2, ..., o_{O-1}$ with o_0 corresponding to the first bit of the first field in each of the tables, o_1 corresponding to the second bit of the first field in each of the tables, and o_{O-1} corresponding to the last bit in the last field in each of the tables. The field of PMI shall start with the wideband PMI followed by the PMI for the M selected subbands. The first bit of each field corresponds to MSB and the last bit LSB. The RI bits sequence in Table 5.2.2.6.3-3, Table 5.2.2.6.3-3B, Table 5.2.2.6.3-3D, Table 5.2.2.6.3-3E, and the CRI sequence in Table 5.2.2.6.3-3A and Table 5.2.2.6.3-3C are encoded according to clause 5.2.2.6.

For transmission mode 9/10 configured with Class B CSI reporting and K>1, the number of antenna port in Table 5.2.2.6.3-3B refers to the maximum number of antenna ports of K CSI-RS resources configured for the CSI-process for the UE.

For transmission mode 9/10 configured with Class B CSI reporting and K>1 and with *activatedResources*>1, the number of antenna port in Table 5.2.2.6.3-3D refers to the maximum number of antenna ports of N CSI-RS resources activated for the CSI-process for the UE. N is the value of higher layer parameter *activatedResources*.

5.2.2.6.4 Channel coding for CQI/PMI information in PUSCH

The channel quality bits input to the channel coding block are denoted by $o_0, o_1, o_2, o_3, ..., o_{O-1}$ where O is the number of bits. The number of channel quality bits depends on the transmission format. When PUCCH-based reporting format is used, the number of CQI/PMI bits is defined in clause 5.2.3.3.1 for wideband reports and in clause 5.2.3.3.2 for UE selected subbands reports. When PUSCH-based reporting format is used, the number of CQI/PMI bits is defined in clause 5.2.2.6.1 for wideband reports, in clause 5.2.2.6.2 for higher layer configured subbands reports and in clause 5.2.2.6.3 for UE selected subbands reports.

The channel quality information is first coded using a (32, O) block code. The code words of the (32, O) block code are a linear combination of the 11 basis sequences denoted $M_{i,n}$ and defined in Table 5.2.2.6.4-1.

Table 5.2.2.6.4-1: Basis sequences for (32, *O*) code

i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$	$M_{i,5}$	$M_{i,6}$	$M_{i,7}$	$M_{i,8}$	$M_{i,9}$	$M_{i,10}$
0	1	1	0	0	0	0	0	0	0	0	1
1	1	1	1	0	0	0	0	0	0	1	1
2	1	0	0	1	0	0	1	0	1	1	1
3	1	0	1	1	0	0	0	0	1	0	1
4	1	1	1	1	0	0	0	1	0	0	1
5	1	1	0	0	1	0	1	1	1	0	1
6	1	0	1	0	1	0	1	0	1	1	1
7	1	0	0	1	1	0	0	1	1	0	1
8	1	1	0	1	1	0	0	1	0	1	1
9	1	0	1	1	1	0	1	0	0	1	1
10	1	0	1	0	0	1	1	1	0	1	1
11	1	1	1	0	0	1	1	0	1	0	1
12	1	0	0	1	0	1	0	1	1	1	1
13	1	1	0	1	0	1	0	1	0	1	1
14	1	0	0	0	1	1	0	1	0	0	1
15	1	1	0	0	1	1	1	1	0	1	1
16	1	1	1	0	1	1	1	0	0	1	0
17	1	0	0	1	1	1	0	0	1	0	0
18	1	1	0	1	1	1	1	1	0	0	0
19	1	0	0	0	0	1	1	0	0	0	0
20	1	0	1	0	0	0	1	0	0	0	1
21	1	1	0	1	0	0	0	0	0	1	1
22	1	0	0	0	1	0	0	1	1	0	1
23	1	1	1	0	1	0	0	0	1	1	1
24	1	1	1	1	1	0	1	1	1	1	0
25	1	1	0	0	0	1	1	1	0	0	1
26	1	0	1	1	0	1	0	0	1	1	0
27	1	1	1	1	0	1	0	1	1	1	0
28	1	0	1	0	1	1	1	0	1	0	0
29	1	0	1	1	1	1	1	1	1	0	0
30	1	1	1	1	1	1	1	1	1	1	1
31	1	0	0	0	0	0	0	0	0	0	0

The encoded CQI/PMI block is denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where $B = 32$ and

$$b_i = \sum_{n=0}^{O-1} \left(o_n \cdot M_{i,n}\right) \bmod 2$$ where i = 0, 1, 2, …, B-1.

The output bit sequence $q_0, q_1, q_2, q_3, ..., q_{N_L \cdot Q_{CQI}-1}$ is obtained by circular repetition of the encoded CQI/PMI block as follows

$q_i = b_{(i \bmod B)}$ where i = 0, 1, 2, …, $N_L \cdot Q_{CQI}$-1, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto.

5.2.2.6.5 Channel coding for more than 11 bits of HARQ-ACK information

The HARQ-ACK bits input to the channel coding block are denoted by $o_0^{ACK}\ o_1^{ACK}, ..., o_{O^{ACK}-1}^{ACK}$ where $11 < O^{ACK} \le 22$ is the number of bits.

The sequences of bits $o_0^{ACK}, o_1^{ACK}, o_2^{ACK}, ..., o_{\lceil O^{ACK}/2 \rceil -1}^{ACK}$ and $o_{\lceil O^{ACK}/2 \rceil}^{ACK}, o_{\lceil O^{ACK}/2 \rceil +1}^{ACK}, o_{\lceil O^{ACK}/2 \rceil +2}^{ACK}, ..., o_{O^{ACK}-1}^{ACK}$ are encoded as follows

$$\tilde{q}_i = \sum_{n=0}^{\lceil O^{ACK}/2 \rceil - 1} \left(o_n^{ACK} \cdot M_{i,n} \right) \bmod 2$$

and

$$\tilde{\tilde{q}}_i = \sum_{n=0}^{O^{ACK} - \lceil O^{ACK}/2 \rceil - 1} \left(o_{\lceil O^{ACK}/2 \rceil + n}^{ACK} \cdot M_{i,n} \right) \bmod 2$$

where i = 0, 1, 2, …, 31 and the basis sequences $M_{i,n}$ are defined in Table 5.2.2.6.4-1.

The output bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, ..., q_{Q_{ACK}-1}^{ACK}$ is obtained by the concatenation and circular repetition of the bit sequences $\tilde{q}_0, \tilde{q}_1, \tilde{q}_2, ...,, \tilde{q}_{31}$ and $\tilde{\tilde{q}}_0, \tilde{\tilde{q}}_1, \tilde{\tilde{q}}_2, ...,, \tilde{\tilde{q}}_{31}$ as follows:

Set i = 0

while $i < \lceil Q'/2 \rceil \cdot Q_m$

$q_i^{ACK} = \tilde{q}_{i \bmod 32}$

$i = i + 1$

end while

Set i = 0

while $i < (Q' - \lceil Q'/2 \rceil) \cdot Q_m$

$q_{\lceil Q'/2 \rceil \cdot Q_m + i}^{ACK} = \tilde{\tilde{q}}_{i \bmod 32}$

$i = i + 1$

end while

5.2.2.7 Data and control multiplexing

The control and data multiplexing is performed such that HARQ-ACK information is present on both slots and is mapped to resources around the demodulation reference signals. In addition, the multiplexing ensures that control and data information are mapped to different modulation symbols.

The inputs to the data and control multiplexing are the coded bits of the control information denoted by $q_0, q_1, q_2, q_3, ..., q_{N_L \cdot Q_{CQI}-1}$ and the coded bits of the UL-SCH denoted by $f_0, f_1, f_2, f_3, ..., f_{G-1}$. The output of the data and control multiplexing operation is denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, \underline{g}_3, ..., \underline{g}_{H'-1}$, where $H = (G + N_L \cdot Q_{CQI})$ and $H' = H / (N_L \cdot Q_m)$, and where $\underline{g}_i$, $i = 0, ..., H'-1$ are column vectors of length $(Q_m \cdot N_L)$. H is the total number of coded bits allocated for UL-SCH data and CQI/PMI information across the N_L transmission layers of the transport block.

In case where more than one UL-SCH transport block are transmitted in a subframe of an UL cell, the CQI/PMI information is multiplexed with data only on the UL-SCH transport block with highest I_{MCS} value on the initial grant. In case the two transport blocks have the same I_{MCS} value in the corresponding initial UL grant, the CQI/PMI information is multiplexed with data only on the first transport block. For that UL-SCH transport block or in the case of single transport block transmission, and assuming that N_L is the number of layers onto which the UL-SCH transport block is mapped, the control information and the data shall be multiplexed as follows:

Set i, j, k to 0

while $j < N_L.Q_{CQI}$ -- first place the control information

$\underline{g}_k = [q_j \ldots q_{j+N_L \cdot Q_m - 1}]^T$

$j = j + N_L \cdot Q_m$

$k = k + 1$

end while

while $i < G$ -- then place the data

$\underline{g}_k = [f_i \ldots f_{i+Q_m \cdot N_L - 1}]^T$

$i = i + Q_m \cdot N_L$

$k = k + 1$

end while

5.2.2.8 Channel interleaver

The channel interleaver described in this clause in conjunction with the resource element mapping for PUSCH in [2] implements a time-first mapping of modulation symbols onto the transmit waveform while ensuring that the HARQ-ACK and RI information are present on both slots in the subframe. HARQ-ACK information is mapped to resources around the uplink demodulation reference signals while RI information is mapped to resources around those used by HARQ-ACK.

The input to the channel interleaver are denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, ..., \underline{g}_{H'-1}$, $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, ..., \underline{q}_{Q'_{RI}-1}^{RI}$ and $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, ..., \underline{q}_{Q'_{ACK}-1}^{ACK}$. In case where more than one UL-SCH transport block are transmitted in a subframe of an UL cell, the HARQ-ACK and RI information are multiplexed with data on both UL-SCH transport blocks.

The number of modulation symbols per layer in the subframe is given by $H'_{total} = H' + Q'_{RI}$. The output bit sequence from the channel interleaver is derived as follows:

(1) Assign $C_{mux} = N_{\text{symb}}^{\text{PUSCH}}$ to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2,…, $C_{mux} - 1$ from left to right. $N_{\text{symb}}^{\text{PUSCH}}$ is determined according to clause 5.2.2.6, or by higher layer parameter symPUSCH-UpPts for PUSCH transmission in UpPTS.

(2) The number of rows of the matrix is $R_{mux} = \left(H'_{total} \cdot Q_m \cdot N_L\right) / C_{mux}$ and we define $R'_{mux} = R_{mux} / \left(Q_m \cdot N_L\right)$.

The rows of the rectangular matrix are numbered 0, 1, 2,…, $R_{mux} - 1$ from top to bottom.

(3) If rank information is transmitted in this subframe, the vector sequence $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, ..., \underline{q}_{Q'_{RI}-1}^{RI}$ is written onto the columns indicated by Table 5.2.2.8-1 or Table 5.2.2.8-1A and by sets of $\left(Q_m \cdot N_L\right)$ rows starting from the last row and moving upwards according to the following pseudo-code.

Set *i*, *j* to 0.

Set *r* to $R'_{mux} - 1$

while *i* < Q'_{RI}

$c_{RI} = \text{Column Set}(j)$

$\underline{y}_{r \times C_{mux} + c_{RI}} = \underline{q}_i^{RI}$

$i = i + 1$

$r = R'_{mux} - 1 - \lfloor i/4 \rfloor$

$j = (j + 3) \bmod 4$

end while,

where ColumnSet is given in Table 5.2.2.8-1 or Table 5.2.2.8-1A and indexed left to right from 0 to 3.

(4) Write the input vector sequence, for k = 0, 1,…, $H' - 1$, into the $(R_{mux} \times C_{mux})$ matrix by sets of $(Q_m \cdot N_L)$ rows starting with the vector $\underline{y}_0$ in column 0 and rows 0 to $(Q_m \cdot N_L - 1)$ and skipping the matrix entries that are already occupied:

$$\begin{bmatrix} \underline{y}_0 & \underline{y}_1 & \underline{y}_2 & \cdots & \underline{y}_{C_{mux}-1} \\ \underline{y}_{C_{mux}} & \underline{y}_{C_{mux}+1} & \underline{y}_{C_{mux}+2} & \cdots & \underline{y}_{2C_{mux}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \underline{y}_{(R'_{mux}-1)\times C_{mux}} & \underline{y}_{(R'_{mux}-1)\times C_{mux}+1} & \underline{y}_{(R'_{mux}-1)\times C_{mux}+2} & \cdots & \underline{y}_{(R'_{mux}\times C_{mux}-1)} \end{bmatrix}$$

The pseudocode is as follows:

Set i, k to 0.

while k < H',

if $\underline{y}_i$ is not assigned to RI symbols

$\underline{y}_i = \underline{g}_k$

k = k + 1

end if

i = i+1

end while

(5) If HARQ-ACK information is transmitted in this subframe, the vector sequence $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, ..., \underline{q}_{Q'_{ACK}-1}^{ACK}$ is written onto the columns indicated by Table 5.2.2.8-2, and by sets of $(Q_m \cdot N_L)$ rows starting from the last row and moving upwards according to the following pseudo-code. Note that this operation overwrites some of the channel interleaver entries obtained in step (4).

Set i, j to 0.

Set r to $R'_{mux} - 1$

while i < Q'_{ACK}

$c_{ACK} = \text{ColumnSet}(j)$

$\underline{y}_{r \times C_{mux} + c_{ACK}} = \underline{q}_i^{ACK}$

$i = i + 1$

$r = R'_{mux} - 1 - \lfloor i/4 \rfloor$

$j = (j+3) \bmod 4$

end while,

where ColumnSet is given in Table 5.2.2.8-2 and indexed left to right from 0 to 3.

(6) The output of the block interleaver is the bit sequence read out column by column from the $(R_{mux} \times C_{mux})$ matrix. The bits after channel interleaving are denoted by $h_0, h_1, h_2, ..., h_{H+N_L \cdot Q_{RI}-1}$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto.

Table 5.2.2.8-1: Column set for Insertion of rank information for PUSCH not scheduled using DCI Format 0A, 4A, 0B and 4B

CP configuration	Column Set
Normal	{1, 4, 7, 10}
Extended	{0, 3, 5, 8}

Table 5.2.2.8-1A: Column set for Insertion of rank information for PUSCH scheduled using DCI Format 0A, 4A, 0B and 4B

CP Configuration	PUSCH Starting Position	Column Set
Normal	At symbol 0	{1, 4, 7, 10}
	Within symbol 0 or at symbol 1	{0, 3 ,6, 9}

Table 5.2.2.8-2: Column set for Insertion of HARQ-ACK information

CP configuration	Column Set
Normal	{2, 3, 8, 9}
Extended	{1, 2, 6, 7}

The same channel interleaver procedures for RI are applied for CRI, using CRI instead of RI in the equations.

5.2.3 Uplink control information on PUCCH

Data arrives to the coding unit in the form of indicators for measurement indication, scheduling request and HARQ acknowledgement.

Three forms of channel coding are used as shown in Figure 5.2.3-1,

- one for HARQ-ACK and for combination of HARQ-ACK and periodic CSI transmitted on PUCCH format 3, including the cases with scheduling request,
- another for the channel quality information CQI/PMI transmitted on PUCCH format 2,
- and another for combination of CQI/PMI and HARQ-ACK transmitted on PUCCH format 2/2a/2b.

A fourth form of channel coding is used as shown in Figure 5.2.3-2, for HARQ-ACK and for combination of HARQ-ACK and periodic CSI transmitted on PUCCH format 4 or PUCCH format 5 including the cases with scheduling request, or for periodic CSI transmitted on PUCCH format 4 or PUCCH format 5 including the cases with scheduling request.