

CR-Form-v11

CHANGE REQUEST

36.212 **CR 0158** rev **-** Current version: **12.0.0**

For **HELP** on using this form: comprehensive instructions can be found at
<http://www.3gpp.org/Change-Requests>.

Proposed change affects: UICC apps ☐ ME ☒ Radio Access Network ☒ Core Network ☐

Title:	Introduction of Rel 12 features of TDD-FDD CA and eIMTA										
Source to WG:	Huawei										
Source to TSG:											
Work item code:	LTE_CA_TDD_FDD-Core, LTE_TDD_eIMTA	Date:	2014-06-02								
Category:	B Use <u>one</u> 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 .	Release:	Rel-12								
		Use <u>one</u> of the following releases:	Rel-4 (Release 4) Rel-5 (Release 5) Rel-6 (Release 6) Rel-7 (Release 7) Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) Rel-12 (Release 12) Rel-13 (Release 13)								
Reason for change:	Inclusion of Rel-12 features for TDD-FDD CA and eIMTA.										
Summary of change:	Support for TDD-FDD carrier aggregation and eIMTA. In addition, corrected typos in Table 5.2.2.6.2-2A and in Table 5.2.2.6.2-2B.										
Consequences if not approved:	TDD-FDD CA and eIMTA will be incomplete										
Clauses affected:	5.1.4.1.2, 5.2.2.6, 5.2.2.6.2, 5.2.2.6.5, 5.2.3.1, 5.3.3.1.1, 5.3.3.1.2, 5.3.3.1.3, 5.3.3.1.3A, 5.3.3.1.4, 5.3.3.1.4A, 5.3.3.1.5, 5.3.3.1.5A, 5.3.3.1.5B, 5.3.3.1.5C, 5.3.3.1.5D, 5.3.3.1.8										
Other specs affected: (show related CRs)	<table border="1"> <tr> <td>Y</td> <td>N</td> </tr> <tr> <td>X</td> <td></td> </tr> <tr> <td></td> <td></td> </tr> <tr> <td></td> <td></td> </tr> </table>	Y	N	X						Other core specifications Test specifications O&M Specifications	36.213
Y	N										
X											
Other comments:											

5.1.4.1.2 Bit collection, selection and transmission

The circular buffer of length $K_w = 3K_{\Pi}$ for the r -th coded block is generated as follows:

$$w_k = v_k^{(0)} \quad \text{for } k = 0, \dots, K_{\Pi} - 1$$

$$w_{K_{\Pi}+2k} = v_k^{(1)} \quad \text{for } k = 0, \dots, K_{\Pi} - 1$$

$$w_{K_{\Pi}+2k+1} = v_k^{(2)} \quad \text{for } k = 0, \dots, K_{\Pi} - 1$$

Denote the soft buffer size for the transport block by N_{IR} bits and the soft buffer size for the r -th code block by N_{cb} bits. The size N_{cb} is obtained as follows, where C is the number of code blocks computed in section 5.1.2:

$$\begin{aligned} - N_{cb} &= \min \left(\left\lfloor \frac{N_{IR}}{C} \right\rfloor, K_w \right) && \text{for DL-SCH and PCH transport channels} \\ - N_{cb} &= K_w && \text{for UL-SCH and MCH transport channels} \end{aligned}$$

where N_{IR} is equal to:

$$N_{IR} = \left\lfloor \frac{N_{soft}}{K_C \cdot K_{MIMO} \cdot \min(M_{DL_HARQ}, M_{limit})} \right\rfloor$$

where:

If the UE signals *ue-Category-v1020*, and is configured with transmission mode 9 or transmission mode 10 for the DL cell, N_{soft} is the total number of soft channel bits [4] according to the UE category indicated by *ue-Category-v1020* [6]. Otherwise, N_{soft} is the total number of soft channel bits [4] according to the UE category indicated by *ue-Category* (without suffix) [6].

If $N_{soft} = 35982720$,

$$K_C = 5,$$

elseif $N_{soft} = 3654144$ and the UE is capable of supporting no more than a maximum of two spatial layers for the DL cell,

$$K_C = 2$$

else

$$K_C = 1$$

End if.

K_{MIMO} is equal to 2 if the UE is configured to receive PDSCH transmissions based on transmission modes 3, 4, 8, 9 or 10 as defined in section 7.1 of [3], and is equal to 1 otherwise.

If the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, M_{DL_HARQ} is the maximum number of DL HARQ processes as defined in Table 7-1 in [3] for the DL-reference UL/DL configuration of the serving cell. Otherwise, M_{DL_HARQ} is the maximum number of DL HARQ processes as defined in section 7 of [3].

M_{limit} is a constant equal to 8.

Denoting by E the rate matching output sequence length for the r -th coded block, and rv_{idx} the redundancy version number for this transmission ($rv_{idx} = 0, 1, 2$ or 3), the rate matching output bit sequence is e_k , $k = 0, 1, \dots, E-1$.

Define by G the total number of bits available for the transmission of one transport block.

Set $G' = G / (N_L \cdot Q_m)$ where Q_m is equal to 2 for QPSK, 4 for 16QAM and 6 for 64QAM, and where

- For transmit diversity:
 - N_L is equal to 2,
- Otherwise:
 - N_L is equal to the number of layers a transport block is mapped onto

Set $\gamma = G' \bmod C$, where C is the number of code blocks computed in section 5.1.2.

if $r \leq C - \gamma - 1$

set $E = N_L \cdot Q_m \cdot \lfloor G' / C \rfloor$

else

set $E = N_L \cdot Q_m \cdot \lceil G' / C \rceil$

end if

Set $k_0 = R_{subblock}^{TC} \cdot \left(2 \cdot \left\lceil \frac{N_{cb}}{8R_{subblock}^{TC}} \right\rceil \cdot rv_{idx} + 2 \right)$, where $R_{subblock}^{TC}$ is the number of rows defined in section 5.1.4.1.1.

Set $k = 0$ and $j = 0$

while { $k < E$ }

if $w_{(k_0+j) \bmod N_{cb}} \neq \text{NULL}$ >

$e_k = w_{(k_0+j) \bmod N_{cb}}$

$k = k + 1$

end if

$j = j + 1$

end while

5.2.2.6 Channel coding of control information

Control data arrives at the coding unit in the form of channel quality information (CQI and/or PMI), HARQ-ACK and rank indication. Different coding rates for the control information are achieved by allocating different number of coded symbols for its transmission. When control data are transmitted in the PUSCH, the channel coding for HARQ-ACK, rank indication and channel quality information $o_0, o_1, o_2, \dots, o_{O-1}$ is done independently.

For the cases with TDD primary cell, the number of HARQ-ACK bits is determined as described in section 7.3 of [3].

When the UE transmits HARQ-ACK bits or rank indicator bits, it shall determine the number of coded modulation symbols per layer Q' for HARQ-ACK or rank indicator as follows.

For the case when only one transport block is transmitted in the PUSCH conveying the HARQ-ACK bits or rank indicator bits:

$$Q' = \min \left(\left\lceil \frac{O \cdot M_{sc}^{PUSCH-initial} \cdot N_{sym}^{PUSCH-initial} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C-1} K_r} \right\rceil, 4 \cdot M_{sc}^{PUSCH} \right)$$

where O is the number of HARQ-ACK bits or rank indicator bits, M_{sc}^{PUSCH} is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, expressed as a number of subcarriers in [2], and $N_{symb}^{PUSCH-initial}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the same transport block, respectively, given by $N_{symb}^{PUSCH-initial} = (2 \cdot (N_{symb}^{UL} - 1) - N_{SRS})$, where N_{SRS} is equal to 1 if UE transmits PUSCH and SRS in the same subframe for initial transmission, or if the PUSCH resource allocation for initial transmission even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or if the subframe for initial transmission is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or if the subframe for initial transmission is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs. Otherwise N_{SRS} is equal to 0. $M_{sc}^{PUSCH-initial}$, C , and K_r are obtained from the initial PDCCH or EPDCCH for the same transport block. If there is no initial PDCCH or EPDCCH with DCI format 0 for the same transport block, $M_{sc}^{PUSCH-initial}$, C , and K_r shall be determined from:

- the most recent semi-persistent scheduling assignment PDCCH or EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
- the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

For the case when two transport blocks are transmitted in the PUSCH conveying the HARQ-ACK bits or rank indicator bits:

$$Q' = \max \left[\min \left(Q'_{temp}, 4 \cdot M_{sc}^{PUSCH} \right), Q'_{min} \right] \text{ with}$$

$$Q'_{temp} = \left\lfloor \frac{O \cdot M_{sc}^{PUSCH-initial(1)} \cdot N_{symb}^{PUSCH-initial(1)} \cdot M_{sc}^{PUSCH-initial(2)} \cdot N_{symb}^{PUSCH-initial(2)} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C^{(1)}-1} K_r^{(1)} \cdot M_{sc}^{PUSCH-initial(2)} \cdot N_{symb}^{PUSCH-initial(2)} + \sum_{r=0}^{C^{(2)}-1} K_r^{(2)} \cdot M_{sc}^{PUSCH-initial(1)} \cdot N_{symb}^{PUSCH-initial(1)}} \right\rfloor$$

where O is the number of HARQ-ACK bits or rank indicator bits, $Q'_{min} = O$ if $O \leq 2$, $Q'_{min} = \lceil 2O / Q'_m \rceil$ if $3 \leq O \leq 11$ with $Q'_m = \min(Q_m^1, Q_m^2)$ where $Q_m^x, x = \{1, 2\}$ is the modulation order of transport block “x”, and $Q'_{min} = \lceil 2O_1 / Q'_m \rceil + \lceil 2O_2 / Q'_m \rceil$ if $O > 11$ with $O_1 = \lceil O / 2 \rceil$ and $O_2 = O - \lceil O / 2 \rceil$. $M_{sc}^{PUSCH-initial(x)}, x = \{1, 2\}$ are the scheduled bandwidths for PUSCH transmission in the initial sub-frame for the first and second transport block, respectively, expressed as a number of subcarriers in [2], and $N_{symb}^{PUSCH-initial(x)}, x = \{1, 2\}$ are the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the first and second transport block given by $N_{symb}^{PUSCH-initial(x)} = (2 \cdot (N_{symb}^{UL} - 1) - N_{SRS}^{(x)})$, $x = \{1, 2\}$, where $N_{SRS}^{(x)}, x = \{1, 2\}$ is equal to 1 if UE transmits PUSCH and SRS in the same subframe for initial transmission of transport block “x”, or if the PUSCH resource allocation for initial transmission of transport block “x” even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or if the subframe for initial transmission of transport block “x” is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or if the subframe for initial transmission of transport block “x” is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs. Otherwise $N_{SRS}^{(x)}, x = \{1, 2\}$ is equal to 0. $M_{sc}^{PUSCH-initial(x)}, x = \{1, 2\}$, $C^{(x)}, x = \{1, 2\}$, and $K_r^{(x)}, x = \{1, 2\}$ are obtained from the initial PDCCH or EPDCCH for the corresponding transport block.

For HARQ-ACK, $Q_{ACK} = Q_m \cdot Q'$ and $\beta_{offset}^{PUSCH} = \beta_{offset}^{HARQ-ACK}$, where Q_m is the modulation order of a given transport block, and $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH.

For rank indication, $Q_{RI} = Q_m \cdot Q'$ and $\beta_{offset}^{PUSCH} = \beta_{offset}^{RI}$, where Q_m is the modulation order of a given transport block, and β_{offset}^{RI} shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH, and on the uplink power control subframe set for the corresponding PUSCH when two uplink power control subframe sets are configured by higher layers for the cell.

For HARQ-ACK

- Each positive acknowledgement (ACK) is encoded as a binary ‘1’ and each negative acknowledgement (NACK) is encoded as a binary ‘0’
- If HARQ-ACK feedback consists of 1-bit of information, i.e., $[o_0^{ACK}]$, it is first encoded according to Table 5.2.2.6-1.
- If HARQ-ACK feedback consists of 2-bits of information, i.e., $[o_0^{ACK} o_1^{ACK}]$ with o_0^{ACK} corresponding to HARQ-ACK bit for codeword 0 and o_1^{ACK} corresponding to that for codeword 1, or if HARQ-ACK feedback consists of 2-bits of information as a result of the aggregation of HARQ-ACK bits corresponding to two DL cells with which the UE is configured by higher layers, or if HARQ-ACK feedback consists of 2-bits of information corresponding to two DL subframes for TDD, it is first encoded according to Table 5.2.2.6-2 where $o_2^{ACK} = (o_0^{ACK} + o_1^{ACK}) \bmod 2$.

Table 5.2.2.6-1: Encoding of 1-bit HARQ-ACK.

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK} y]$
4	$[o_0^{ACK} y x x]$
6	$[o_0^{ACK} y x x x x]$

Table 5.2.2.6-2: Encoding of 2-bit HARQ-ACK.

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK} o_1^{ACK} o_2^{ACK} o_0^{ACK} o_1^{ACK} o_2^{ACK}]$
4	$[o_0^{ACK} o_1^{ACK} x x o_2^{ACK} o_0^{ACK} x x o_1^{ACK} o_2^{ACK} x x]$
6	$[o_0^{ACK} o_1^{ACK} x x x x o_2^{ACK} o_0^{ACK} x x x x o_1^{ACK} o_2^{ACK} x x x x]$

- If HARQ-ACK feedback consists of $3 \leq O^{ACK} \leq 11$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, i.e., $o_0^{ACK} o_1^{ACK} \dots, o_{O^{ACK}-1}^{ACK}$, then a coded bit sequence $\tilde{q}_0^{ACK} \tilde{q}_1^{ACK} \dots, \tilde{q}_{31}^{ACK}$ is obtained by using the bit sequence $o_0^{ACK} o_1^{ACK} \dots, o_{O^{ACK}-1}^{ACK}$ as the input to the channel coding block described in section 5.2.2.6.4. In turn, the bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q^{ACK}-1}^{ACK}$ is obtained by the circular repetition of the bit sequence $\tilde{q}_0^{ACK} \tilde{q}_1^{ACK} \dots, \tilde{q}_{31}^{ACK}$ so that the total bit sequence length is equal to Q^{ACK} .
- If HARQ-ACK feedback consists of $11 < O^{ACK} \leq 20$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, i.e., $o_0^{ACK} o_1^{ACK} \dots, o_{O^{ACK}-1}^{ACK}$, then the coded bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q^{ACK}-1}^{ACK}$ is obtained by using the bit sequence $o_0^{ACK} o_1^{ACK} \dots, o_{O^{ACK}-1}^{ACK}$ as the input to the channel coding block described in section 5.2.2.6.5.

The “x” and “y” in Table 5.2.2.6-1 and 5.2.2.6-2 are placeholders for [2] to scramble the HARQ-ACK bits in a way that maximizes the Euclidean distance of the modulation symbols carrying HARQ-ACK information.

For FDD or TDD HARQ-ACK multiplexing or the aggregation of more than one DL cell including at least one cell using FDD and at least one cell using TDD when HARQ-ACK consists of one or two bits of information, the bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q^{ACK}-1}^{ACK}$ is obtained by concatenation of multiple encoded HARQ-ACK blocks where

Q_{ACK} is the total number of coded bits for all the encoded HARQ-ACK blocks. The last concatenation of the encoded HARQ-ACK block may be partial so that the total bit sequence length is equal to Q_{ACK} .

For FDD when HARQ ACK consists of 2 or more bits of information as a result of the aggregation of more than one DL cell, the bit sequence $o_0^{ACK} o_1^{ACK} \dots, o_{O_{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for the multiple DL cells according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c < N_{cells}^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$o_j^{ACK} =$ HARQ-ACK bit of this cell

$j = j + 1$

else

$o_j^{ACK} =$ HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$o_j^{ACK} =$ HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

end if

$c = c + 1$

end while

For the aggregation of more than one DL cell including a primary cell using FDD and at least one secondary cell using TDD, the bit sequence $o_0^{ACK} o_1^{ACK} \dots, o_{O_{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for one or multiple

DL cells. Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits in UL subframe n for the c -th serving cell. For a cell using TDD, the subframes are determined by the DL-reference UL/DL configuration if the UE is configured with higher layer parameter *eimta-HarqReferenceConfig*, and determined by the UL/DL configuration otherwise. For a cell using TDD, $B_c^{DL} = 1$ if subframe $n-4$ in the cell is a DL subframe or a special subframe with special subframe configurations 1/2/3/4/6/7/8/9 and normal downlink CP or a special subframe with special subframe configurations 1/2/3/5/6/7 and extended downlink CP, and $B_c^{DL} = 0$ otherwise. For a cell using FDD, $B_c^{DL} = 1$.

The bit sequence $o_0^{ACK} o_1^{ACK} \dots, o_{O_{ACK}-1}^{ACK}$ is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

if $B_c^{DL} = 1$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$o_j^{ACK} =$ HARQ-ACK bit of this cell

$j = j + 1$

else

$o_j^{ACK} =$ HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$o_j^{ACK} =$ HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

end if

end if

$c = c + 1$

end while

For the cases with TDD primary cell when HARQ-ACK is for the aggregation of one or more DL cells and the UE is configured with PUCCH Format 3 [3], the bit sequence $o_0^{ACK} o_1^{ACK} \dots o_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for the one or more DL cells configured by higher layers and the multiple subframes as defined in [3].

Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of downlink subframes for which the UE needs to feed back HARQ-ACK bits as defined in Section 7.3 of [3].

The number of HARQ-ACK bits for the UE to convey if it is configured with PUCCH Format 3 is computed as follows:

Set $k = 0$ – counter of HARQ-ACK bits

Set $c=0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

while $c < N_{cells}^{DL}$

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$k = k + 1$

else

$k = k + 2$

end if

$l = l + 1$

end while

$c = c + 1$

end while

If $k \leq 20$ when TDD is used in all the configured serving cell(s) of the UE, or if $k \leq 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$[\tilde{o}_j^{ACK}, \tilde{o}_{j+1}^{ACK}] = [o_{c,2l}^{ACK}, o_{c,2l+1}^{ACK}]$ HARQ-ACK bits of this cell as defined in Section 7.3 of [3]

$j = j + 2$

end if

$l = l + 1$

end while

$c = c + 1$

end while

If $k > 20$ when TDD is used in all the configured serving cell(s) of the UE, or if $k > 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell, spatial bundling is applied to all subframes in all cells and the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell as defined in Section 7.3 of [3]

$j = j + 1$

end if

$l = l + 1$

end while

$c = c + 1$

end while

For $o^{ACK} \leq 11$, the bit sequence $o_0^{ACK} o_1^{ACK} \dots, o_{O^{ACK}-1}^{ACK}$ is obtained by setting $o_i^{ACK} = \tilde{o}_i^{ACK}$.

For $11 < o^{ACK} \leq 20$, the bit sequence $o_0^{ACK} o_1^{ACK} \dots, o_{O^{ACK}-1}^{ACK}$ is obtained by setting $o_{i/2}^{ACK} = \tilde{o}_i^{ACK}$ if i is even and $o_{\lceil O^{ACK}/2 \rceil + (i-1)/2}^{ACK} = \tilde{o}_i^{ACK}$ if i is odd.

For the cases with TDD primary cell when HARQ-ACK is for the aggregation of two DL cells and the UE is configured with PUCCH format 1b with channel selection, the bit sequence $o_0^{ACK} o_1^{ACK} \dots, o_{O^{ACK}-1}^{ACK}$ is obtained as described in section 7.3 of [3].

For TDD HARQ-ACK bundling, a bit sequence $\tilde{q}_0^{ACK}, \tilde{q}_1^{ACK}, \tilde{q}_2^{ACK}, \dots, \tilde{q}_{Q_{ACK}-1}^{ACK}$ is obtained by concatenation of multiple encoded HARQ-ACK blocks where Q_{ACK} is the total number of coded bits for all the encoded HARQ-ACK blocks. The last concatenation of the encoded HARQ-ACK block may be partial so that the total bit sequence length is equal to Q_{ACK} . A scrambling sequence $[w_0^{ACK} w_1^{ACK} w_2^{ACK} w_3^{ACK}]$ is then selected from Table 5.2.2.6-A with index $i = (N_{bundled} - 1) \bmod 4$, where $N_{bundled}$ is determined as described in section 7.3 of [3]. The bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q_{ACK}-1}^{ACK}$ is then generated by setting $m = 1$ if HARQ-ACK consists of 1-bit and $m = 3$ if HARQ-ACK consists of 2-bits and then scrambling $\tilde{q}_0^{ACK}, \tilde{q}_1^{ACK}, \tilde{q}_2^{ACK}, \dots, \tilde{q}_{Q_{ACK}-1}^{ACK}$ as follows

Set i, k to 0

while $i < Q_{ACK}$

if $\tilde{q}_i^{ACK} = y$ // place-holder repetition bit

$$q_i^{ACK} = (\tilde{q}_{i-1}^{ACK} + w_{\lfloor k/m \rfloor}^{ACK}) \bmod 2$$

$$k = (k + 1) \bmod 4m$$

else

if $\tilde{q}_i^{ACK} = x$ // a place-holder bit

$$q_i^{ACK} = \tilde{q}_i^{ACK}$$

else // coded bit

$$q_i^{ACK} = (\tilde{q}_i^{ACK} + w_{\lfloor k/m \rfloor}^{ACK}) \bmod 2$$

$$k = (k + 1) \bmod 4m$$

end if

$i = i + 1$

end while

Table 5.2.2.6-A: Scrambling sequence selection for TDD HARQ-ACK bundling.

i	$[w_0^{ACK} w_1^{ACK} w_2^{ACK} w_3^{ACK}]$
0	[1 1 1 1]
1	[1 0 1 0]
2	[1 1 0 0]
3	[1 0 0 1]

When HARQ-ACK information is to be multiplexed with UL-SCH at a given PUSCH, the HARQ-ACK information is multiplexed in all layers of all transport blocks of that PUSCH. For a given transport block, the vector sequence output of the channel coding for HARQ-ACK information is denoted by $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \dots, \underline{q}_{Q'_{ACK}-1}^{ACK}$, where $\underline{q}_i^{ACK}$,

$i = 0, \dots, Q'_{ACK} - 1$ are column vectors of length $(Q_m \cdot N_L)$ and where $Q'_{ACK} = Q_{ACK} / Q_m$ is obtained as follows:

Set i, k to 0

while $i < Q_{ACK}$

$\hat{\underline{q}}_k^{ACK} = [\underline{q}_i^{ACK} \dots \underline{q}_{i+Q_m-1}^{ACK}]$ -- temporary row vector

$\underline{q}_k^{ACK} = [\hat{\underline{q}}_k^{ACK} \dots \hat{\underline{q}}_k^{ACK}]^T$ -- replicating the row vector $\hat{\underline{q}}_k^{ACK}$ N_L times and transposing into a column vector

$i = i + Q_m$

$k = k + 1$

end while

where N_L is the number of layers onto which the UL-SCH transport block is mapped.

For rank indication (RI) (RI only, joint report of RI and i1, and joint report of RI and PTI)

- The corresponding bit widths for RI feedback for PDSCH transmissions are given by Tables 5.2.2.6.1-2, 5.2.2.6.2-3, 5.2.2.6.3-3, 5.2.3.3.1-3, 5.2.3.3.1-3A, 5.2.3.3.2-4, and 5.2.3.3.2-4A, which are determined assuming the maximum number of layers as follows:
 - If the UE is configured with transmission mode 9, and the *supportedMIMO-CapabilityDL-r10* field is included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the configured number of CSI-RS ports and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
 - If the UE is configured with transmission mode 9, and the *supportedMIMO-CapabilityDL-r10* field is not included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the configured number of CSI-RS ports and *ue-Category* (without suffix).
 - If the UE is configured with transmission mode 10, and the *supportedMIMO-CapabilityDL-r10* field is included in the *UE-EUTRA-Capability*, the maximum number of layers for each CSI process is determined according to the minimum of the configured number of CSI-RS ports for that CSI process and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
 - If the UE is configured with transmission mode 10, and the *supportedMIMO-CapabilityDL-r10* field is not included in the *UE-EUTRA-Capability*, the maximum number of layers for each CSI process is determined according to the minimum of the configured number of CSI-RS ports for that CSI process and *ue-Category* (without suffix).
 - Otherwise the maximum number of layers is determined according to the minimum of the number of PBCH antenna ports and *ue-Category* (without suffix).
- If RI feedback consists of 1-bit of information, i.e., $[o_0^{RI}]$, it is first encoded according to Table 5.2.2.6-3. The $[o_0^{RI}]$ to RI mapping is given by Table 5.2.2.6-5.

- If RI feedback consists of 2-bits of information, i.e., $[o_0^{RI} \ o_1^{RI}]$ with o_0^{RI} corresponding to MSB of 2-bit input and o_1^{RI} corresponding to LSB, it is first encoded according to Table 5.2.2.6-4 where $o_2^{RI} = (o_0^{RI} + o_1^{RI}) \bmod 2$. The $[o_0^{RI} \ o_1^{RI}]$ to RI mapping is given by Table 5.2.2.6-6.

Table 5.2.2.6-3: Encoding of 1-bit RI.

Q_m	Encoded RI
2	$[o_0^{RI} \ y]$
4	$[o_0^{RI} \ y \ x \ x]$
6	$[o_0^{RI} \ y \ x \ x \ x \ x]$

Table 5.2.2.6-4: Encoding of 2-bit RI.

Q_m	Encoded RI
2	$[o_0^{RI} \ o_1^{RI} \ o_2^{RI} \ o_0^{RI} \ o_1^{RI} \ o_2^{RI}]$
4	$[o_0^{RI} \ o_1^{RI} \ x \ x \ o_2^{RI} \ o_0^{RI} \ x \ x \ o_1^{RI} \ o_2^{RI} \ x \ x]$
6	$[o_0^{RI} \ o_1^{RI} \ x \ x \ x \ x \ o_2^{RI} \ o_0^{RI} \ x \ x \ x \ x \ o_1^{RI} \ o_2^{RI} \ x \ x \ x \ x]$

Table 5.2.2.6-5: o_0^{RI} to RI mapping.

o_0^{RI}	RI
0	1
1	2

Table 5.2.2.6-6: o_0^{RI}, o_1^{RI} to RI mapping.

o_0^{RI}, o_1^{RI}	RI
0, 0	1
0, 1	2
1, 0	3
1, 1	4

Table 5.2.2.6-7: $o_0^{RI}, o_1^{RI}, o_2^{RI}$ to RI mapping.

$o_0^{RI}, o_1^{RI}, o_2^{RI}$	RI
0, 0, 0	1
0, 0, 1	2
0, 1, 0	3
0, 1, 1	4
1, 0, 0	5
1, 0, 1	6
1, 1, 0	7
1, 1, 1	8

- If RI feedback for a given DL cell consists of 3-bits of information, i.e., $[o_0^{RI} \ o_1^{RI} \ o_2^{RI}]$ with o_0^{RI} corresponding to MSB of 3-bit input and o_2^{RI} corresponding to LSB. The $[o_0^{RI} \ o_1^{RI} \ o_2^{RI}]$ to RI mapping is given by Table 5.2.2.6-7.

- If RI feedback consists of $3 \leq O^{RI} \leq 11$ bits of information, i.e., $[o_0^{RI} o_1^{RI} \dots, o_{O^{RI}-1}^{RI}]$, then a coded bit sequence $[\tilde{q}_0^{RI} \tilde{q}_1^{RI} \dots, \tilde{q}_{31}^{RI}]$ is obtained by using the bit sequence $[o_0^{RI} o_1^{RI} \dots, o_{O^{RI}-1}^{RI}]$ as the input to the channel coding block described in section 5.2.2.6.4.
- If RI feedback consists of $11 < O^{RI} \leq 15$ bits of information as a result of the aggregation of RI bits corresponding to multiple DL cells or multiple CSI processes, i.e., $[o_0^{RI} o_1^{RI} \dots, o_{O^{RI}-1}^{RI}]$, then the coded bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI} \dots, q_{Q_{RI}-1}^{RI}$ is obtained by using the bit sequence $[o_0^{RI} o_1^{RI} \dots, o_{O^{RI}-1}^{RI}]$ as the input to the channel coding block described in section 5.2.2.6.5.

The “x” and “y” in Table 5.2.2.6-3 and 5.2.2.6-4 are placeholders for [2] to scramble the RI bits in a way that maximizes the Euclidean distance of the modulation symbols carrying rank information.

For the case where RI feedback for more than one DL cell is to be reported, the RI report for each DL cell is concatenated prior to coding in increasing order of cell index.

For the case where RI feedback for more than one CSI process is to be reported, the RI reports are concatenated prior to coding first in increasing order of CSI process index for each DL cell and then in increasing order of cell index.

For the case where RI feedback consists of one or two bits of information the bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI} \dots, q_{Q_{RI}-1}^{RI}$ is obtained by concatenation of multiple encoded RI blocks where Q_{RI} is the total number of coded bits for all the encoded RI blocks. The last concatenation of the encoded RI block may be partial so that the total bit sequence length is equal to Q_{RI} .

For the case where RI feedback consists of $3 \leq O^{RI} \leq 11$ bits of information, the bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI} \dots, q_{Q_{RI}-1}^{RI}$ is obtained by the circular repetition of the bit sequence $\tilde{q}_0^{RI} \tilde{q}_1^{RI} \dots, \tilde{q}_{31}^{RI}$ so that the total bit sequence length is equal to Q_{RI} .

When rank information is to be multiplexed with UL-SCH at a given PUSCH, the rank information is multiplexed in all layers of all transport blocks of that PUSCH. For a given transport block, the vector sequence output of the channel coding for rank information is denoted by $\underline{q}_0^{RI}, \underline{q}_1^{RI} \dots, \underline{q}_{Q'_{RI}-1}^{RI}$, where $\underline{q}_i^{RI}$, $i = 0, \dots, Q'_{RI} - 1$ are column vectors of length $(Q_m \cdot N_L)$ and where $Q'_{RI} = Q_{RI} / Q_m$. The vector sequence is obtained as follows:

Set i, j, k to 0

while $i < Q_{RI}$

$\hat{\underline{q}}_k^{RI} = [q_i^{RI} \dots q_{i+Q_m-1}^{RI}]$ -- temporary row vector

$\underline{q}_k^{RI} = [\hat{\underline{q}}_k^{RI} \dots \hat{\underline{q}}_k^{RI}]^T$ -- replicating the row vector $\hat{\underline{q}}_k^{RI}$ N_L times and transposing into a column vector

$i = i + Q_m$

$k = k + 1$

end while

where N_L is the number of layers onto which the UL-SCH transport block is mapped.

For channel quality control information (CQI and/or PMI denoted as CQI/PMI)

When the UE transmits channel quality control information bits, it shall determine the number of modulation coded symbols per layer Q' for channel quality information as

$$Q' = \min \left(\left\lceil \frac{(O + L) \cdot M_{sc}^{PUSCH-initial(x)} \cdot N_{symb}^{PUSCH-initial(x)} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C^{(x)}-1} K_r^{(x)}} \right\rceil, M_{sc}^{PUSCH} \cdot N_{symb}^{PUSCH} - \frac{Q_{RI}^{(x)}}{Q_m^{(x)}} \right)$$

where O is the number of CQI/PMI bits, L is the number of CRC bits given by $L = \begin{cases} 0 & O \leq 11 \\ 8 & \text{otherwise} \end{cases}$,

$Q_{CQI} = Q_m^{(x)} \cdot Q'$ and $\beta_{offset}^{PUSCH} = \beta_{offset}^{CQI}$, where β_{offset}^{CQI} shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH, [and on the uplink power control subframe set for the corresponding PUSCH when two uplink power control subframe sets are configured by higher layers for the cell](#). If RI is not transmitted then $Q_{RI}^{(x)} = 0$.

The variable “ x ” in $K_r^{(x)}$ represents the transport block index corresponding to the highest I_{MCS} value indicated by the initial UL grant. In case the two transport blocks have the same I_{MCS} value in the corresponding initial UL grant, “ $x=1$ ”, which corresponds to the first transport block. $M_{sc}^{PUSCH-initial(x)}$, $C^{(x)}$, and $K_r^{(x)}$ are obtained from the initial PDCCH or EPDCCH for the same transport block. If there is no initial PDCCH or EPDCCH with DCI format 0 for the same transport block, $M_{sc}^{PUSCH-initial(x)}$, $C^{(x)}$, and $K_r^{(x)}$ shall be determined from:

- the most recent semi-persistent scheduling assignment PDCCH or EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
- the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

$N_{symb}^{PUSCH-initial(x)}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the same transport block.

For UL-SCH data information $G = N_L^{(x)} \cdot (N_{symb}^{PUSCH} \cdot M_{sc}^{PUSCH} \cdot Q_m^{(x)} - Q_{CQI} - Q_{RI}^{(x)})$, where $N_L^{(x)}$ is the number of layers the corresponding UL-SCH transport block is mapped onto, M_{sc}^{PUSCH} is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, and N_{symb}^{PUSCH} is the number of SC-FDMA symbols in the current PUSCH transmission sub-frame given by $N_{symb}^{PUSCH} = (2 \cdot (N_{symb}^{UL} - 1) - N_{SRS})$, where N_{SRS} is equal to 1 if UE transmits PUSCH and SRS in the same subframe for the current subframe, or if the PUSCH resource allocation for the current subframe even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or if the current subframe is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or if the current subframe is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs. Otherwise N_{SRS} is equal to 0.

In case of CQI/PMI report for more than one DL cell, $o_0, o_1, o_2, \dots, o_{O-1}$ is the result of concatenating the CQI/PMI report for each DL cell in increasing order of cell index. For the case where CQI/PMI feedback for more than one CSI process is to be reported, $o_0, o_1, o_2, \dots, o_{O-1}$ is the result of concatenating the CQI/PMI reports in increasing order of CSI process index for each DL cell and then in increasing order of cell index.

- If the payload size is less than or equal to 11 bits, the channel coding of the channel quality information is performed according to section 5.2.2.6.4 with input sequence $o_0, o_1, o_2, \dots, o_{O-1}$.
- For payload sizes greater than 11 bits, the CRC attachment, channel coding and rate matching of the channel quality information is performed according to sections 5.1.1, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $o_0, o_1, o_2, \dots, o_{O-1}$. The output bit sequence of the CRC

attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

The output sequence for the channel coding of channel quality information is denoted by $q_0, q_1, q_2, q_3, \dots, q_{N_L \cdot Q_{CQI} - 1}$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto.

5.2.2.6.2 Channel quality information formats for higher layer configured subband CQI reports

Table 5.2.2.6.2-1 shows the fields and the corresponding bit width for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port. N in Table 5.2.2.6.2-1 is defined in section 7.2 of [3].

Table 5.2.2.6.2-1: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port)

Field	Bit width
Wide-band CQI codeword	4
Subband differential CQI	$2N$

Table 5.2.2.6.2-2, Table 5.2.2.6.2-2A and Table 5.2.2.6.2-2B show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 4, transmission mode 5, transmission mode 6, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports. N in Table 5.2.2.6.2-2, Table 5.2.2.6.2-2A and Table 5.2.2.6.2-2B is defined in section 7.2 of [3].

Table 5.2.2.6.2-2: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 4, transmission mode 5, transmission mode 6, transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wide-band CQI codeword 1	0	4	0	4
Subband differential CQI codeword 1	0	$2N$	0	$2N$
Precoding matrix indicator	2	1	4	4

Table 5.2.2.6.2-2A: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports and transmission mode 10 configured with PMI/RI reporting with 8 antenna ports).

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4

Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	2	2
<u>Subband-Wideband</u> second PMI i2	4	4	4	3
Field	Bitwidth			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1	2	2	2	0
<u>Subband-Wideband</u> second PMI i2	0	0	0	0

Table 5.2.2.6.2-2B: Fields for channel quality information feedback for higher layer configured subband CQI reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	0	0
<u>Subband-Wideband</u> second PMI i2	4	4	4	4

Table 5.2.2.6.2-2C, Table 5.2.2.6.2-2D and Table 5.2.2.6.2-2E show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 4, transmission mode 6, transmission mode 8 configured with subband PMI/RI reporting, transmission mode 9 configured with subband PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 10 configured with subband PMI/RI reporting with 2/4/8 antenna ports. N in Table 5.2.2.6.2-2C, Table 5.2.2.6.2-2D and Table 5.2.2.6.2-2E is defined in section 7.2 of [3].

Table 5.2.2.6.2-2C: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports (transmission mode 4 and transmission mode 6 configured with subband PMI reporting, transmission mode 8 configured with subband PMI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 and transmission 10 configured with subband PMI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*).

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI codeword 0	4	4	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	$2N$
Wide-band CQI codeword 1	0	4	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	0	$2N$	$2N$	$2N$
Subband precoding matrix indicator	$2N$	N	$4N$	$4N$	$4N$	$4N$

Table 5.2.2.6.2-2D: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports with 8 antenna ports (transmission mode 9 configured with subband PMI reporting and transmission mode 10 configured with subband PMI reporting)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	2	2
Subband second PMI i2	$4N$	$4N$	$4N$	$3N$
Field	Bitwidth			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1	2	2	2	0
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2E: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with subband PMI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	0	0
Subband second PMI i2	$4N$	$4N$	$4N$	$4N$

Table 5.2.2.6.2-3 shows the fields and the corresponding bit width for the rank indication feedback for higher layer configured subband CQI reports for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports.

Table 5.2.2.6.2-3: Fields for rank indication feedback for higher layer configured subband CQI reports (transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8 antenna ports		
		Max 2 layers	Max 4 layers	Max 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

The channel quality bits in Table 5.2.2.6.2-1, Table 5.2.2.6.2-2, Table 5.2.2.6.2-2A, Table 5.2.2.6.2-2B, Table 5.2.2.6.2-2C, Table 5.2.2.6.2-2D, and Table 5.2.2.6.2-2E form the bit sequence $o_0, o_1, o_2, \dots, o_{O-1}$ 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 the PMI and subband differential CQI shall be in the increasing order of the subband index [3]. The first bit of each field corresponds to MSB and the last bit LSB. The RI bits sequence in Table 5.2.2.6.2-3 is encoded according to section 5.2.2.6.

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 $o_0^{ACK}, o_1^{ACK}, \dots, o_{O^{ACK}-1}^{ACK}$ where $11 < O^{ACK} \leq 20$ is the number of bits.

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

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

and

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

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

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

5.2.3.1 Channel coding for UCI HARQ-ACK

The HARQ-ACK bits are received from higher layers for each subframe of each cell. Each positive acknowledgement (ACK) is encoded as a binary '1' and each negative acknowledgement (NACK) is encoded as a binary '0'. For the case where PUCCH format 3 [2] is configured by higher layers and is used for transmission of the HARQ-ACK feedback information, the HARQ-ACK feedback consists of the concatenation of HARQ-ACK bits for each of the serving cells. For cells configured with transmission modes 1, 2, 5, 6 or 7 [3], i.e., single codeword transmission modes, 1 bit of HARQ-ACK information, a_k , is used for that cell. For cells configured with other transmission modes, 2 bits of HARQ-ACK information are used for those cells, i.e., a_k, a_{k+1} with a_k corresponding to HARQ-ACK bit for codeword 0 and a_{k+1} corresponding to that for codeword 1.

Define O^{ACK} as the number of HARQ-ACK feedback bits and $N_{A/N}^{PUCCHformat3}$ as the number of HARQ-ACK feedback bits including the possible concurrent transmission of scheduling request and/or periodic CSI when PUCCH format 3 is used for transmission of HARQ-ACK feedback (section 10.1 in [3]).

For FDD, the sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for different cells according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c < N_{cells}^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} =$ HARQ-ACK bit of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK} =$ HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK} =$ HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

end if

$c = c + 1$

end while

For the aggregation of more than one DL cell including a primary cell using FDD and at least one secondary cell using TDD, the sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for different cells. Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits in UL subframe n for the c -th serving cell. For a cell using TDD, the subframes are determined by the DL-reference UL/DL configuration if the UE is configured with higher layer parameter *eimta-HarqReferenceConfig*, and determined by the UL/DL configuration otherwise. For a cell using TDD, $B_c^{DL} = 1$ if subframe $n-4$ in the cell is a DL subframe or a special subframe with special subframe configurations 1/2/3/4/6/7/8/9 and normal downlink CP or a special subframe with special subframe configurations 1/2/3/5/6/7 and extended downlink CP, and $B_c^{DL} = 0$ otherwise. For a cell using FDD, $B_c^{DL} = 1$.

The sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

```

if  $B_c^{DL} = 1$ 
    if transmission mode configured in cell  $c \in \{1,2,5,6,7\}$  -- 1 bit HARQ-ACK feedback for this cell
         $\tilde{o}_j^{ACK} =$  HARQ-ACK bit of this cell
         $j = j + 1$ 
    else
         $\tilde{o}_j^{ACK} =$  HARQ-ACK bit corresponding to the first codeword of this cell
         $j = j + 1$ 
         $\tilde{o}_j^{ACK} =$  HARQ-ACK bit corresponding to the second codeword of this cell
         $j = j + 1$ 
    end if
end if
 $c = c + 1$ 
end while

```

For the cases with TDD primary cell, the sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O_{ACK}-1}^{ACK}$ is obtained from the HARQ-ACK bits for different cells and different subframes.

Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of downlink subframes for which the UE needs to feed back HARQ-ACK bits in cell c as defined in Section 7.3 of [3].

The number of HARQ-ACK bits k and the number of HARQ-ACK bits after spatial bundling k_b are computed as follows:

Set $k = 0$ – counter of HARQ-ACK bits

Set $k_b = 0$ – counter of HARQ-ACK bits after spatial bundling

Set $c = 0$ – cell index; lower indices correspond to lower RRC indices of corresponding cell

while $c < N_{cells}^{DL}$

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$k = k + 1$

$k_b = k_b + 1$

else

$k = k + 2$

$k_b = k_b + 1$

end if

$l = l+1$

end while

$c = c + 1$

end while

In case the transmission of HARQ-ACK feedback using PUCCH format 3 coincides with a sub-frame configured to the UE by higher layers for transmission of scheduling request, the number of scheduling request bit O^{SR} is 1; otherwise $O^{SR}=0$.

In case the transmission of HARQ-ACK feedback using PUCCH format 3 coincides with a sub-frame configured to the UE by higher layers for transmission of periodic CSI, O^{CSI} is the number of periodic CSI bit(s) for the CSI report as defined in section 7.2.2 [3]; otherwise $O^{CSI}=0$.

The number of HARQ-ACK feedback bits O^{ACK} is computed as follows:

Set $k_{\max} = 20$ when TDD is used in all the configured serving cell(s) of the UE and $k_{\max} = 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell.

If ~~$k \leq 20$~~ $k \leq k_{\max}$ and $O^{CSI} = 0$, or if $k + O^{CSI} + O^{SR} \leq 22$ and $O^{CSI} > 0$, or if $k_b + O^{CSI} + O^{SR} > 22$ and

~~$k \leq 20$~~ $k \leq k_{\max}$ then

- $O^{ACK} = k$

else,

- $O^{ACK} = k_b$.

If $O^{ACK} = k$, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$[\tilde{o}_j^{ACK}, \tilde{o}_{j+1}^{ACK}] = [o_{c,2l}^{ACK}, o_{c,2l+1}^{ACK}]$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 2$

end if

$l = l+1$

end while

$c = c + 1$

end while

If $O^{ACK} = k_b$, spatial bundling is applied to all subframes in all cells and the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell as defined in Section 7.3 of [3]

$j = j + 1$

end if

$l = l + 1$

end while

$c = c + 1$

end while

In case the transmission of HARQ-ACK feedback using PUCCH format 3 [2] coincides with a sub-frame configured to the UE by higher layers for transmission of scheduling request, the scheduling request bit (1 = positive SR; 0 = negative SR) is appended at the end of the sequence of concatenated HARQ-ACK bits.

In case the transmission of HARQ-ACK feedback using PUCCH format 3 [2] coincides with a sub-frame configured to the UE by higher layers for transmission of periodic CSI, and periodic CSI is not dropped as defined in section 7.3.2 and section 10.1.1 of [3], the periodic CSI bits for the CSI report as defined in section 7.2.2 [3] are appended at the end of the sequence of concatenated HARQ-ACK bits and scheduling request bit (if any). As with the transmission of the scheduling request, the procedure above is used with $N_{A/N}^{PUCCHformat3}$ including the number of periodic CSI bits and scheduling request bit (if any).

For $N_{A/N}^{PUCCHformat3} \leq 11$, the bit sequence $a_0, a_1, a_2, \dots, a_{N_{A/N}^{PUCCHformat3}-1}$ is obtained by setting $a_i = \tilde{o}_i^{ACK}$.

For $11 < N_{A/N}^{PUCCHformat3} \leq 22$, the bit sequence $a_0, a_1, a_2, \dots, a_{N_{A/N}^{PUCCHformat3}-1}$ is obtained by setting $a_{i/2} = \tilde{o}_i^{ACK}$ if i is even and $a_{\lceil N_{A/N}^{PUCCHformat3}/2 \rceil + (i-1)/2} = \tilde{o}_i^{ACK}$ if i is odd.

For $N_{A/N}^{PUCCHformat3} \leq 11$, the sequence of bits $a_0, a_1, a_2, \dots, a_{N_{A/N}^{PUCCHformat3}-1}$ is encoded as follows

$$\tilde{b}_i = \sum_{n=0}^{N_{A/N}^{\text{PUCCHformat } 3} - 1} (a_n \cdot M_{i,n}) \bmod 2$$

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

The output bit sequence $b_0, b_1, b_2, \dots, b_{B-1}$ is obtained by circular repetition of the sequence $\tilde{b}_0, \tilde{b}_1, \tilde{b}_2, \dots, \tilde{b}_{31}$

$$b_i = \tilde{b}_{(i \bmod 32)}$$

where $i = 0, 1, 2, \dots, B-1$ and where $B = 4 \cdot N_{\text{sc}}^{\text{RB}}$.

For $11 < N_{A/N}^{\text{PUCCHformat } 3} \leq 22$, the sequences of bits $a_0, a_1, a_2, \dots, a_{\lceil N_{A/N}^{\text{PUCCHformat } 3/2} \rceil - 1}$ and

$a_{\lceil N_{A/N}^{\text{PUCCHformat } 3/2} \rceil}, a_{\lceil N_{A/N}^{\text{PUCCHformat } 3/2} \rceil + 1}, a_{\lceil N_{A/N}^{\text{PUCCHformat } 3/2} \rceil + 2}, \dots, a_{N_{A/N}^{\text{PUCCHformat } 3} - 1}$ are encoded as follows

$$\tilde{b}_i = \sum_{n=0}^{\lceil N_{A/N}^{\text{PUCCHformat } 3/2} \rceil - 1} (a_n \cdot M_{i,n}) \bmod 2$$

and

$$\tilde{\tilde{b}}_i = \sum_{n=0}^{N_{A/N}^{\text{PUCCHformat } 3} - \lceil N_{A/N}^{\text{PUCCHformat } 3/2} \rceil - 1} \left(a_{\lceil N_{A/N}^{\text{PUCCHformat } 3/2} \rceil + n} \cdot M_{i,n} \right) \bmod 2$$

where $i = 0, 1, 2, \dots, 23$ and the basis sequences $M_{i,n}$ are defined in Table 5.2.2.6.4-1.

The output bit sequence $b_0, b_1, b_2, \dots, b_{B-1}$ where $B = 4 \cdot N_{\text{sc}}^{\text{RB}}$ is obtained by the alternate concatenation of the bit sequences $\tilde{b}_0, \tilde{b}_1, \tilde{b}_2, \dots, \tilde{b}_{23}$ and $\tilde{\tilde{b}}_0, \tilde{\tilde{b}}_1, \tilde{\tilde{b}}_2, \dots, \tilde{\tilde{b}}_{23}$ as follows

Set $i, j = 0$

while $i < 4 \cdot N_{\text{sc}}^{\text{RB}}$

$$b_i = \tilde{b}_j, b_{i+1} = \tilde{b}_{j+1}$$

$$b_{i+2} = \tilde{\tilde{b}}_j, b_{i+3} = \tilde{\tilde{b}}_{j+1}$$

$$i = i + 4$$

$$j = j + 2$$

end while

When PUCCH format 3 is not used for transmission of HARQ-ACK feedback, the HARQ-ACK bits are processed for transmission according to section 10.1 in [3].

5.3.3.1.1 Format 0

DCI format 0 is used for the scheduling of PUSCH in one UL cell.

The following information is transmitted by means of the DCI format 0:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].
- Flag for format0/format1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A

- Frequency hopping flag – 1 bit as defined in section 8.4 of [3]. This field is used as the MSB of the corresponding resource allocation field for resource allocation type 1.
 - Resource block assignment and hopping resource allocation – $\left\lceil \log_2 (N_{RB}^{UL} (N_{RB}^{UL} + 1) / 2) \right\rceil$ bits
 - For PUSCH hopping (resource allocation type 0 only):
 - N_{UL_hop} MSB bits are used to obtain the value of $\tilde{n}_{PRB}(i)$ as indicated in section 8.4 of [3]
 - $\left(\left\lceil \log_2 (N_{RB}^{UL} (N_{RB}^{UL} + 1) / 2) \right\rceil - N_{UL_hop} \right)$ bits provide the resource allocation of the first slot in the UL subframe
 - For non-hopping PUSCH with resource allocation type 0:
 - $\left(\left\lceil \log_2 (N_{RB}^{UL} (N_{RB}^{UL} + 1) / 2) \right\rceil \right)$ bits provide the resource allocation in the UL subframe as defined in section 8.1.1 of [3]
 - For non-hopping PUSCH with resource allocation type 1:
 - The concatenation of the frequency hopping flag field and the resource block assignment and hopping resource allocation field provides the resource allocation field in the UL subframe as defined in section 8.1.2 of [3]
 - Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3]
 - New data indicator – 1 bit
 - TPC command for scheduled PUSCH – 2 bits as defined in section 5.1.1.1 of [3]
 - Cyclic shift for DM RS and OCC index – 3 bits as defined in section 5.5.2.1.1 of [2]
 - UL index – 2 bits as defined in sections 5.1.1.1, 7.2.1, 8 and 8.4 of [3] (this field is present only for TDD operation with uplink-downlink configuration 0)
 - Downlink Assignment Index (DAI) – 2 bits as defined in section 7.3 of [3] (this field is present only for cases with TDD primary cell and either TDD operation with uplink-downlink configurations 1-6 or FDD operation)
 - CSI request – 1 or 2 bits as defined in section 7.2.1 of [3]. The 2-bit field applies to
 - UEs that are configured with more than one DL cell and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3],
 - UEs that are configured by higher layers with more than one CSI process and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];
 - UEs that are configured with two CSI measurement sets by higher layers with the parameter $csi-MeasSubframeSet$, and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];
- otherwise the 1-bit field applies
- SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PUSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in section 8.2 of [3]
 - Resource allocation type – 1 bit. This field is only present if $N_{RB}^{UL} \leq N_{RB}^{DL}$. The interpretation of this field is provided in section 8.1 of [3]

If the number of information bits in format 0 mapped onto a given search space is less than the payload size of format 1A for scheduling the same serving cell and mapped onto the same search space (including any padding bits appended to format 1A), zeros shall be appended to format 0 until the payload size equals that of format 1A.

5.3.3.1.2 Format 1

DCI format 1 is used for the scheduling of one PDSCH codeword in one cell.

The following information is transmitted by means of the DCI format 1:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].
- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]
If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

- For resource allocation type 0 as defined in section 7.1.6.1 of [3]:

- $\lceil N_{RB}^{DL} / P \rceil$ bits provide the resource allocation

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]:

- $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

- 1 bit indicates a shift of the resource allocation span

- $\left(\lceil N_{RB}^{DL} / P \rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section 7.1.6.1 of [3]

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- HARQ process number – 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)
- New data indicator – 1 bit
- Redundancy version – 2 bits
- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index ~~(this field is present TDD all the uplink–downlink configurations. If the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configuration of all serving cells is same, then this field only applies to serving cell with UL/DL configuration 1-6; if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then this field applies to a serving cell with DL reference UL/DL configuration 1-6 as defined in section 10.2 of [3]. This field is not present FDD—2 bits—number of bits as specified in Table 5.3.3.1.2-2.~~

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If the UE is not configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI and the number of information bits in format 1 is equal to that for format 0/1A, one bit of value zero shall be appended to format 1.

If the UE is configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI and the number of information bits in format 1 is equal to that for format 0/1A for scheduling the same serving cell and mapped onto the UE specific search space given by the C-RNTI as defined in [3], one bit of value zero shall be appended to format 1.

If the number of information bits in format 1 carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one or more zero bit(s) shall be appended to format 1 until the payload size of format 1 does not belong to one of the sizes in Table 5.3.3.1.2-1 and is not equal to that of format 0/1A mapped onto the same search space.

Table 5.3.3.1.2-1: Ambiguous Sizes of Information Bits.

{12, 14, 16, 20, 24, 26, 32, 40, 44, 56}

Table 5.3.3.1.2-2: Number of bits for Downlink Assignment Index.

Number of bits	
2	This field is present for FDD or TDD operation, for cases with TDD primary cell. If the UL/DL configuration of all TDD serving cells is same and the UE is not configured to decode PDCCH with CRC scrambled by <i>eimta-RNTI</i>, then this field only applies to serving cell with UL/DL configuration 1-6 If at least two TDD serving cells have different UL/DL configurations or the UE is configured to decode PDCCH with CRC scrambled by <i>eimta-RNTI</i>, then this field applies to a serving cell with DL-reference UL/DL configuration 1-6 as defined in section 10.2 of [3]
0	This field is not present for FDD or TDD operation, for cases with FDD primary cell.

5.3.3.1.3 Format 1A

DCI format 1A is used for the compact scheduling of one PDSCH codeword in one cell and random access procedure initiated by a PDCCH order. The DCI corresponding to a PDCCH order can be carried by PDCCH or EPDCCH.

The following information is transmitted by means of the DCI format 1A:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].
- Flag for format0/format1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A

Format 1A is used for random access procedure initiated by a PDCCH order only if format 1A CRC is scrambled with C-RNTI and all the remaining fields are set as follows:

- Localized/Distributed VRB assignment flag – 1 bit is set to ‘0’
- Resource block assignment – $\left\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \right\rceil$ bits, where all bits shall be set to 1
- Preamble Index – 6 bits
- PRACH Mask Index – 4 bits, [5]
- All the remaining bits in format 1A for compact scheduling assignment of one PDSCH codeword are set to zero

Otherwise,

- Localized/Distributed VRB assignment flag – 1 bit as defined in 7.1.6.3 of [3]
- Resource block assignment – $\left\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \right\rceil$ bits as defined in section 7.1.6.3 of [3]:

- For localized VRB:

$\left\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \right\rceil$ bits provide the resource allocation

- For distributed VRB:

- If $N_{RB}^{DL} < 50$ or if the format 1A CRC is scrambled by RA-RNTI, P-RNTI, or SI-RNTI

- $\left\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \right\rceil$ bits provide the resource allocation

- Else

- 1 bit, the MSB indicates the gap value, where value 0 indicates $N_{\text{gap}} = N_{\text{gap},1}$ and value 1 indicates $N_{\text{gap}} = N_{\text{gap},2}$

- $\left\lceil \log_2 (N_{\text{RB}}^{\text{DL}} (N_{\text{RB}}^{\text{DL}} + 1) / 2) \right\rceil - 1$ bits provide the resource allocation,

where N_{gap} is defined in [2].

- Modulation and coding scheme – 5bits as defined in section 7.1.7 of [3]

- HARQ process number – 3 bits (for cases with FDD primary cell) , 4 bits (for cases with TDD primary cell)

- New data indicator – 1 bit

- If the format 1A CRC is scrambled by RA-RNTI, P-RNTI, or SI-RNTI:

- If $N_{\text{RB}}^{\text{DL}} \geq 50$ and Localized/Distributed VRB assignment flag is set to 1

- the new data indicator bit indicates the gap value, where value 0 indicates $N_{\text{gap}} = N_{\text{gap},1}$ and value 1 indicates $N_{\text{gap}} = N_{\text{gap},2}$.

- Else the new data indicator bit is reserved.

- Else

- The new data indicator bit as defined in [5]

- Redundancy version – 2 bits

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- If the format 1A CRC is scrambled by RA-RNTI, P-RNTI, or SI-RNTI:

- The most significant bit of the TPC command is reserved.

- The least significant bit of the TPC command indicates column N_{PRB}^{1A} of the TBS table defined of [3].

- If least significant bit is 0 then $N_{\text{PRB}}^{1A} = 2$ else $N_{\text{PRB}}^{1A} = 3$.

- Else

- The two bits including the most significant bit indicates the TPC command

- Downlink Assignment Index ~~(this field is present in TDD for all the uplink-downlink configurations. If the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configuration of all serving cells is same, then this field only applies to serving cell with UL/DL configuration 1-6; if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then this field applies to a serving cell with DL reference UL/DL configuration 1-6 as defined in section 10.2 of [3]. This field is not present in FDD—2 bits—number of bits as specified in Table 5.3.3.1.2-2.~~

- SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PDSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in section 8.2 of [3]

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If the UE is not configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI, and the number of information bits in format 1A is less than that of format 0, zeros shall be appended to format 1A until the payload size equals that of format 0.

If the UE is configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI and the number of information bits in format 1A mapped onto a given search space is less than that of format 0 for scheduling the same serving cell and mapped onto the same search space, zeros shall be appended to format 1A until the payload size equals that of format 0, except when format 1A assigns downlink resource on a secondary cell without an uplink configuration associated with the secondary cell.

If the number of information bits in format 1A carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 1A.

When the format 1A CRC is scrambled with a RA-RNTI, P-RNTI, or SI-RNTI then the following fields among the fields above are reserved:

- HARQ process number
- Downlink Assignment Index (used for cases with TDD primary cell and either FDD operation or TDD operation, TDD only and is not present for cases with FDD primary cell and either FDD operation or TDD operation)

5.3.3.1.3A Format 1B

DCI format 1B is used for the compact scheduling of one PDSCH codeword in one cell with precoding information.

The following information is transmitted by means of the DCI format 1B:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Localized/Distributed VRB assignment flag – 1 bit as defined in section 7.1.6.3 of [3]
- Resource block assignment – $\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \rceil$ bits as defined in section 7.1.6.3 of [3]
 - For localized VRB:

$$\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \rceil$$
 bits provide the resource allocation
 - For distributed VRB:
 - For $N_{RB}^{DL} < 50$
 - $\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \rceil$ bits provide the resource allocation
 - For $N_{RB}^{DL} \geq 50$
 - 1 bit, the MSB indicates the gap value, where value 0 indicates $N_{gap} = N_{gap,1}$ and value 1 indicates $N_{gap} = N_{gap,2}$
 - $(\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \rceil - 1)$ bits provide the resource allocation
- Modulation and coding scheme – 5bits as defined in section 7.1.7 of [3]
- HARQ process number – 3 bits (for cases with FDD primary cell) , 4 bits (for cases with TDD primary cell)
- New data indicator – 1 bit
- Redundancy version – 2 bits
- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index ~~(this field is present in TDD for all the uplink – downlink configurations . If the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configuration of all serving cells is same, then this field only applies to serving cell with UL/DL configuration 1-6; if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then this field applies to a serving cell with DL reference UL/DL configuration 1-6 as defined in section 10.2 of [3]. This field is not present in FDD – 2 bits – number of bits as specified in Table 5.3.3.1.2-2.~~

- TPMI information for precoding – number of bits as specified in Table 5.3.3.1.3A-1

TPMI information indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2] corresponding to the single-layer transmission.

- PMI confirmation for precoding – 1 bit as specified in Table 5.3.3.1.3A-2
- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If PMI confirmation indicates that the eNodeB has applied precoding according to PMI(s) reported by the UE, the precoding for the corresponding RB(s) in subframe n is according to the latest PMI(s) in an aperiodic CSI reported on or before subframe $n-4$.

Table 5.3.3.1.3A-1: Number of bits for TPMI information.

Number of antenna ports at eNodeB	Number of bits
2	2
4	4

Table 5.3.3.1.3A-2: Content of PMI confirmation.

Bit field mapped to index	Message
0	Precoding according to the indicated TPMI in the TPMI information field
1	Precoding using the precoder(s) according to PMI(s) indicated in the latest aperiodic CSI report. For aperiodic CSI mode 2-2: - Precoding of scheduled resource blocks belonging to the reported preferred M subband(s), use precoder(s) according to the preferred M subband PMI(s) indicated in the latest aperiodic CSI report; - Precoding of scheduled resource blocks not belonging to the reported preferred M subband(s), precoding using a precoder according to the wideband PMI indicated in the latest aperiodic CSI report.

If the number of information bits in format 1B is equal to that for format 0/1A for scheduling the same serving cell and mapped onto the UE specific search space given by the C-RNTI as defined in [3], one bit of value zero shall be appended to format 1B.

If the number of information bits in format 1B carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one or more zero bit(s) shall be appended to format 1B until the payload size of format 1B does not belong to one of the sizes in Table 5.3.3.1.2-1 and is not equal to that of format 0/1A mapped onto the same search space.

5.3.3.1.4 Format 1C

DCI format 1C is used for very compact scheduling of one PDSCH codeword, ~~and~~ notifying MCCH change [6], and reconfiguring TDD.

The following information is transmitted by means of the DCI format 1C:

If the format 1C is used for very compact scheduling of one PDSCH codeword

- 1 bit indicates the gap value, where value 0 indicates $N_{\text{gap}} = N_{\text{gap},1}$ and value 1 indicates $N_{\text{gap}} = N_{\text{gap},2}$
- For $N_{\text{RB}}^{\text{DL}} < 50$, there is no bit for gap indication
- Resource block assignment – $\left\lceil \log_2 \left(\left\lfloor N_{\text{VRB,gap1}}^{\text{DL}} / N_{\text{RB}}^{\text{step}} \right\rfloor \cdot \left(\left\lfloor N_{\text{VRB,gap1}}^{\text{DL}} / N_{\text{RB}}^{\text{step}} \right\rfloor + 1 \right) / 2 \right) \right\rceil$ bits as defined in 7.1.6.3 of [3] where $N_{\text{VRB,gap1}}^{\text{DL}}$ is defined in [2] and $N_{\text{RB}}^{\text{step}}$ is defined in [3]
- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

Else if the format 1C is used for notifying MCCH change

- Information for MCCH change notification – 8 bits as defined in section 5.8.1.3 of [6]
- Reserved information bits are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

Else

- UL/DL configuration indication:

UL/DL configuration number 1, UL/DL configuration number 2,..., UL/DL configuration number I

Where each UL/DL configuration is 3 bits, $I = \left\lfloor \frac{L_{\text{format 1c}}}{3} \right\rfloor$, $L_{\text{format c}}$ is equal to the payload size of format 1C used for very compact scheduling of one PDSCH codeword. The parameter *eimta-ReConfigIndex* provided by higher layers determines the index to the UL/DL configuration indication for a serving cell.

- Zeros are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

5.3.3.1.4A Format 1D

DCI format 1D is used for the compact scheduling of one PDSCH codeword in one cell with precoding and power offset information.

The following information is transmitted by means of the DCI format 1D:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Localized/Distributed VRB assignment flag – 1 bit as defined in section 7.1.6.3 of [3]
- Resource block assignment – $\left\lceil \log_2 (N_{\text{RB}}^{\text{DL}} (N_{\text{RB}}^{\text{DL}} + 1) / 2) \right\rceil$ bits as defined in section 7.1.6.3 of [3]:
 - For localized VRB:

$$\left\lceil \log_2 (N_{\text{RB}}^{\text{DL}} (N_{\text{RB}}^{\text{DL}} + 1) / 2) \right\rceil$$
 bits provide the resource allocation
 - For distributed VRB:
 - For $N_{\text{RB}}^{\text{DL}} < 50$

- $\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \rceil$ bits provide the resource allocation
- For $N_{RB}^{DL} \geq 50$
 - 1 bit, the MSB indicates the gap value, where value 0 indicates $N_{gap} = N_{gap,1}$ and value 1 indicates $N_{gap} = N_{gap,2}$
 - $(\lceil \log_2 (N_{RB}^{DL} (N_{RB}^{DL} + 1) / 2) \rceil - 1)$ bits provide the resource allocation
- Modulation and coding scheme – 5bits as defined in section 7.1.7 of [3]
- HARQ process number – 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)
- New data indicator – 1 bit
- Redundancy version – 2 bits
- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]
- Downlink Assignment Index (~~this field is present in TDD for all the uplink-downlink configurations. If the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configuration of all serving cells is same, then this field only applies to serving cell with UL/DL configuration 1-6; if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then this field applies to a serving cell with DL reference UL/DL configuration 1-6 as defined in section 10.2 of [3]. This field is not present in FDD— 2 bits— number of bits as specified in Table 5.3.3.1.2-2.~~)
- TPMI information for precoding – number of bits as specified in Table 5.3.3.1.4A-1

TPMI information indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2] corresponding to the single-layer transmission.
- Downlink power offset – 1 bit as defined in section 7.1.5 of [3]
- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

Table 5.3.3.1.4A-1: Number of bits for TPMI information.

Number of antenna ports at eNodeB	Number of bits
2	2
4	4

If the number of information bits in format 1D is equal to that for format 0/1A for scheduling the same serving cell and mapped onto the UE specific search space given by the C-RNTI as defined in [3], one bit of value zero shall be appended to format 1D.

If the number of information bits in format 1D carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one or more zero bit(s) shall be appended to format 1D until the payload size of format 1D does not belong to one of the sizes in Table 5.3.3.1.2-1 and is not equal to that of format 0/1A mapped onto the same search space.

5.3.3.1.5 Format 2

The following information is transmitted by means of the DCI format 2:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

- For resource allocation type 0 defined in section 7.1.6.1 of [3]:

- $\lceil N_{RB}^{DL} / P \rceil$ bits provide the resource allocation

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]:

- $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

- 1 bit indicates a shift of the resource allocation span

- $\left(\lceil N_{RB}^{DL} / P \rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section 7.1.6.1 of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index ~~(this field is present in TDD for all the uplink–downlink configurations. If the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configuration of all serving cells is same, then this field only applies to serving cell with UL/DL configuration 1-6; if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then this field applies to a serving cell with DL reference UL/DL configuration 1-6 as defined in section 10.2 of [3]. This field is not present in FDD— 2 bits— number of bits as specified in Table 5.3.3.1.2-2.~~

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Transport block to codeword swap flag – 1 bit

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- Precoding information – number of bits as specified in Table 5.3.3.1.5-3

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-1.

In case one of the transport blocks is disabled as specified in section 7.1.7.2 of [3], the transport block to codeword swap flag is reserved and the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2.

Table 5.3.3.1.5-1: Transport block to codeword mapping (two transport blocks enabled).

transport block to codeword swap flag value	codeword 0 (enabled)	codeword 1 (enabled)
0	transport block 1	transport block 2
1	transport block 2	transport block 1

Table 5.3.3.1.5-2: Transport block to codeword mapping (one transport block enabled).

transport block 1	transport block 2	codeword 0 (enabled)	codeword 1 (disabled)
enabled	disabled	transport block 1	-
disabled	enabled	transport block 2	-

The interpretation of the precoding information field depends on the number of enabled codewords according to Table 5.3.3.1.5-4 and Table 5.3.3.1.5-5. Note that TPMI indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2]. For a single enabled codeword, indices 18 to 34 inclusive in Table 5.3.3.1.5-5 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers with closed-loop spatial multiplexing.

If the number of information bits in format 2 carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2.

Some entries in Table 5.3.3.1.5-4 and Table 5.3.3.1.5-5 are used for indicating that the eNodeB has applied precoding according to PMI(s) reported by the UE. In these cases the precoding for the corresponding RB(s) in subframe n is according to the latest PMI(s) in an aperiodic CSI reported on or before subframe $n-4$. For aperiodic CSI mode 2-2: Precoding of scheduled resource blocks belonging to the reported preferred M subband(s) use precoder(s) according to the preferred M subband PMI indicated by the latest aperiodic CSI report; Precoding of scheduled resource blocks not belonging to the reported preferred M subband(s) use a precoder according to the wideband PMI indicated by the latest aperiodic CSI report.

Table 5.3.3.1.5-3: Number of bits for precoding information.

Number of antenna ports at eNodeB	Number of bits for precoding information
2	3
4	6

Table 5.3.3.1.5-4: Content of precoding information field for 2 antenna ports.

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	2 layers: Transmit diversity	0	2 layers: Precoding corresponding to precoder matrix $\frac{1}{2} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$
1	1 layer: Precoding corresponding to precoding vector $[1 \ 1]^T / \sqrt{2}$	1	2 layers: Precoding corresponding to precoder matrix $\frac{1}{2} \begin{bmatrix} 1 & 1 \\ j & -j \end{bmatrix}$
2	1 layer: Precoding corresponding to precoder vector $[1 \ -1]^T / \sqrt{2}$	2	2 layers: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s)
3	1 layer: Precoding corresponding to precoder vector $[1 \ j]^T / \sqrt{2}$	3	reserved
4	1 layer: Precoding corresponding to precoder vector $[1 \ -j]^T / \sqrt{2}$	4	reserved
5	1 layer: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s), if RI=2 was reported, using 1 st column multiplied by $\sqrt{2}$ of all precoders implied by the reported PMI(s)	5	reserved
6	1 layer: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s), if RI=2 was reported, using 2 nd column multiplied by $\sqrt{2}$ of all precoders implied by the reported PMI(s)	6	reserved
7	reserved	7	reserved

Table 5.3.3.1.5-5: Content of precoding information field for 4 antenna ports.

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	4 layers: Transmit diversity	0	2 layers: TPMI=0
1	1 layer: TPMI=0	1	2 layers: TPMI=1
2	1 layer: TPMI=1	⋮	⋮
⋮	⋮	15	2 layers: TPMI=15
16	1 layer: TPMI=15	16	2 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)
17	1 layer: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)	17	3 layers: TPMI=0
18	2 layers: TPMI=0	18	3 layers: TPMI=1
19	2 layers: TPMI=1	⋮	⋮
⋮	⋮	32	3 layers: TPMI=15
33	2 layers: TPMI=15	33	3 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)
34	2 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)	34	4 layers: TPMI=0
35 – 63	reserved	35	4 layers: TPMI=1
		⋮	⋮
		49	4 layers: TPMI=15
		50	4 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)
		51 – 63	Reserved

5.3.3.1.5A Format 2A

The following information is transmitted by means of the DCI format 2A:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

- For resource allocation type 0 as defined in section 7.1.6.1 of [3]

- $\lceil N_{RB}^{DL} / P \rceil$ bits provide the resource allocation

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]

- $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

- 1 bit indicates a shift of the resource allocation span

- $(\lceil N_{RB}^{DL} / P \rceil - \lceil \log_2(P) \rceil - 1)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section 7.1.6.1 of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index ~~(this field is present in TDD for all the uplink–downlink configurations. If the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configuration of all serving cells is same, then this field only applies to serving cell with UL/DL configuration 1-6; if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then this field applies to a serving cell with DL reference UL/DL configuration 1-6 as defined in section 10.2 of [3]. This field is not present in FDD—2 bits—number of bits as specified in Table 5.3.3.1.2-2.~~

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Transport block to codeword swap flag – 1 bit

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- Precoding information – number of bits as specified in Table 5.3.3.1.5A-1

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-1.

In case one of the transport blocks is disabled, the transport block to codeword swap flag is reserved and the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2.

The precoding information field is defined according to Table 5.3.3.1.5A-2. For a single enabled codeword, index 1 in Table 5.3.3.1.5A-2 is only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers with large delay CDD.

For transmission with 2 antenna ports, the precoding information field is not present. The number of transmission layers is equal to 2 if both codewords are enabled; transmit diversity is used if codeword 0 is enabled while codeword 1 is disabled.

If the number of information bits in format 2A carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2A.

Table 5.3.3.1.5A-1: Number of bits for precoding information.

Number of antenna ports at eNodeB	Number of bits for precoding information
2	0
4	2

Table 5.3.3.1.5A-2: Content of precoding information field for 4 antenna ports.

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	4 layers: Transmit diversity	0	2 layers: precoder cycling with large delay CDD
1	2 layers: precoder cycling with large delay CDD	1	3 layers: precoder cycling with large delay CDD
2	reserved	2	4 layers: precoder cycling with large delay CDD
3	reserved	3	reserved

5.3.3.1.5B Format 2B

The following information is transmitted by means of the DCI format 2B:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

- For resource allocation type 0 as defined in section 7.1.6.1 of [3]

- $\lceil N_{RB}^{DL} / P \rceil$ bits provide the resource allocation

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]

- $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

- 1 bit indicates a shift of the resource allocation span

- $\left\lceil N_{RB}^{DL} / P \right\rceil - \lceil \log_2(P) \rceil - 1$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section [7.1.6.1] of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]
- Downlink Assignment Index ~~(this field is present in TDD for all the uplink–downlink configurations. If the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configuration of all serving cells is same, then this field only applies to serving cell with UL/DL configuration 1-6; if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then this field applies to a serving cell with DL reference UL/DL configuration 1-6 as defined in section 10.2 of [3]. This field is not present in FDD— 2 bits— number of bits as specified in Table 5.3.3.1.2-2.~~
- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)
- Scrambling identity– 1 bit as defined in section 6.10.3.1 of [2]
- SRS request – [0-1] bit. This field can only be present for TDD and if present is defined in section 8.2 of [3]

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- New data indicator – 1 bit
- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- New data indicator – 1 bit
- Redundancy version – 2 bits
- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled, the number of layers equals two; transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1. Antenna ports 7 and 8 are used for spatial multiplexing.

In case one of the transport blocks is disabled, the number of layers equals one; the transport block to codeword mapping is specified according to Table 5.3.3.1.5B-2; and the antenna port for single-antenna port transmission is according to Table 5.3.3.1.5B-1.

Table 5.3.3.1.5B-1: Antenna port for single-antenna port transmission (one transport block disabled).

New data indicator of the disabled transport block	Antenna port
0	7
1	8

If the number of information bits in format 2B carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2B.

5.3.3.1.5C Format 2C

The following information is transmitted by means of the DCI format 2C:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

- For resource allocation type 0 as defined in section 7.1.6.1 of [3]

- $\lceil N_{RB}^{DL} / P \rceil$ bits provide the resource allocation

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]

- $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

- 1 bit indicates a shift of the resource allocation span

- $(\lceil N_{RB}^{DL} / P \rceil - \lceil \log_2(P) \rceil - 1)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section [7.1.6.1] of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index ~~(this field is present in TDD for all the uplink–downlink configurations. If the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configuration of all serving cells is same, then this field only applies to serving cell with UL/DL configuration 1-6; if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then this field applies to a serving cell with DL reference UL/DL configuration 1-6 as defined in section 10.2 of [3]. This field is not present in FDD—2 bits—number of bits as specified in Table 5.3.3.1.2-2.~~

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Antenna port(s), scrambling identity and number of layers – 3 bits as specified in Table 5.3.3.1.5C-1 where n_{SCID} is the scrambling identity for antenna ports 7 and 8 defined in section 6.10.3.1 of [2]

- SRS request – [0-1] bit. This field can only be present for TDD and if present is defined in section 8.2 of [3]

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- New data indicator – 1 bit
- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- New data indicator – 1 bit
- Redundancy version – 2 bits

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled; transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1.

In case one of the transport blocks is disabled; the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For the single enabled codeword, Value = 4, 5, 6 in Table 5.3.3.1.5C-1 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two, three or four layers, respectively.

If the number of information bits in format 2C carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2C.

Table 5.3.3.1.5C-1: Antenna port(s), scrambling identity and number of layers indication

One Codeword: Codeword 0 enabled, Codeword 1 disabled		Two Codewords: Codeword 0 enabled, Codeword 1 enabled	
Value	Message	Value	Message
0	1 layer, port 7, $n_{SCID}=0$	0	2 layers, ports 7-8, $n_{SCID}=0$
1	1 layer, port 7, $n_{SCID}=1$	1	2 layers, ports 7-8, $n_{SCID}=1$
2	1 layer, port 8, $n_{SCID}=0$	2	3 layers, ports 7-9
3	1 layer, port 8, $n_{SCID}=1$	3	4 layers, ports 7-10
4	2 layers, ports 7-8	4	5 layers, ports 7-11
5	3 layers, ports 7-9	5	6 layers, ports 7-12
6	4 layers, ports 7-10	6	7 layers, ports 7-13
7	Reserved	7	8 layers, ports 7-14

5.3.3.1.5D Format 2D

The following information is transmitted by means of the DCI format 2D:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.
- Resource block assignment:
 - For resource allocation type 0 as defined in section 7.1.6.1 of [3]
 - $\lceil N_{RB}^{DL} / P \rceil$ bits provide the resource allocation
 - For resource allocation type 1 as defined in section 7.1.6.2 of [3]
 - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset
 - 1 bit indicates a shift of the resource allocation span
 - $\left(\lceil N_{RB}^{DL} / P \rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section [7.1.6.1] of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index ~~(this field is present in TDD for all the uplink-downlink configurations. If the UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configuration of all serving cells is same, then this field only applies to serving cell with UL/DL configuration 1-6; if the UE is configured with more than one serving cell and if at least two serving cells have different~~

~~UL/DL configurations, then this field applies to a serving cell with DL reference UL/DL configuration 1-6 as defined in section 10.2 of [3]. This field is not present in FDD—2 bits—number of bits as specified in Table 5.3.3.1.2-2.~~

- HARQ process number - 3 bits (~~for cases with FDD primary cell-~~), 4 bits (~~for cases with TDD primary cell~~)
- Antenna port(s), scrambling identity and number of layers – 3 bits as specified in Table 5.3.3.1.5C-1 where n_{SCID} is the scrambling identity for antenna ports 7 and 8 defined in section 6.10.3.1 of [2]
- SRS request – [0-1] bit. This field can only be present for TDD and if present is defined in section 8.2 of [3]

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- New data indicator – 1 bit
- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]
- New data indicator – 1 bit
- Redundancy version – 2 bits
- PDSCH RE Mapping and Quasi-Co-Location Indicator – 2 bits as defined in sections 7.1.9 and 7.1.10 of [3]
- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled; transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1.

In case one of the transport blocks is disabled; the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For the single enabled codeword, Value = 4, 5, 6 in Table 5.3.3.1.5C-1 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two, three or four layers, respectively.

If the number of information bits in format 2D carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2D.

5.3.3.1.8 Format 4

DCI format 4 is used for the scheduling of PUSCH in one UL cell with multi-antenna port transmission mode,

The following information is transmitted by means of the DCI format 4:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Resource block assignment - $\max \left(\left\lceil \log_2 (N_{RB}^{UL} (N_{RB}^{UL} + 1) / 2) \right\rceil, \left\lceil \log_2 \left(\left\lceil \frac{N_{RB}^{UL}}{4} / P + 1 \right\rceil \right) \right\rceil \right)$ bits, where P is the UL RBG size as defined in section 8.1.2 of [3]
- For resource allocation type 0:

- The $\left\lceil \log_2(N_{RB}^{UL}(N_{RB}^{UL}+1)/2) \right\rceil$ LSBs provide the resource allocation in the UL subframe as defined in section 8.1.1 of [3]
- For resource allocation type 1:
 - The $\left\lceil \log_2\left(\left\lceil \frac{N_{RB}^{UL}}{P} + 1 \right\rceil\right) \right\rceil$ LSBs provide the resource allocation in the UL subframe as defined in section 8.1.2 of [3]
- TPC command for scheduled PUSCH – 2 bits as defined in section 5.1.1.1 of [3]
- Cyclic shift for DM RS and OCC index – 3 bits as defined in section 5.5.2.1.1 of [2]
- UL index – 2 bits as defined in sections 5.1.1.1, 7.2.1, 8 and 8.4 of [3] (this field is present only for TDD operation with uplink-downlink configuration 0)
- Downlink Assignment Index (DAI) – 2 bits as defined in section 7.3 of [3] (this field is present only for cases with TDD primary cell and either TDD operation with uplink-downlink configurations 1-6 or FDD operation)
- CSI request – 1 or 2 bits as defined in section 7.2.1 of [3]. The 2-bit field applies to
 - UEs that are configured with more than one DL cell,
 - UEs that are configured by higher layers with more than one CSI process;
 - UEs that are configured with two CSI measurement sets by higher layers with the parameter *csi-MeasSubframeSet*, and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];

otherwise the 1-bit field applies

- SRS request – 2 bits as defined in section 8.2 of [3]
- Resource allocation type – 1 bit as defined in section 8.1 of [3]

In addition, for transport block 1:

- Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3]
- New data indicator – 1 bit

In addition, for transport block 2:

- Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3]
- New data indicator – 1 bit

Precoding information and number of layers: number of bits as specified in Table 5.3.3.1.8-1. Bit field as shown in Table 5.3.3.1.8-2 and Table 5.3.3.1.8-3. Note that TPMI for 2 antenna ports indicates which codebook index is to be used in Table 5.3.3A.2-1 of [2], and TPMI for 4 antenna ports indicates which codebook index is to be used in Table 5.3.3A.2-2, Table 5.3.3A.2-3, Table 5.3.3A.2-4 and Table 5.3.3A.2-5 of [2]. If both transport blocks are enabled, transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1. In case one of the transport blocks is disabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For a single enabled codeword, indices 24 to 39 in Table 5.3.3.1.8-3 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers.

Table 5.3.3.1.8-1: Number of bits for precoding information.

Number of antenna ports at UE	Number of bits for precoding information
2	3
4	6

Table 5.3.3.1.8-2: Content of precoding information field for 2 antenna ports

One codeword: Codeword 0 enabled Codeword 1 disabled		Two codewords: Codeword 0 enabled Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	1 layer: TPMI=0	0	2 layers: TPMI=0
1	1 layer: TPMI=1	1-7	reserved
2	1 layer: TPMI=2		
...	...		
5	1 layer: TPMI=5		
6-7	reserved		

Table 5.3.3.1.8-3: Content of precoding information field for 4 antenna ports

One codeword: Codeword 0 enabled Codeword 1 disabled		Two codewords: Codeword 0 enabled Codeword 1 enabled	
Bit field mapped to index	Message	Bit field mapped to index	Message
0	1 layer: TPMI=0	0	2 layers: TPMI=0
1	1 layer: TPMI=1	1	2 layers: TPMI=1
...	...	...	...
23	1 layer: TPMI=23	15	2 layers: TPMI=15
24	2 layers: TPMI=0	16	3 layers: TPMI=0
25	2 layers: TPMI=1	17	3 layers: TPMI=1
...	...	...	...
39	2 layers: TPMI=15	27	3 layers: TPMI=11
40-63	reserved	28	4 layers: TPMI=0
		29 - 63	Reserved

If the number of information bits in format 4 is equal to the payload size for DCI format 1, 2, 2A, 2B, 2C or 2D associated with the configured DL transmission mode in the same serving cell, one zero bit shall be appended to format 4.