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Contents

Foreword

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1 Scope

The present document specifies and establishes the characteristics of the physicals layer procedures in the FDD and TDD modes of E-UTRA.

2 References

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

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document.*

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

[2] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer – General Description".

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

[4] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".

[5] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer – Measurements".

[6] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".

[7] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

[8] 3GPP TS 36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".

[9] 3GPP TS 36.423, "Evolved Universal Terrestrial Radio Access (E-UTRA); X2 Application Protocol (X2AP)".

[10] 3GPP TS 36.133, "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management".

[11] 3GPP TS 36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification".

[12] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".

3 Symbols and abbreviations

3.1 Symbols

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

n_f	System frame number as defined in [3]
n_s	Slot number within a radio frame as defined in [3]
N_{cells}^{DL}	Number of configured cells
$N_{\mathrm{RB}}^{\mathrm{DL}}$	Downlink bandwidth configuration, expressed in units of $N_{\mathrm{sc}}^{\mathrm{RB}}$ as defined in [3]
$N_{\mathrm{RB}}^{\mathrm{UL}}$	Uplink bandwidth configuration, expressed in units of $N_{\mathrm{sc}}^{\mathrm{RB}}$ as defined in [3]
$N_{\mathrm{symb}}^{\mathrm{UL}}$	Number of SC-FDMA symbols in an uplink slot as defined in [3]
$N_{\mathrm{sc}}^{\mathrm{RB}}$	Resource block size in the frequency domain, expressed as a number of subcarriers as defined in [3]
T_s	Basic time unit as defined in [3]

3.2 Abbreviations

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

ACK	Acknowledgement
BCH	Broadcast Channel
CCE	Control Channel Element
CDD	Cyclic Delay Diversity
CIF	Carrier Indicator Field
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CSI	Channel State Information
CSI-IM	CSI-interference measurement
DAI	Downlink Assignment Index
DCI	Downlink Control Information
DL	Downlink
DL-SCH	Downlink Shared Channel
DTX	Discontinuous Transmission
EPDCCH	Enhanced Physical Downlink Control Channel
EPRE	Energy Per Resource Element
MCS	Modulation and Coding Scheme
NACK	Negative Acknowledgement
PBCH	Physical Broadcast Channel
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PHICH	Physical Hybrid ARQ Indicator Channel
PMCH	Physical Multicast Channel
PMI	Precoding Matrix Indicator
PRACH	Physical Random Access Channel
PRS	Positioning Reference Signal
PRB	Physical Resource Block
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
PTI	Precoding Type Indicator
RBG	Resource Block Group

RE	Resource Element
RI	Rank Indication
RS	Reference Signal
SINR	Signal to Interference plus Noise Ratio
SPS C-RNTI	Semi-Persistent Scheduling C-RNTI
SR	Scheduling Request
SRS	Sounding Reference Symbol
TAG	Timing Advance Group
TBS	Transport Block Size
UCI	Uplink Control Information
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel
VRB	Virtual Resource Block

4 Synchronization procedures

4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards.

The following signals are transmitted in the downlink to facilitate cell search: the primary and secondary synchronization signals.

A UE may assume the antenna ports 0 – 3 and the antenna port for the primary/secondary synchronization signals of a serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift and average delay.

4.2 Timing synchronization

4.2.1 Radio link monitoring

The downlink radio link quality of the primary cell shall be monitored by the UE for the purpose of indicating out-of-sync/in-sync status to higher layers.

In non-DRX mode operation, the physical layer in the UE shall every radio frame assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds (Q_{out} and Q_{in}) defined by relevant tests in [10].

In DRX mode operation, the physical layer in the UE shall at least once every DRX period assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds (Q_{out} and Q_{in}) defined by relevant tests in [10].

If higher-layer signalling indicates certain subframes for restricted radio link monitoring, the radio link quality shall not be monitored in any subframe other than those indicated.

The physical layer in the UE shall in radio frames where the radio link quality is assessed indicate out-of-sync to higher layers when the radio link quality is worse than the threshold Q_{out}. When the radio link quality is better than the threshold Q_{in}, the physical layer in the UE shall in radio frames where the radio link quality is assessed indicate in-sync to higher layers.

4.2.2 Inter-cell synchronization

No functionality is specified in this clause in this release.

4.2.3 Transmission timing adjustments

Upon reception of a timing advance command for a TAG containing the primary cell, the UE shall adjust uplink transmission timing for PUCCH/PUSCH/SRS of the primary cell based on the received timing advance command. The UL transmission timing for PUSCH/SRS of a secondary cell is the same as the primary cell if the secondary cell and the primary cell belong to the same TAG.

Upon reception of a timing advance command for a TAG not containing the primary cell, the UE shall adjust uplink transmission timing for PUSCH/SRS of all the secondary cells in the TAG based on the received timing advance command where the UL transmission timing for PUSCH /SRS is the same for all the secondary cells in the TAG.

The timing advance command for a TAG indicates the change of the uplink timing relative to the current uplink timing for the TAG as multiples of $16\,T_s$. The start timing of the random access preamble is specified in [3].

In case of random access response, an 11-bit timing advance command [8], T_A, for a TAG indicates N_{TA} values by index values of T_A = 0, 1, 2, ..., 1282, where an amount of the time alignment for the TAG is given by $N_{TA} = T_A \times 16$. N_{TA} is defined in [3].

In other cases, a 6-bit timing advance command [8], T_A, for a TAG indicates adjustment of the current N_{TA} value, $N_{TA,old}$, to the new N_{TA} value, $N_{TA,new}$, by index values of T_A = 0, 1, 2,..., 63, where $N_{TA,new} = N_{TA,old} + (T_A - 31) \times 16$. Here, adjustment of N_{TA} value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing for the TAG by a given amount respectively.

For a timing advance command received on subframe *n*, the corresponding adjustment of the uplink transmission timing shall apply from the beginning of subframe *n+6*. For serving cells in the same TAG, when the UE's uplink PUCCH/PUSCH/SRS transmissions in subframe *n* and subframe *n*+1 are overlapped due to the timing adjustment, the UE shall complete transmission of subframe *n* and not transmit the overlapped part of subframe *n*+1.

If the received downlink timing changes and is not compensated or is only partly compensated by the uplink timing adjustment without timing advance command as specified in [10], the UE changes N_{TA} accordingly.

4.3 Timing for Secondary Cell Activation / Deactivation

When a UE receives an activation command [8] for a secondary cell in subframe *n*, the corresponding actions in [8] shall be applied no later than the minimum requirement defined in [10] and no earlier than subframe n+8, except for the following:

- the actions related to CSI reporting

- the actions related to the *sCellDeactivationTimer* associated with the secondary cell [8]

which shall be applied in subframe *n+8*.

When a UE receives a deactivation command [8] for a secondary cell or the *sCellDeactivationTimer* associated with the secondary cell expires in subframe *n*, the corresponding actions in [8] shall apply no later than the minimum requirement defined in [10], except for the actions related to CSI reporting which shall be applied in subframe *n+8*.

5 Power control

Downlink power control determines the Energy Per Resource Element (EPRE). The term Resource Element Energy denotes the energy prior to CP insertion. The term resource element energy also denotes the average energy taken over all constellation points for the modulation scheme applied. Uplink power control determines the average power over a SC-FDMA symbol in which the physical channel is transmitted.

5.1 Uplink power control

Uplink power control controls the transmit power of the different uplink physical channels.

For PUSCH, the transmit power $\hat{P}_{\text{PUSCH},c}(i)$ defined in clause 5.1.1, is first scaled by the ratio of the number of antennas ports with a non-zero PUSCH transmission to the number of configured antenna ports for the transmission scheme. The resulting scaled power is then split equally across the antenna ports on which the non-zero PUSCH is transmitted.

For PUCCH or SRS, the transmit power $\hat{P}_{\text{PUCCH}}(i)$, defined in clause 5.1.1.1, or $\hat{P}_{\text{SRS,c}}(i)$ is split equally across the configured antenna ports for PUCCH or SRS. $\hat{P}_{\text{SRS,c}}(i)$ is the linear value of $P_{\text{SRS,c}}(i)$ defined in clause 5.1.3.

A cell wide overload indicator (OI) and a High Interference Indicator (HII) to control UL interference are defined in [9].

5.1.1 Physical uplink shared channel

5.1.1.1 UE behaviour

The setting of the UE Transmit power for a Physical Uplink Shared Channel (PUSCH) transmission is defined as follows.

If the UE transmits PUSCH without a simultaneous PUCCH for the serving cell c, then the UE transmit power $P_{\text{PUSCH},c}(i)$ for PUSCH transmission in subframe i for the serving cell c is given by

$$P_{\text{PUSCH,c}}(i) = \min\begin{Bmatrix} P_{\text{CMAX},c}(i), \\ 10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i) \end{Bmatrix} \quad \text{[dBm]}$$

If the UE transmits PUSCH simultaneous with PUCCH for the serving cell c, then the UE transmit power $P_{\text{PUSCH},c}(i)$ for the PUSCH transmission in subframe i for the serving cell c is given by

$$P_{\text{PUSCH,c}}(i) = \min\begin{Bmatrix} 10\log_{10}\left(\hat{P}_{\text{CMAX},c}(i) - \hat{P}_{\text{PUCCH}}(i)\right), \\ 10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i) \end{Bmatrix} \quad \text{[dBm]}$$

If the UE is not transmitting PUSCH for the serving cell c, for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall assume that the UE transmit power $P_{\text{PUSCH},c}(i)$ for the PUSCH transmission in subframe i for the serving cell c is computed by

$$P_{\text{PUSCH,c}}(i) = \min\left\{P_{\text{CMAX,c}}(i),\, P_{\text{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right\} \quad \text{[dBm]}$$

where,

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell c and $\hat{P}_{\text{CMAX,c}}(i)$ is the linear value of $P_{\text{CMAX,c}}(i)$. If the UE transmits PUCCH without PUSCH in subframe i for the serving cell c, for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall assume $P_{\text{CMAX,c}}(i)$ as given by clause 5.1.2.1. If the UE does not transmit PUCCH and PUSCH in subframe i for the serving cell c, for the accumulation of TPC command received with DCI format 3/3A for

PUSCH, the UE shall compute $P_{\text{CMAX,c}}(i)$ assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR, A-MPR, P-MPR and ΔT_C are defined in [6].

- $\hat{P}_{\text{PUCCH}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$ defined in clause 5.1.2.1
- $M_{\text{PUSCH,c}}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for subframe *i* and serving cell c.
- $P_{\text{O\_PUSCH,c}}(j)$ is a parameter composed of the sum of a component $P_{\text{O\_NOMINAL\_ PUSCH,c}}(j)$ provided from higher layers for *j=0* and *1* and a component $P_{\text{O\_UE\_PUSCH,c}}(j)$ provided by higher layers for *j=0* and *1* for serving cell c. For PUSCH (re)transmissions corresponding to a semi-persistent grant then *j=0* , for PUSCH (re)transmissions corresponding to a dynamic scheduled grant then *j=1* and for PUSCH (re)transmissions corresponding to the random access response grant then *j=2*. $P_{\text{O\_UE\_PUSCH,c}}(2)=0$ and $P_{\text{O\_NOMINAL\_PUSCH,c}}(2)=P_{\text{O\_PRE}}+\Delta_{PREAMBLE\_Msg3}$, where the parameter *preambleInitialReceivedTargetPower* [8] ($P_{\text{O\_PRE}}$) and $\Delta_{PREAMBLE\_Msg3}$ are signalled from higher layers for serving cell c.
- For *j* =0 or *1*, $\alpha_c \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$ is a 3-bit parameter provided by higher layers for serving cell c. For j=2, $\alpha_c(j)=1$.
- PL_c is the downlink pathloss estimate calculated in the UE for serving cell c in dB and PL_c = *referenceSignalPower* – higher layer filtered RSRP, where *referenceSignalPower* is provided by higher layers and RSRP is defined in [5] for the reference serving cell and the higher layer filter configuration is defined in [11] for the reference serving cell. If serving cell c belongs to a TAG containing the primary cell then, for the uplink of the primary cell, the primary cell is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP. For the uplink of the secondary cell, the serving cell configured by the higher layer parameter *pathlossReferenceLinking* defined in [11] is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP. If serving cell c belongs to a TAG not containing the primary cell then serving cell c is used as the reference serving cell for determining *referenceSignalPower* and higher layer filtered RSRP.
- $\Delta_{TF,c}(i)=10\log_{10}\left(\left(2^{BPRE\cdot K_s}-1\right)\cdot\beta_{offset}^{PUSCH}\right)$ for $K_S=1.25$ and 0 for $K_S=0$ where K_S is given by the parameter *deltaMCS-Enabled* provided by higher layers for each serving cell c. $BPRE$ and β_{offset}^{PUSCH}, for each serving cell c, are computed as below. $K_S=0$ for transmission mode 2.
  - o $BPRE=O_{\text{CQI}}/N_{\text{RE}}$ for control data sent via PUSCH without UL-SCH data and $\sum_{r=0}^{C-1}K_r/N_{\text{RE}}$ for other cases.
    - ▪ where C is the number of code blocks, K_r is the size for code block r, O_{CQI} is the number of CQI/PMI bits including CRC bits and N_{RE} is the number of resource elements determined as $N_{\text{RE}}=M_{sc}^{PUSCH-initial}\cdot N_{\text{symb}}^{\text{PUSCH-initial}}$, where C, K_r, $M_{sc}^{PUSCH-initial}$ and $N_{\text{symb}}^{\text{PUSCH-initial}}$ are defined in [4].
  - o $\beta_{offset}^{PUSCH}=\beta_{offset}^{CQI}$ for control data sent via PUSCH without UL-SCH data and 1 for other cases.
- $\delta_{\text{PUSCH,c}}$ is a correction value, also referred to as a TPC command and is included in PDCCH/EPDCCH with DCI format 0/4 for serving cell c or jointly coded with other TPC commands in PDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUSCH-RNTI. The current PUSCH power control adjustment state for serving cell c is given by $f_c(i)$ which is defined by:
  - o $f_c(i)=f_c(i-1)+\delta_{\text{PUSCH,c}}(i-K_{\text{PUSCH}})$ if accumulation is enabled based on the parameter *Accumulation-enabled* provided by higher layers or if the TPC command $\delta_{\text{PUSCH,c}}$ is included in a

PDCCH/EPDCCH with DCI format 0 for serving cell c where the CRC is scrambled by the Temporary C-RNTI

- where $\delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ was signalled on PDCCH/EPDCCH with DCI format 0/4 or PDCCH with DCI format 3/3A on subframe $i - K_{PUSCH}$, and where $f_c(0)$ is the first value after reset of accumulation.
- The value of K_{PUSCH} is
  - For FDD, K_{PUSCH} = 4
  - For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, the "TDD UL/DL configuration" refers to the UL-reference UL/DL configuration (defined in clause 8.0) for serving cell c.
  - For TDD UL/DL configurations 1-6, K_{PUSCH} is given in Table 5.1.1.1-1
  - For TDD UL/DL configuration 0
    - If the PUSCH transmission in subframe *2* or *7* is scheduled with a PDCCH/EPDCCH of DCI format 0/4 in which the LSB of the UL index is set to 1, K_{PUSCH} = 7
    - For all other PUSCH transmissions, K_{PUSCH} is given in Table 5.1.1.1-1.
- For serving cell c the UE attempts to decode a PDCCH/EPDCCH of DCI format 0/4 with the UE's C-RNTI or DCI format 0 for SPS C-RNTI and a PDCCH of DCI format 3/3A with this UE's TPC-PUSCH-RNTI in every subframe except when in DRX or where serving cell c is deactivated.
- If DCI format 0/4 for serving cell c and DCI format 3/3A are both detected in the same subframe, then the UE shall use the $\delta_{\text{PUSCH,c}}$ provided in DCI format 0/4.
- $\delta_{\text{PUSCH,c}} = 0$ dB for a subframe where no TPC command is decoded for serving cell c or where DRX occurs or i is not an uplink subframe in TDD.
- The $\delta_{\text{PUSCH,c}}$ dB accumulated values signalled on PDCCH/EPDCCH with DCI format 0/4 are given in Table 5.1.1.1-2. If the PDCCH/EPDCCH with DCI format 0 is validated as a SPS activation or release PDCCH/EPDCCH, then $\delta_{\text{PUSCH,c}}$ is 0dB.
- The δ_{PUSCH} dB accumulated values signalled on PDCCH with DCI format 3/3A are one of SET1 given in Table 5.1.1.1-2 or SET2 given in Table 5.1.1.1-3 as determined by the parameter *TPC-Index* provided by higher layers.
- If UE has reached $P_{\text{CMAX,c}}(i)$ for serving cell c, positive TPC commands for serving cell c shall not be accumulated
- If UE has reached minimum power, negative TPC commands shall not be accumulated
- UE shall reset accumulation
  - For serving cell c, when $P_{\text{O\_UE\_PUSCH,c}}$ value is changed by higher layers
  - For serving cell c, when the UE receives random access response message for serving cell c

o $f_c(i) = \delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ if accumulation is not enabled for serving cell c based on the parameter *Accumulation-enabled* provided by higher layers

- where $\delta_{\text{PUSCH,c}}(i - K_{\text{PUSCH}})$ was signalled on PDCCH/EPDCCH with DCI format 0/4 for serving cell c on subframe $i - K_{PUSCH}$
- The value of K_{PUSCH} is

- For FDD, K_{PUSCH} = 4
- For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, the "TDD UL/DL configuration" refers to the UL-reference UL/DL configuration (defined in clause 8.0) for serving cell c.
- For TDD UL/DL configurations 1-6, K_{PUSCH} is given in Table 5.1.1.1-1.
- For TDD UL/DL configuration 0
  - o If the PUSCH transmission in subframe *2* or *7* is scheduled with a PDCCH/EPDCCH of DCI format 0/4 in which the LSB of the UL index is set to 1, K_{PUSCH} = 7
  - o For all other PUSCH transmissions, K_{PUSCH} is given in Table 5.1.1.1-1.

- The $\delta_{\mathrm{PUSCH,c}}$ dB absolute values signalled on PDCCH/EPDCCH with DCI format 0/4 are given in Table 5.1.1.1-2. If the PDCCH/EPDCCH with DCI format 0 is validated as a SPS activation or release PDCCH/EPDCCH, then $\delta_{\mathrm{PUSCH,c}}$ is 0dB.
- $f_c(i) = f_c(i-1)$ for a subframe where no PDCCH/EPDCCH with DCI format 0/4 is decoded for serving cell c or where DRX occurs or *i* is not an uplink subframe in TDD.

o For both types of $f_c(*)$ (accumulation or current absolute) the first value is set as follows:

- If $P_{\mathrm{O\_UE\_PUSCH,c}}$ value is changed by higher layers and serving cell c is the primary cell or, if $P_{\mathrm{O\_UE\_PUSCH,c}}$ value is received by higher layers and serving cell c is a Secondary cell
  - $f_c(0) = 0$
- Else
  - If the UE receives the random access response message for a serving cell c
    - o $f_c(0) = \Delta P_{rampupc} + \delta_{msg2,c}$, where
      - $\delta_{msg2,c}$ is the TPC command indicated in the random access response corresponding to the random access preamble transmitted in the serving cell c, see clause 6.2, and
      - $$\Delta P_{rampup,c} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \begin{pmatrix} 10\log_{10}(M_{PUSCH,c}(0)) \\ + P_{O\_PUSCH,c}(2) + \delta_{msg2} \\ + \alpha_c(2)\cdot PL + \Delta_{TF,c}(0) \end{pmatrix}\right)\right\}, \Delta P_{rampuprequested,c}\right]$$

      and $\Delta P_{rampuprequested,c}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last preamble in the serving cell c, $M_{\mathrm{PUSCH,c}}(0)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for the subframe of first PUSCH transmission in the serving cell c, and $\Delta_{TF,c}(0)$ is the power adjustment of first PUSCH transmission in the serving cell c.

Table 5.1.1.1-1: K_{PUSCH} for TDD configuration 0-6

TDD UL/DL Configuration	subframe number *i*									
	0	1	2	3	4	5	6	7	8	9
0	-	-	6	7	4	-	-	6	7	4
1	-	-	6	4	-	-	-	6	4	-
2	-	-	4	-	-	-	-	4	-	-
3	-	-	4	4	4	-	-	-	-	-
4	-	-	4	4	-	-	-	-	-	-
5	-	-	4	-	-	-	-	-	-	-
6	-	-	7	7	5	-	-	7	7	-

Table 5.1.1.1-2: Mapping of TPC Command Field in DCI format 0/3/4 to absolute and accumulated $\delta_{\text{PUSCH,c}}$ values

TPC Command Field in DCI format 0/3/4	Accumulated $\delta_{\text{PUSCH,c}}$ [dB]	Absolute $\delta_{\text{PUSCH,c}}$ [dB] only DCI format 0/4
0	-1	-4
1	0	-1
2	1	1
3	3	4

Table 5.1.1.1-3: Mapping of TPC Command Field in DCI format 3A to accumulated $\delta_{\text{PUSCH,c}}$ values

TPC Command Field in DCI format 3A	Accumulated $\delta_{\text{PUSCH,c}}$ [dB]
0	-1
1	1

If the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cell c in subframe i such that the condition

$$\sum_{c} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUCCH}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$, $\hat{P}_{\text{PUSCH},c}(i)$ is the linear value of $P_{\text{PUSCH},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of the UE total configured maximum output power P_{CMAX} defined in [6] in subframe i and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c where $0 \le w(i) \le 1$. In case there is no PUCCH transmission in subframe i $\hat{P}_{\text{PUCCH}}(i) = 0$.

If the UE has PUSCH transmission with UCI on serving cell j and PUSCH without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cells without UCI in subframe i such that the condition

$$\sum_{c \ne j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \le \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUSCH},j}(i)$ is the PUSCH transmit power for the cell with UCI and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c without UCI. In this case, no power scaling is applied to $\hat{P}_{\text{PUSCH},j}(i)$ unless $\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) = 0$ and the total transmit power of the UE still would exceed $\hat{P}_{CMAX}(i)$.

Note that $w(i)$ values are the same across serving cells when $w(i) > 0$ but for certain serving cells $w(i)$ may be zero.

If the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell j and PUSCH transmission without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE obtains $\hat{P}_{\text{PUSCH},c}(i)$ according to

$$\hat{P}_{\text{PUSCH},j}(i) = \min\left(\hat{P}_{\text{PUSCH},j}(i), \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i)\right)\right)$$

and

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \leq \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$$

If the UE is configured with multiple TAGs, and if the PUCCH/PUSCH transmission of the UE on subframe i for a given serving cell in a TAG overlaps some portion of the first symbol of the PUSCH transmission on subframe $i+1$ for a different serving cell in another TAG the UE shall adjust its total transmission power to not exceed P_{CMAX} on any overlapped portion.

If the UE is configured with multiple TAGs, and if the PUSCH transmission of the UE on subframe i for a given serving cell in a TAG overlaps some portion of the first symbol of the PUCCH transmission on subframe $i+1$ for a different serving cell in another TAG the UE shall adjust its total transmission power to not exceed P_{CMAX} on any overlapped portion.

If the UE is configured with multiple TAGs, and if the SRS transmission of the UE in a symbol on subframe i for a given serving cell in a TAG overlaps with the PUCCH/PUSCH transmission on subframe i or subframe $i+1$ for a different serving cell in the same or another TAG the UE shall drop SRS if its total transmission power exceeds P_{CMAX} on any overlapped portion of the symbol.

If the UE is configured with multiple TAGs and more than 2 serving cells, and if the SRS transmission of the UE in a symbol on subframe i for a given serving cell overlaps with the SRS transmission on subframe i for a different serving cell(s) and with PUSCH/PUCCH transmission on subframe i or subframe $i+1$ for another serving cell(s) the UE shall drop the SRS transmissions if the total transmission power exceeds P_{CMAX} on any overlapped portion of the symbol.

If the UE is configured with multiple TAGs, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in parallel with SRS transmission in a symbol on a subframe of a different serving cell belonging to a different TAG, drop SRS if the total transmission power exceeds P_{CMAX} on any overlapped portion in the symbol.

If the UE is configured with multiple TAGs, the UE shall, when requested by higher layers, to transmit PRACH in a secondary serving cell in parallel with PUSCH/PUCCH in a different serving cell belonging to a different TAG, adjust the transmission power of PUSCH/PUCCH so that its total transmission power does not exceed P_{CMAX} on the overlapped portion.

5.1.1.2 Power headroom

There are two types of UE power headroom reports defined. A UE power headroom PH is valid for subframe i for serving cell c.

Type 1:

If the UE transmits PUSCH without PUCCH in subframe i for serving cell c, power headroom for a Type 1 report is computed using

$$PH_{\text{type1,c}}(i) = P_{\text{CMAX},c}(i) - \left\{10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right\} \text{ [dB]}$$

where, $P_{\text{CMAX},c}(i)$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, PL_c, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are defined in clause 5.1.1.1.

If the UE transmits PUSCH with PUCCH in subframe i for serving cell c, power headroom for a Type 1 report is computed using

$$PH_{\text{type1,c}}(i) = \tilde{P}_{\text{CMAX},c}(i) - \left\{10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right\} \text{ [dB]}$$

where, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, PL_c, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are defined in clause 5.1.1.1. $\tilde{P}_{\text{CMAX},c}(i)$ is computed based on the requirements in [6] assuming a PUSCH only transmission in subframe i. For this case, the physical layer delivers $\tilde{P}_{\text{CMAX},c}(i)$ instead of $P_{\text{CMAX},c}(i)$ to higher layers.

If the UE does not transmit PUSCH in subframe i for serving cell c, power headroom for a Type 1 report is computed using

$$PH_{\text{type1,c}}(i) = \tilde{P}_{\text{CMAX},c}(i) - \left\{P_{\text{O\_PUSCH,c}}(1) + \alpha_c(1)\cdot PL_c + f_c(i)\right\} \text{ [dB]}$$

where, $\tilde{P}_{\text{CMAX,c}}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR , A-MPR, P-MPR and ΔT_C are defined in [6]. $P_{\text{O\_PUSCH,c}}(1)$, $\alpha_c(1)$, PL_c, and $f_c(i)$ are defined in clause 5.1.1.1.

Type 2:

If the UE transmits PUSCH simultaneous with PUCCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\begin{pmatrix}10^{\left(10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i)\right)/10}\end{pmatrix} \text{ [dB]}$$

where, $P_{\text{CMAX,c}}$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in clause 5.1.1.1 and $P_{\text{O\_PUCCH}}$, PL_c, $h(n_{CQI}, n_{HARQ}, n_{SR})$, $\Delta_{\text{F\_PUCCH}}(F)$, $\Delta_{TxD}(F')$ and $g(i)$ are defined in clause 5.1.2.1

If the UE transmits PUSCH without PUCCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\begin{pmatrix}10^{\left(10\log_{10}(M_{\text{PUSCH,c}}(i)) + P_{\text{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + \Delta_{\text{TF,c}}(i) + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + g(i)\right)/10}\end{pmatrix} \text{ [dB]}$$

where, $P_{\text{CMAX,c}}(i)$, $M_{\text{PUSCH,c}}(i)$, $P_{\text{O\_PUSCH,c}}(j)$, $\alpha_c(j)$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in clause 5.1.1.1 and $P_{\text{O\_PUCCH}}$, PL_c and $g(i)$ are defined in clause 5.1.2.1.

If the UE transmits PUCCH without PUSCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(P_{\text{O\_PUSCH,c}}(1) + \alpha_c(1) \cdot PL_c + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + h\left(n_{CQI}, n_{HARQ}, n_{SR}\right) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i)\right)/10} \end{array} \right) \text{ [dB]}$$

where, $P_{\text{O\_PUSCH,c}}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in clause 5.1.1.1, $P_{\text{CMAX,c}}(i)$, $P_{\text{O\_PUCCH}}$, PL_c, $h(n_{CQI}, n_{HARQ}, n_{SR})$, $\Delta_{\text{F\_PUCCH}}(F)$, $\Delta_{TxD}(F')$ and $g(i)$ are also defined in clause 5.1.2.1.

If the UE does not transmit PUCCH or PUSCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = \tilde{P}_{\text{CMAX},c}(i) - 10\log_{10}\left(\begin{array}{l} 10^{\left(P_{\text{O\_PUSCH,c}}(1) + \alpha_c(1) \cdot PL_c + f_c(i)\right)/10} \\ +\ 10^{\left(P_{\text{0\_PUCCH}} + PL_c + g(i)\right)/10} \end{array} \right) \text{ [dB]}$$

where, $\tilde{P}_{CMAX,c}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR , A-MPR, P-MPR and ΔT_C are defined in [6], $P_{\text{O\_PUSCH,c}}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in clause 5.1.1.1 and $P_{\text{O\_PUCCH}}$, PL_c and $g(i)$ are defined in clause 5.1.2.1.

The power headroom shall be rounded to the closest value in the range [40; -23] dB with steps of 1 dB and is delivered by the physical layer to higher layers.

5.1.2 Physical uplink control channel

5.1.2.1 UE behaviour

If serving cell c is the primary cell, the setting of the UE Transmit power P_{PUCCH} for the physical uplink control channel (PUCCH) transmission in subframe i is defined by

$$P_{\text{PUCCH}}(i) = \min\left\{ \begin{array}{l} P_{\text{CMAX,c}}(i), \\ P_{\text{0\_PUCCH}} + PL_c + h\left(n_{CQI}, n_{HARQ}, n_{SR}\right) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{TxD}(F') + g(i) \end{array} \right\} \text{ [dBm]}$$

If the UE is not transmitting PUCCH for the primary cell, for the accumulation of TPC command for PUCCH, the UE shall assume that the UE transmit power P_{PUCCH} for PUCCH in subframe i is computed by

$$P_{\text{PUCCH}}(i) = \min\left\{P_{\text{CMAX,c}}(i), P_{\text{0\_PUCCH}} + PL_c + g(i)\right\} \text{ [dBm]}$$

where

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell c. If the UE transmits PUSCH without PUCCH in subframe i for the serving cell c, for the accumulation of TPC command for PUCCH, the UE shall assume $P_{\text{CMAX,c}}(i)$ as given by clause 5.1.1.1. If the UE does not transmit PUCCH and PUSCH in subframe i for the serving cell c, for the accumulation of TPC command for PUCCH, the UE shall compute $P_{\text{CMAX,c}}(i)$ assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ΔT_C =0dB, where MPR, A-MPR, P-MPR and ΔT_C are defined in [6].
- The parameter $\Delta_{\text{F\_PUCCH}}(F)$ is provided by higher layers. Each $\Delta_{\text{F\_PUCCH}}(F)$ value corresponds to a PUCCH format (F) relative to PUCCH format 1a, where each PUCCH format (F) is defined in Table 5.4-1 of [3].

- If the UE is configured by higher layers to transmit PUCCH on two antenna ports, the value of $\Delta_{TxD}(F')$ is provided by higher layers where each PUCCH format *F'* is defined in Table 5.4-1 of [3] ; otherwise, $\Delta_{TxD}(F')=0$.
- $h(n_{CQI}, n_{HARQ}, n_{SR})$ is a PUCCH format dependent value, where n_{CQI} corresponds to the number of information bits for the channel quality information defined in clause 5.2.3.3 in [4]. n_{SR} = 1 if subframe *i* is configured for SR for the UE not having any associated transport block for UL-SCH, otherwise n_{SR} =0. If the UE is configured with more than one serving cell, or the UE is configured with one serving cell and transmitting using PUCCH format 3, the value of n_{HARQ} is defined in clause 10.1; otherwise, n_{HARQ} is the number of HARQ-ACK bits sent in subframe *i*.
  - For PUCCH format 1,1a and 1b $h(n_{CQI}, n_{HARQ}, n_{SR})=0$
  - For PUCCH format 1b with channel selection, if the UE is configured with more than one serving cell, $h(n_{CQI}, n_{HARQ}, n_{SR})=\frac{(n_{HARQ}-1)}{2}$, otherwise, $h(n_{CQI}, n_{HARQ}, n_{SR})=0$
  - For PUCCH format 2, 2a, 2b and normal cyclic prefix
    $$h(n_{CQI}, n_{HARQ}, n_{SR})=\begin{cases}10\log_{10}\left(\frac{n_{CQI}}{4}\right) & \text{if } n_{CQI}\geq 4\\ 0 & \text{otherwise}\end{cases}$$
  - For PUCCH format 2 and extended cyclic prefix
    $$h(n_{CQI}, n_{HARQ}, n_{SR})=\begin{cases}10\log_{10}\left(\frac{n_{CQI}+n_{HARQ}}{4}\right) & \text{if } n_{CQI}+n_{HARQ}\geq 4\\ 0 & \text{otherwise}\end{cases}$$
  - For PUCCH format 3 and when UE transmits HARQ-ACK/SR without periodic CSI,
    - If the UE is configured by higher layers to transmit PUCCH format 3 on two antenna ports, or if the UE transmits more than 11 bits of HARQ-ACK/SR
      $$h(n_{CQI}, n_{HARQ}, n_{SR})=\frac{n_{HARQ}+n_{SR}-1}{3}$$
    - Otherwise
      $$h(n_{CQI}, n_{HARQ}, n_{SR})=\frac{n_{HARQ}+n_{SR}-1}{2}$$
  - For PUCCH format 3 and when UE transmits HARQ-ACK/SR and periodic CSI,
    - If the UE is configured by higher layers to transmit PUCCH format 3 on two antenna ports, or if the UE transmits more than 11 bits of HARQ-ACK/SR and CSI
      $$h(n_{CQI}, n_{HARQ}, n_{SR})=\frac{n_{HARQ}+n_{SR}+n_{CQI}-1}{3}$$
    - Otherwise
      $$h(n_{CQI}, n_{HARQ}, n_{SR})=\frac{n_{HARQ}+n_{SR}+n_{CQI}-1}{2}$$
- $P_{\text{O\_PUCCH}}$ is a parameter composed of the sum of a parameter $P_{\text{O\_NOMINAL\_PUCCH}}$ provided by higher layers and a parameter $P_{\text{O\_UE\_PUCCH}}$ provided by higher layers.
- δ_{PUCCH} is a UE specific correction value, also referred to as a TPC command, included in a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D for the primary cell, or included in an EPDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D for the primary cell, or sent jointly coded with other UE specific PUCCH correction values on a PDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUCCH-RNTI.

- If a UE is not configured for EPDCCH monitoring, the UE attempts to decode a PDCCH of DCI format 3/3A with the UE's TPC-PUCCH-RNTI and one or several PDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C/2D with the UE's C-RNTI or SPS C-RNTI on every subframe except when in DRX.
- If a UE is configured for EPDCCH monitoring, the UE attempts to decode
  - a PDCCH of DCI format 3/3A with the UE's TPC-PUCCH-RNTI and one or several PDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C/2D with the UE's C-RNTI or SPS C-RNTI as described in clause 9.1.1, and
  - one or several EPDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C/2D with the UE's C-RNTI or SPS C-RNTI, as described in clause 9.1.4.
- If the UE decodes
  - a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D or
  - an EPDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D

  for the primary cell and the corresponding detected RNTI equals the C-RNTI or SPS C-RNTI of the UE and the TPC field in the DCI format is not used to determine the PUCCH resource as in clause 10.1, the UE shall use the δ_{PUCCH} provided in that PDCCH/EPDCCH.

  else

  - if the UE decodes a PDCCH with DCI format 3/3A, the UE shall use the δ_{PUCCH} provided in that PDCCH

    else the UE shall set δ_{PUCCH} = 0 dB.

- $g(i) = g(i-1) + \sum_{m=0}^{M-1} \delta_{PUCCH}(i-k_m)$ where $g(i)$ is the current PUCCH power control adjustment state and where $g(0)$ is the first value after reset.
  - For FDD, $M = 1$ and $k_0 = 4$.
  - For TDD, values of M and k_m are given in Table 10.1.3.1-1.
  - The δ_{PUCCH} dB values signalled on PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D or EPDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C/2D are given in Table 5.1.2.1-1. If the PDCCH with DCI format 1/1A/2/2A/2B/2C/2D or EPDCCH with DCI format 1/1A/2A/2/2B/2C/2D is validated as an SPS activation PDCCH/EPDCCH, or the PDCCH/EPDCCH with DCI format 1A is validated as an SPS release PDCCH/EPDCCH, then δ_{PUCCH} is 0dB.
  - The δ_{PUCCH} dB values signalled on PDCCH with DCI format 3/3A are given in Table 5.1.2.1-1 or in Table 5.1.2.1-2 as semi-statically configured by higher layers.
  - If $P_{\text{O\_UE\_PUCCH}}$ value is changed by higher layers,
    - $g(0) = 0$
  - Else
    - $g(0) = \Delta P_{rampup} + \delta_{msg2}$, where
      - δ_{msg2} is the TPC command indicated in the random access response corresponding to the random access preamble transmitted in the primary cell, see clause 6.2 and
      - If UE is transmitting PUCCH in subframe *i*,

$$\Delta P_{rampup} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \begin{pmatrix} P_{0\_PUCCH} \\ + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR}) \\ + \Delta_{F\_PUCCH}(F) + \Delta_{TxD}(F') \end{pmatrix}\right)\right\}, \Delta P_{rampuprequested}\right]$$

Otherwise,

$$\Delta P_{rampup} = \min\left[\left\{\max\left(0, P_{CMAX,c} - \left(P_{0\_PUCCH} + PL_c\right)\right)\right\}, \Delta P_{rampuprequested}\right]$$

and $\Delta P_{rampuprequested}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last preamble in the primary cell

- If UE has reached $P_{\mathrm{CMAX,c}}(i)$ for the primary cell, positive TPC commands for the primary cell shall not be accumulated
- If UE has reached minimum power, negative TPC commands shall not be accumulated
- UE shall reset accumulation
  - when $P_{\mathrm{O\_UE\_PUCCH}}$ value is changed by higher layers
  - when the UE receives a random access response message for the primary cell
- $g(i) = g(i-1)$ if i is not an uplink subframe in TDD.

Table 5.1.2.1-1: Mapping of TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2D/2/3 to δ_{PUCCH} values

TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2D/2/3	δ_{PUCCH} [dB]
0	-1
1	0
2	1
3	3

Table 5.1.2.1-2: Mapping of TPC Command Field in DCI format 3A to δ_{PUCCH} values

TPC Command Field in DCI format 3A	δ_{PUCCH} [dB]
0	-1
1	1

5.1.3 Sounding Reference Symbol (SRS)

5.1.3.1 UE behaviour

The setting of the UE Transmit power P_{SRS} for the SRS transmitted on subframe *i* for serving cell c is defined by

$$P_{\mathrm{SRS,c}}(i) = \min\left\{ P_{\mathrm{CMAX,c}}(i),\ P_{\mathrm{SRS\_OFFSET,c}}(m) + 10\log_{10}(M_{\mathrm{SRS,c}}) + P_{\mathrm{O\_PUSCH,c}}(j) + \alpha_c(j)\cdot PL_c + f_c(i) \right\} \quad \text{[dBm]}$$

where

- $P_{\text{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] in subframe *i* for serving cell c.
- $P_{\text{SRS\_OFFSET,c}}(m)$ is semi-statically configured by higher layers for *m=0* and *m=1* for serving cell c. For SRS transmission given trigger type 0 then *m=0* and for SRS transmission given trigger type 1 then *m=1*.
- $M_{\text{SRS,c}}$ is the bandwidth of the SRS transmission in subframe *i* for serving cell c expressed in number of resource blocks.
- $f_c(i)$ is the current PUSCH power control adjustment state for serving cell c, see clause 5.1.1.1.
- $P_{\text{O\_PUSCH,c}}(j)$ and $\alpha_c(j)$ are parameters as defined in clause 5.1.1.1, where $j=1$.

If the total transmit power of the UE for the Sounding Reference Symbol in an SC-FDMA symbol would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\text{SRS},c}(i)$ for the serving cell c and the SC-FDMA symbol in subframe *i* such that the condition

$$\sum_c w(i) \cdot \hat{P}_{\text{SRS},c}(i) \le \hat{P}_{CMAX}(i)$$

is satisfied where $\hat{P}_{\text{SRS},c}(i)$ is the linear value of $P_{\text{SRS},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of P_{CMAX} defined in [6] in subframe *i* and $w(i)$ is a scaling factor of $\hat{P}_{\text{SRS},c}(i)$ for serving cell c where $0 < w(i) \le 1$. Note that $w(i)$ values are the same across serving cells.

If the UE is configured with multiple TAGs and the SRS transmission of the UE in an SC-FDMA symbol for a serving cell in subframe i in a TAG overlaps with the SRS transmission in another SC-FDMA symbol in subframe i for a serving cell in another TAG, and if the total transmit power of the UE for the Sounding Reference Symbol in the overlapped portion would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{\text{SRS},c}(i)$ for the serving cell c and each of the overlapped SRS SC-FDMA symbols in subframe i such that the condition

$$\sum_c w(i) \cdot \hat{P}_{\text{SRS},c}(i) \le \hat{P}_{CMAX}(i)$$

is satisfied where $\hat{P}_{\text{SRS},c}(i)$ is the linear value of $P_{\text{SRS},c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of P_{CMAX} defined in [6] in subframe *i* and $w(i)$ is a scaling factor of $\hat{P}_{\text{SRS},c}(i)$ for serving cell c where $0 < w(i) \le 1$. Note that $w(i)$ values are the same across serving cells.

5.2 Downlink power allocation

The eNodeB determines the downlink transmit energy per resource element.

A UE may assume downlink cell-specific RS EPRE is constant across the downlink system bandwidth and constant across all subframes until different cell-specific RS power information is received. The downlink cell-specific reference-signal EPRE can be derived from the downlink reference-signal transmit power given by the parameter *referenceSignalPower* provided by higher layers. The downlink reference-signal transmit power is defined as the linear average over the power contributions (in [W]) of all resource elements that carry cell-specific reference signals within the operating system bandwidth.

The ratio of PDSCH EPRE to cell-specific RS EPRE among PDSCH REs (not applicable to PDSCH REs with zero EPRE) for each OFDM symbol is denoted by either ρ_A or ρ_B according to the OFDM symbol index as given by Table 5.2-2 and Table 5.2-3. In addition, ρ_A and ρ_B are UE-specific.

For a UE in transmission mode 8 - 10 when UE-specific RSs are not present in the PRBs upon which the corresponding PDSCH is mapped or in transmission modes 1 – 7, the UE may assume that for 16 QAM, 64 QAM, spatial multiplexing with more than one layer or for PDSCH transmissions associated with the multi-user MIMO transmission scheme,

- ρ_A is equal to $\delta_{\text{power-offset}} + P_A + 10\log_{10}(2)$ [dB] when the UE receives a PDSCH data transmission using precoding for transmit diversity with 4 cell-specific antenna ports according to clause 6.3.4.3 of [3];
- ρ_A is equal to $\delta_{\text{power-offset}} + P_A$ [dB] otherwise

where $\delta_{\text{power-offset}}$ is 0 dB for all PDSCH transmission schemes except multi-user MIMO and where P_A is a UE specific parameter provided by higher layers.

For transmission mode 7, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs shall be a constant, and that constant shall be maintained over all the OFDM symbols containing the UE-specific RSs in the corresponding PRBs. In addition, the UE may assume that for 16QAM or 64QAM, this ratio is 0 dB.

For transmission mode 8, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs is 0 dB.

For transmission mode 9 or 10, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RS is 0 dB for number of transmission layers less than or equal to two and -3 dB otherwise.

A UE may assume that downlink positioning reference signal EPRE is constant across the positioning reference signal bandwidth and across all OFDM symbols that contain positioning reference signals in a given positioning reference signal occasion [10].

If CSI-RS is configured in a serving cell then a UE shall assume downlink CSI-RS EPRE is constant across the downlink system bandwidth and constant across all subframes for each CSI-RS resource.

The cell-specific ratio ρ_B / ρ_A is given by Table 5.2-1 according to cell-specific parameter P_B signalled by higher layers and the number of configured eNodeB cell specific antenna ports.

Table 5.2-1: The cell-specific ratio ρ_B / ρ_A for 1, 2, or 4 cell specific antenna ports

P_B	ρ_B / ρ_A	
	One Antenna Port	**Two and Four Antenna Ports**
0	1	5/4
1	4/5	1
2	3/5	3/4
3	2/5	1/2

For PMCH with 16QAM or 64QAM, the UE may assume that the ratio of PMCH EPRE to MBSFN RS EPRE is equal to 0 dB.

Table 5.2-2: OFDM symbol indices within a slot of a non-MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A or ρ_B

Number of antenna ports	OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A		OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_B	
	Normal cyclic prefix	**Extended cyclic prefix**	**Normal cyclic prefix**	**Extended cyclic prefix**
One or two	1, 2, 3, 5, 6	1, 2, 4, 5	0, 4	0, 3
Four	2, 3, 5, 6	2, 4, 5	0, 1, 4	0, 1, 3

Table 5.2-3: OFDM symbol indices within a slot of an MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A or ρ_B

Number of antenna ports	OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A				OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_B			
	Normal cyclic prefix		Extended cyclic prefix		Normal cyclic prefix		Extended cyclic prefix	
	n_s mod 2 = 0	n_s mod 2 = 1	n_s mod 2 = 0	n_s mod 2 = 1	n_s mod 2 = 0	n_s mod 2 = 1	n_s mod 2 = 0	n_s mod 2 = 1
One or two	1, 2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	0, 1, 2, 3, 4, 5	0	-	0	-
Four	2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	2, 4, 3, 5	0, 1, 2, 3, 4, 5	0, 1	-	0, 1	-

5.2.1 eNodeB Relative Narrowband TX Power (RNTP) restrictions

The determination of reported Relative Narrowband TX Power indication $RNTP(n_{PRB})$ is defined as follows:

$$RNTP(n_{PRB}) = \begin{cases} 0 & \text{if} \quad \dfrac{E_A(n_{PRB})}{E_{\max\_nom}^{(p)}} \le RNTP_{threshold} \\ 1 & \text{if} \quad \text{no promise about the upper limit of } \dfrac{E_A(n_{PRB})}{E_{\max\_nom}^{(p)}} \text{ is made} \end{cases}$$

where $E_A(n_{PRB})$ is the maximum intended EPRE of UE-specific PDSCH REs in OFDM symbols not containing RS in this physical resource block on antenna port *p* in the considered future time interval; n_{PRB} is the physical resource block number $n_{PRB} = 0,..., N_{RB}^{DL} - 1$; $RNTP_{threshold}$ takes on one of the following values $RNTP_{threshold} \in \{-\infty,-11,-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,0,+1,+2,+3\}$ [dB] and

$$E_{\max\_nom}^{(p)} = \frac{P_{\max}^{(p)} \cdot \dfrac{1}{\Delta f}}{N_{RB}^{DL} \cdot N_{SC}^{RB}}$$

where $P_{\max}^{(p)}$ is the base station maximum output power described in [7], and Δf, N_{RB}^{DL} and N_{SC}^{RB} are defined in [3].

6 Random access procedure

Prior to initiation of the non-synchronized physical random access procedure, Layer 1 shall receive the following information from the higher layers:

1. Random access channel parameters (PRACH configuration and frequency position)
2. Parameters for determining the root sequences and their cyclic shifts in the preamble sequence set for the primary cell (index to logical root sequence table, cyclic shift (N_{CS}), and set type (unrestricted or restricted set))

6.1 Physical non-synchronized random access procedure

From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble and random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB is not prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission.

The following steps are required for the L1 random access procedure:

1. Layer 1 procedure is triggered upon request of a preamble transmission by higher layers.
2. A preamble index, a target preamble received power (PREAMBLE_RECEIVED_TARGET_POWER), a corresponding RA-RNTI and a PRACH resource are indicated by higher layers as part of the request.
3. A preamble transmission power P_{PRACH} is determined as
   P_{PRACH} = min{ $P_{\mathrm{CMAX,c}}(i)$, PREAMBLE_RECEIVED_TARGET_POWER + PL_c }_[dBm], where $P_{\mathrm{CMAX,c}}(i)$ is the configured UE transmit power defined in [6] for subframe *i* of serving cell c and PL_c is the downlink pathloss estimate calculated in the UE for serving cell c .
4. A preamble sequence is selected from the preamble sequence set using the preamble index.
5. A single preamble is transmitted using the selected preamble sequence with transmission power P_{PRACH} on the indicated PRACH resource.
6. Detection of a PDCCH with the indicated RA-RNTI is attempted during a window controlled by higher layers (see [8], clause 5.1.4). If detected, the corresponding DL-SCH transport block is passed to higher layers. The higher layers parse the transport block and indicate the 20-bit uplink grant to the physical layer, which is processed according to clause 6.2.

6.1.1 Timing

For the L1 random access procedure, UE's uplink transmission timing after a random access preamble transmission is as follows.

a. If a PDCCH with associated RA-RNTI is detected in subframe *n*, and the corresponding DL-SCH transport block contains a response to the transmitted preamble sequence, the UE shall, according to the information in the response, transmit an UL-SCH transport block in the first subframe $n+k_1$, $k_1 \geq 6$, if the UL delay field in clause 6.2 is set to zero where $n+k_1$ is the first available UL subframe for PUSCH transmission. The UE shall postpone the PUSCH transmission to the next available UL subframe after $n+k_1$ if the field is set to 1.

b. If a random access response is received in subframe *n*, and the corresponding DL-SCH transport block does not contain a response to the transmitted preamble sequence, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n+5$.

c. If no random access response is received in subframe *n*, where subframe *n* is the last subframe of the random access response window, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n+4$.

In case a random access procedure is initiated by a "PDCCH order" in subframe *n*, the UE shall, if requested by higher layers, transmit random access preamble in the first subframe $n+k_2$, $k_2 \geq 6$, where a PRACH resource is available.

If a UE is configured with multiple TAGs, and if the UE is configured with the carrier indicator field for a given serving cell, the UE shall use the carrier indicator field value from the detected "PDCCH order" to determine the serving cell for the corresponding random access preamble transmission.

6.2 Random Access Response Grant

The higher layers indicate the 20-bit UL Grant to the physical layer, as defined in 3GPP TS 36.321 [8].
This is referred to the Random Access Response Grant in the physical layer.
The content of these 20 bits starting with the MSB and ending with the LSB are as follows:

- Hopping flag – 1 bit
- Fixed size resource block assignment – 10 bits
- Truncated modulation and coding scheme – 4 bits
- TPC command for scheduled PUSCH – 3 bits
- UL delay – 1 bit
- CSI request – 1 bit

The UE shall use the single-antenna port uplink transmission scheme for the PUSCH transmission corresponding to the Random Access Response Grant and the PUSCH retransmission for the same transport block.

The UE shall perform PUSCH frequency hopping if the single bit frequency hopping (FH) field in a corresponding Random Access Response Grant is set as 1 and the uplink resource block assignment is type 0, otherwise no PUSCH frequency hopping is performed. When the hopping flag is set, the UE shall perform PUSCH hopping as indicated via the fixed size resource block assignment detailed below.

The fixed size resource block assignment field is interpreted as follows:

if $N_{\mathrm{RB}}^{\mathrm{UL}} \leq 44$

Truncate the fixed size resource block assignment to its *b* least significant bits, where $b = \left\lceil \log_2\left(N_{\mathrm{RB}}^{\mathrm{UL}} \cdot \left(N_{\mathrm{RB}}^{\mathrm{UL}}+1\right)/2\right)\right\rceil$, and interpret the truncated resource block assignment according to the rules for a regular DCI format 0

else

Insert *b* most significant bits with value set to '0' after the N_{UL_hop} hopping bits in the fixed size resource block assignment, where the number of hopping bits N_{UL_hop} is zero when the hopping flag bit is not set to 1, and is defined in Table 8.4-1 when the hopping flag bit is set to 1, and $b = \left(\left\lceil \log_2\left(N_{\mathrm{RB}}^{\mathrm{UL}} \cdot \left(N_{\mathrm{RB}}^{\mathrm{UL}}+1\right)/2\right)\right\rceil - 10\right)$, and interpret the expanded resource block assignment according to the rules for a regular DCI format 0

end if

The truncated modulation and coding scheme field is interpreted such that the modulation and coding scheme corresponding to the Random Access Response grant is determined from MCS indices 0 through 15 in Table 8.6.1-1.

The TPC command δ_{msg2} shall be used for setting the power of the PUSCH, and is interpreted according to Table 6.2-1.

Table 6.2-1: TPC Command δ_{msg2} for Scheduled PUSCH

TPC Command	Value (in dB)
0	-6
1	-4
2	-2
3	0
4	2
5	4
6	6
7	8

In non-contention based random access procedure, the CSI request field is interpreted to determine whether an aperiodic CQI, PMI, and RI report is included in the corresponding PUSCH transmission according to clause 7.2.1. In contention based random access procedure, the CSI request field is reserved.

The UL delay applies for both TDD and FDD and this field can be set to 0 or 1 to indicate whether the delay of PUSCH is introduced as shown in clause 6.1.1.

7 Physical downlink shared channel related procedures

For FDD, there shall be a maximum of 8 downlink HARQ processes per serving cell.

For TDD, if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, the maximum number of downlink HARQ processes per serving cell shall be determined by the UL/DL configuration (Table 4.2-2 of [3]), as indicated in Table 7-1.

For TDD, if a UE is configured with more than one serving cell and if the TDD UL/DL configuration of at least two configured serving cells is not the same, the maximum number of downlink HARQ processes for a serving cell shall be determined as indicated in Table 7-1, wherein the "TDD UL/DL configuration" in Table 7-1 refers to the DL-reference UL/DL configuration for the serving cell (as defined in clause 10.2).

The dedicated broadcast HARQ process defined in [8] is not counted as part of the maximum number of HARQ processes for both FDD and TDD.

Table 7-1: Maximum number of DL HARQ processes for TDD

TDD UL/DL configuration	Maximum number of HARQ processes
0	4
1	7
2	10
3	9
4	12
5	15
6	6

7.1 UE procedure for receiving the physical downlink shared channel

Except the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* of serving cell c, a UE shall

- upon detection of a PDCCH of the serving cell with DCI format 1, 1A, 1B, 1C, 1D, 2, 2A, 2B, 2C, or 2D intended for the UE in a subframe, or
- upon detection of an EPDCCH of the serving cell with DCI format 1, 1A, 1B, 1D, 2, 2A, 2B, 2C, or 2D intended for the UE in a subframe

decode the corresponding PDSCH in the same subframe with the restriction of the number of transport blocks defined in the higher layers.

A UE may assume that positioning reference signals are not present in resource blocks in which it shall decode PDSCH according to a detected PDCCH with CRC scrambled by the SI-RNTI or P-RNTI with DCI format 1A or 1C intended for the UE.

A UE configured with the carrier indicator field for a given serving cell shall assume that the carrier indicator field is not present in any PDCCH of the serving cell in the common search space that is described in clause 9.1. Otherwise, the configured UE shall assume that for the given serving cell the carrier indicator field is present in PDCCH/EPDCCH located in the UE specific search space described in clause 9.1 when the PDCCH/EPDCCH CRC is scrambled by C-RNTI or SPS C-RNTI.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SI-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-1. The scrambling initialization of PDSCH corresponding to these PDCCHs is by SI-RNTI.

Table 7.1-1: PDCCH and PDSCH configured by SI-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2).
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2).

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the P-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-2.
The scrambling initialization of PDSCH corresponding to these PDCCHs is by P-RNTI.

Table 7.1-2: PDCCH and PDSCH configured by P-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the RA-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-3. The scrambling initialization of PDSCH corresponding to these PDCCHs is by RA-RNTI.

When RA-RNTI and either C-RNTI or SPS C-RNTI are assigned in the same subframe, the UE is not required to decode a PDSCH on the primary cell indicated by a PDCCH/EPDCCH with a CRC scrambled by C-RNTI or SPS C-RNTI.

Table 7.1-3: PDCCH and PDSCH configured by RA-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)

The UE is semi-statically configured via higher layer signalling to receive PDSCH data transmissions signalled via PDCCH/EPDCCH according to one of the transmission modes, denoted mode 1 to mode 10.

For frame structure type 1,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5, 7, 8, 9, 10, 11, 12, 13 or 14 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of either PBCH or primary or secondary synchronization signals in the same subframe;

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7 for which distributed VRB resource allocation is assigned.

- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

For frame structure type 2,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of PBCH in the same subframe;

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7, 8, 9, 10, 11, 12, 13 or 14 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of primary or secondary synchronization signals in the same subframe;

- with normal CP configuration, the UE is not expected to receive PDSCH on antenna port 5 for which distributed VRB resource allocation is assigned in the special subframe with configuration #1 or #6;

- the UE is not expected to receive PDSCH on antenna port 7 for which distributed VRB resource allocation is assigned;

- with normal cyclic prefix, the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in DwPTS when the UE is configured with special subframe configuration 9.

- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and any corresponding PDSCH according to the respective combinations defined in Table 7.1-5. The scrambling initialization of PDSCH corresponding to these PDCCHs is by C-RNTI.

If a UE is configured by higher layers to decode EPDCCH with CRC scrambled by the C-RNTI, the UE shall decode the EPDCCH and any corresponding PDSCH according to the respective combinations defined in Table 7.1-5A. The scrambling initialization of PDSCH corresponding to these EPDCCHs is by C-RNTI.

If the UE is configured with the carrier indicator field for a given serving cell and, if the UE is configured by higher layers to decode PDCCH/EPDCCH with CRC scrambled by the C-RNTI, then the UE shall decode PDSCH of the serving cell indicated by the carrier indicator field value in the decoded PDCCH/EPDCCH.

When a UE configured in transmission mode 3, 4, 8, 9 or 10 receives a DCI Format 1A assignment, it shall assume that the PDSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals corresponding to these PDCCHs/EPDCCHs is by C-RNTI.

The UE does not support transmission mode 8 if extended cyclic prefix is used in the downlink.

When a UE is configured in transmission mode 9 or 10, in the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* of serving cell c except in subframes for the serving cell

- indicated by higher layers to decode PMCH or,

- configured by higher layers to be part of a positioning reference signal occasion and the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix,

the UE shall upon detection of a PDCCH with CRC scrambled by the C-RNTI with DCI format 1A/2C/2D intended for the UE or, upon detection of an EPDCCH with CRC scrambled by the C-RNTI with DCI format 1A/2C/2D intended for the UE, decode the corresponding PDSCH in the same subframe.

A UE configured in transmission mode 10 can be configured with scrambling identities, $n_{\mathrm{ID}}^{\mathrm{DMRS},i}$, $i = 0,1$ by higher layers for UE-specific reference signal generation as defined in clause 6.10.3.1 of [3] to decode PDSCH according to a detected PDCCH/EPDCCH with CRC scrambled by the C-RNTI with DCI format 2D intended for the UE.

Table 7.1-5: PDCCH and PDSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
Mode 1	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 0 (see clause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see clause 7.1.1)
Mode 2	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 3	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Large delay CDD (see clause 7.1.3) or Transmit diversity (see clause 7.1.2)
Mode 4	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Closed-loop spatial multiplexing (see clause 7.1.4)or Transmit diversity (see clause 7.1.2)
Mode 5	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 1D	UE specific by C-RNTI	Multi-user MIMO (see clause 7.1.5)
Mode 6	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 1B	UE specific by C-RNTI	Closed-loop spatial multiplexing (see clause 7.1.4) using a single transmission layer
Mode 7	DCI format 1A	Common and UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see clause 7.1.1)
Mode 8	DCI format 1A	Common and UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)
	DCI format 2B	UE specific by C-RNTI	Dual layer transmission, port 7 and 8 (see clause 7.1.5A) or single-antenna port, port 7 or 8 (see clause 7.1.1)
Mode 9	DCI format 1A	Common andUE specific by C-RNTI	• Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2) • MBSFN subframe: Single-antenna port, port 7 (see clause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see clause 7.1.5B) or single-antenna port, port 7 or 8 (see clause 7.1.1)
Mode 10	DCI format 1A	Common andUE specific by C-RNTI	• Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2) • MBSFN subframe: Single-antenna port, port 7 (see clause 7.1.1)
	DCI format 2D	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see clause 7.1.5B) or single-antenna port, port 7 or 8 (see clause 7.1.1)

Table 7.1-5A: EPDCCH and PDSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to EPDCCH
Mode 1	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 0 (see clause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see clause 7.1.1)
Mode 2	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 3	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Large delay CDD (see clause 7.1.3) or Transmit diversity (see clause 7.1.2)
Mode 4	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Closed-loop spatial multiplexing (see clause 7.1.4)or Transmit diversity (see clause 7.1.2)
Mode 5	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 1D	UE specific by C-RNTI	Multi-user MIMO (see clause 7.1.5)
Mode 6	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 1B	UE specific by C-RNTI	Closed-loop spatial multiplexing (see clause 7.1.4) using a single transmission layer
Mode 7	DCI format 1A	UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see clause 7.1.1)
Mode 8	DCI format 1A	UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)
	DCI format 2B	UE specific by C-RNTI	Dual layer transmission, port 7 and 8 (see clause 7.1.5A) or single-antenna port, port 7 or 8 (see clause 7.1.1)
Mode 9	DCI format 1A	UE specific by C-RNTI	• Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2) • MBSFN subframe: Single-antenna port, port 7 (see clause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see clause 7.1.5B) or single-antenna port, port 7 or 8 (see clause 7.1.1)
Mode 10	DCI format 1A	UE specific by C-RNTI	• Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2) • MBSFN subframe: Single-antenna port, port 7 (see clause 7.1.1)
	DCI format 2D	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see clause 7.1.5B) or single-antenna port, port 7 or 8 (see clause 7.1.1)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH on the primary cell and any corresponding PDSCH on the primary cell according to the respective combinations defined in Table 7.1-6. The same PDSCH related configuration applies in the case that a PDSCH is transmitted without a corresponding PDCCH. The scrambling initialization of PDSCH corresponding to these PDCCHs and PDSCH without a corresponding PDCCH is by SPS C-RNTI.

If a UE is configured by higher layers to decode EPDCCH with CRC scrambled by the SPS C-RNTI, the UE shall decode the EPDCCH on the primary cell and any corresponding PDSCH on the primary cell according to the respective combinations defined in Table 7.1-6A. The same PDSCH related configuration applies in the case that a PDSCH is transmitted without a corresponding EPDCCH. The scrambling initialization of PDSCH corresponding to these EPDCCHs and PDSCH without a corresponding EPDCCH is by SPS C-RNTI.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals for PDSCH corresponding to these PDCCHs/EPDCCHs and for PDSCH without a corresponding PDCCH/EPDCCH is by SPS C-RNTI.

When a UE is configured in transmission mode 9 or 10, in the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* of serving cell c except in subframes for the serving cell

- indicated by higher layers to decode PMCH or,

- configured by higher layers to be part of a positioning reference signal occasion and the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix,

the UE shall upon detection of a PDCCH with CRC scrambled by the SPS C-RNTI with DCI format 1A/2C/2D, or upon detection of a EPDCCH with CRC scrambled by the SPS C-RNTI with DCI format 1A/2C/2D, or for a configured PDSCH without PDCCH intended for the UE, decode the corresponding PDSCH in the same subframe.

A UE configured in transmission mode 10 can be configured with scrambling identities, $n_{\mathrm{ID}}^{\mathrm{DMRS},i}$, $i = 0,1$ by higher layers for UE-specific reference signal generation as defined in clause 6.10.3.1 of [3] to decode PDSCH according to a detected PDCCH/EPDCCH with CRC scrambled by the SPS C-RNTI with DCI format 2D intended for the UE.

For PDSCH without a corresponding PDCCH/EPDCCH, the UE shall use the value of n_{SCID} and the scrambling identity of $n_{\mathrm{ID}}^{(n_{\mathrm{SCID}})}$ (as defined in clause 6.10.3.1 of [3]) derived from the DCI format 2D corresponding to the associated SPS activation for UE-specific reference signal generation.

Table 7.1-6: PDCCH and PDSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
Mode 1	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 0 (see clause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see clause 7.1.1)
Mode 2	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 3	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 4	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 5	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 6	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 7	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 5 (see clause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see clause 7.1.1)
Mode 8	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7(see clause 7.1.1)
	DCI format 2B	UE specific by C-RNTI	Single-antenna port, port 7 or 8 (see clause 7.1.1)
Mode 9	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7 (see clause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Single-antenna port, port 7 or 8, (see clause 7.1.1)
Mode 10	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7 (see clause 7.1.1)
	DCI format 2D	UE specific by C-RNTI	Single-antenna port, port 7 or 8, (see clause 7.1.1)

Table 7.1-6A: EPDCCH and PDSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to EPDCCH
Mode 1	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 0 (see clause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see clause 7.1.1)
Mode 2	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 3	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 4	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 5	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 6	DCI format 1A	UE specific by C-RNTI	Transmit diversity (see clause 7.1.2)
Mode 7	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 5 (see clause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see clause 7.1.1)
Mode 8	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 7(see clause 7.1.1)
	DCI format 2B	UE specific by C-RNTI	Single-antenna port, port 7 or 8 (see clause 7.1.1)
Mode 9	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 7 (see clause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Single-antenna port, port 7 or 8, (see clause 7.1.1)
Mode 10	DCI format 1A	UE specific by C-RNTI	Single-antenna port, port 7 (see clause 7.1.1)
	DCI format 2D	UE specific by C-RNTI	Single-antenna port, port 7 or 8, (see clause 7.1.1)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the Temporary C-RNTI and is not configured to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to the combination defined in Table 7.1-7. The scrambling initialization of PDSCH corresponding to these PDCCHs is by Temporary C-RNTI.

Table 7.1-7: PDCCH and PDSCH configured by Temporary C-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1A	Common and UE specific by Temporary C-RNTI	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)
DCI format 1	UE specific by Temporary C-RNTI	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see clause 7.1.1), otherwise Transmit diversity (see clause 7.1.2)

The transmission schemes of the PDSCH are described in the following sub-clauses.

7.1.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 0, port 5, port 7 or port 8) of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to clause 6.3.4.1 of [3].

In case an antenna port $p \in \{7,8\}$ is used, the UE cannot assume that the other antenna port in the set $\{7,8\}$ is not associated with transmission of PDSCH to another UE.

7.1.2 Transmit diversity scheme

For the transmit diversity transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to clause 6.3.4.3 of [3]

7.1.3 Large delay CDD scheme

For the large delay CDD transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to large delay CDD as defined in clause 6.3.4.2.2 of [3].

7.1.4 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to the applicable number of transmission layers as defined in clause 6.3.4.2.1 of [3].

7.1.5 Multi-user MIMO scheme

For the multi-user MIMO transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed on one layer and according to clause 6.3.4.2.1 of [3]. The $\delta_{\text{power-offset}}$ dB value signalled on PDCCH/EPDCCH with DCI format 1D using the downlink power offset field is given in Table 7.1.5-1.

Table 7.1.5-1: Mapping of downlink power offset field in DCI format 1D to the $\delta_{\text{power-offset}}$ value.

Downlink power offset field	$\delta_{\text{power-offset}}$ [dB]
0	$-10\log_{10}(2)$
1	0

7.1.5A Dual layer scheme

For the dual layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with two transmission layers on antenna ports 7 and 8 as defined in clause 6.3.4.4 of [3].

7.1.5B Up to 8 layer transmission scheme

For the up to 8 layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with up to 8 transmission layers on antenna ports 7 - 14 as defined in clause 6.3.4.4 of [3].

7.1.6 Resource allocation

The UE shall interpret the resource allocation field depending on the PDCCH/EPDCCH DCI format detected. A resource allocation field in each PDCCH/EPDCCH includes two parts, a resource allocation header field and information consisting of the actual resource block assignment.

PDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 0 and PDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 1 resource allocation have the same format and are distinguished from each other via the single bit resource allocation header field which exists depending on the downlink system bandwidth (clause 5.3.3.1 of [4]), where type 0 is indicated by 0 value and type 1 is indicated otherwise. PDCCH with DCI format 1A, 1B, 1C and 1D have a type 2 resource allocation while PDCCH with DCI format 1, 2, 2A, 2B, 2C and 2D have type 0 or type 1 resource allocation. PDCCH DCI formats with a type 2 resource allocation do not have a resource allocation header field.

EPDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 0 and EPDCCH DCI formats 1, 2, 2A, 2B, 2C and 2D with type 1 resource allocation have the same format and are distinguished from each other via the single bit resource allocation header field which exists depending on the downlink system bandwidth (clause 5.3.3.1 of [4]), where type 0 is indicated by 0 value and type 1 is indicated otherwise. EPDCCH with DCI format 1A, 1B, and 1D have a type 2 resource allocation while EPDCCH with DCI format 1, 2, 2A, 2B, 2C and 2D have type 0 or type 1 resource allocation. EPDCCH DCI formats with a type 2 resource allocation do not have a resource allocation header field.

7.1.6.1 Resource allocation type 0

In resource allocations of type 0, resource block assignment information includes a bitmap indicating the Resource Block Groups (RBGs) that are allocated to the scheduled UE where a RBG is a set of consecutive virtual resource blocks (VRBs) of localized type as defined in clause 6.2.3.1 of [3]. Resource block group size (*P*) is a function of the system bandwidth as shown in Table 7.1.6.1-1. The total number of RBGs (N_{RBG}) for downlink system bandwidth of $N_{\mathrm{RB}}^{\mathrm{DL}}$ is given by $N_{RBG} = \lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \rceil$ where $\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P \rfloor$ of the RBGs are of size P and if $N_{\mathrm{RB}}^{\mathrm{DL}} \bmod P > 0$ then one of the RBGs is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - P \cdot \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P \rfloor$. The bitmap is of size N_{RBG} bits with one bitmap bit per RBG such that each RBG is addressable. The RBGs shall be indexed in the order of increasing frequency and non-increasing RBG sizes starting at the lowest frequency. The order of RBG to bitmap bit mapping is in such way that RBG 0 to RBG $N_{\mathrm{RBG}} - 1$ are mapped to MSB to LSB of the bitmap. The RBG is allocated to the UE if the corresponding bit value in the bitmap is 1, the RBG is not allocated to the UE otherwise.

Table 7.1.6.1-1: Type 0 resource allocation RBG size vs. Downlink System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	RBG Size (*P*)
≤10	1
11 – 26	2
27 – 63	3
64 – 110	4

7.1.6.2 Resource allocation type 1

In resource allocations of type 1, a resource block assignment information of size N_{RBG} indicates to a scheduled UE the VRBs from the set of VRBs from one of *P* RBG subsets. The virtual resource blocks used are of localized type as defined in clause 6.2.3.1 of [3]. Also *P* is the RBG size associated with the system bandwidth as shown in Table 7.1.6.1-1. A RBG subset p, where $0 \le p < P$, consists of every P th RBG starting from RBG p. The resource block assignment information consists of three fields [4].

The first field with $\lceil \log_2(P) \rceil$ bits is used to indicate the selected RBG subset among P RBG subsets.

The second field with one bit is used to indicate a shift of the resource allocation span within a subset. A bit value of 1 indicates shift is triggered. Shift is not triggered otherwise.

The third field includes a bitmap, where each bit of the bitmap addresses a single VRB in the selected RBG subset in such a way that MSB to LSB of the bitmap are mapped to the VRBs in the increasing frequency order. The VRB is allocated to the UE if the corresponding bit value in the bit field is 1, the VRB is not allocated to the UE otherwise. The portion of the bitmap used to address VRBs in a selected RBG subset has size $N_{\mathrm{RB}}^{\mathrm{TYPE1}}$ and is defined as

$$N_{\mathrm{RB}}^{\mathrm{TYPE1}} = \lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \rceil - \lceil \log_2(P) \rceil - 1$$

The addressable VRB numbers of a selected RBG subset start from an offset, $\Delta_{\mathrm{shift}}(p)$ to the smallest VRB number within the selected RBG subset, which is mapped to the MSB of the bitmap. The offset is in terms of the number of VRBs and is done within the selected RBG subset. If the value of the bit in the second field for shift of the resource allocation span is set to 0, the offset for RBG subset p is given by $\Delta_{\mathrm{shift}}(p) = 0$. Otherwise, the offset for RBG subset p is given by $\Delta_{\mathrm{shift}}(p) = N_{\mathrm{RB}}^{\mathrm{RBG\ subset}}(p) - N_{\mathrm{RB}}^{\mathrm{TYPE1}}$, where the LSB of the bitmap is justified with the highest VRB number within the selected RBG subset. $N_{\mathrm{RB}}^{\mathrm{RBG\ subset}}(p)$ is the number of VRBs in RBG subset p and can be calculated by the following equation,

$$N_{\mathrm{RB}}^{\mathrm{RBG\ subset}}(p)=\begin{cases}\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P^2}\right\rfloor \cdot P+P & ,p<\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P}\right\rfloor \bmod P \\ \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P^2}\right\rfloor \cdot P+(N_{\mathrm{RB}}^{\mathrm{DL}}-1)\bmod P+1 & ,p=\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P}\right\rfloor \bmod P \\ \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P^2}\right\rfloor \cdot P & ,p>\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}-1}{P}\right\rfloor \bmod P \end{cases}$$

Consequently, when RBG subset p is indicated, bit i for $i=0,1,\cdots,N_{\mathrm{RB}}^{\mathrm{TYPE1}}-1$ in the bitmap field indicates VRB number,

$$n_{\mathrm{VRB}}^{\mathrm{RBG\ subset}}(p)=\left\lfloor \frac{i+\Delta_{\mathrm{shift}}(p)}{P}\right\rfloor P^2+p\cdot P+\left(i+\Delta_{\mathrm{shift}}(p)\right)\bmod P\ .$$

7.1.6.3 Resource allocation type 2

In resource allocations of type 2, the resource block assignment information indicates to a scheduled UE a set of contiguously allocated localized virtual resource blocks or distributed virtual resource blocks. In case of resource allocation signalled with PDCCH DCI format 1A, 1B or 1D, or for resource allocation signalled with EPDCCH DCI format 1A, 1B, or 1D, one bit flag indicates whether localized virtual resource blocks or distributed virtual resource blocks are assigned (value 0 indicates Localized and value 1 indicates Distributed VRB assignment) while distributed virtual resource blocks are always assigned in case of resource allocation signalled with PDCCH DCI format 1C. Localized VRB allocations for a UE vary from a single VRB up to a maximum number of VRBs spanning the system bandwidth. For DCI format 1A the distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs, where $N_{\mathrm{VRB}}^{\mathrm{DL}}$ is defined in [3], if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI. With PDCCH DCI format 1B, 1D with a CRC scrambled by C-RNTI, or with DCI format 1A with a CRC scrambled with C-RNTI, SPS C-RNTI or Temporary C-RNTI distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 6-49 and vary from a single VRB up to 16 if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 50-110. With EPDCCH DCI format 1B, 1D with a CRC scrambled by C-RNTI, or with DCI format 1A with a CRC scrambled with C-RNTI, SPS C-RNTI distributed VRB allocations for a UE vary from a single VRB up to $N_{\mathrm{VRB}}^{\mathrm{DL}}$ VRBs if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 6-49 and vary from a single VRB up to 16 if $N_{\mathrm{RB}}^{\mathrm{DL}}$ is 50-110. With PDCCH DCI format 1C, distributed VRB allocations for a UE vary from $N_{\mathrm{RB}}^{\mathrm{step}}$ VRB(s) up to $\left\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}}/N_{\mathrm{RB}}^{\mathrm{step}}\right\rfloor \cdot N_{\mathrm{RB}}^{\mathrm{step}}$ VRBs with an increment step of $N_{\mathrm{RB}}^{\mathrm{step}}$, where $N_{\mathrm{RB}}^{\mathrm{step}}$ value is determined depending on the downlink system bandwidth as shown in Table 7.1.6.3-1.

Table 7.1.6.3-1: $N_{\mathrm{RB}}^{\mathrm{step}}$ values vs. Downlink System Bandwidth

System BW ($N_{\mathrm{RB}}^{\mathrm{DL}}$)	$N_{\mathrm{RB}}^{\mathrm{step}}$
	DCI format 1C
6-49	2
50-110	4

For PDCCH DCI format 1A, 1B or 1D, or for EPDCCH DCI format 1A, 1B, or 1D, a type 2 resource allocation field consists of a resource indication value (*RIV*) corresponding to a starting resource block (RB_{start}) and a length in terms of virtually contiguously allocated resource blocks L_{CRBs} . The resource indication value is defined by

if $(L_{CRBs}-1)\le \left\lfloor N_{RB}^{DL}/2\right\rfloor$ then

$$RIV=N_{RB}^{DL}(L_{CRBs}-1)+RB_{start}$$

else

$$RIV = N_{RB}^{DL}(N_{RB}^{DL} - L_{CRBs} + 1) + (N_{RB}^{DL} - 1 - RB_{start})$$

where $L_{CRBs} \geq 1$ and shall not exceed $N_{VRB}^{DL} - RB_{start}$.

For PDCCH DCI format 1C, a type 2 resource block assignment field consists of a resource indication value (*RIV*) corresponding to a starting resource block ($RB_{start} = 0$, $N_{\mathrm{RB}}^{\mathrm{step}}$, $2N_{\mathrm{RB}}^{\mathrm{step}}, \ldots$, $(\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}} / N_{\mathrm{RB}}^{\mathrm{step}} \rfloor - 1) N_{\mathrm{RB}}^{\mathrm{step}}$) and a length in terms of virtually contiguously allocated resource blocks ($L_{CRBs} = N_{\mathrm{RB}}^{\mathrm{step}}$, $2N_{\mathrm{RB}}^{\mathrm{step}}, \ldots$, $\lfloor N_{\mathrm{VRB}}^{\mathrm{DL}} / N_{\mathrm{RB}}^{\mathrm{step}} \rfloor \cdot N_{\mathrm{RB}}^{\mathrm{step}}$).
The resource indication value is defined by:

if $(L'_{CRBs} - 1) \leq \lfloor N'^{DL}_{VRB} / 2 \rfloor$ then

$$RIV = N'^{DL}_{VRB}(L'_{CRBs} - 1) + RB'_{start}$$

else

$$RIV = N'^{DL}_{VRB}(N'^{DL}_{VRB} - L'_{CRBs} + 1) + (N'^{DL}_{VRB} - 1 - RB'_{start})$$

where $L'_{CRBs} = L_{CRBs} / N_{RB}^{step}$, $RB'_{start} = RB_{start} / N_{RB}^{step}$ and $N'^{DL}_{VRB} = \lfloor N_{VRB}^{DL} / N_{RB}^{step} \rfloor$. Here,

$L'_{CRBs} \geq 1$ and shall not exceed $N'^{DL}_{VRB} - RB'_{start}$.

7.1.6.4 PDSCH starting position

The starting OFDM symbol for the PDSCH of each activated serving cell is given by index $l_{\mathrm{DataStart}}$ in the first slot in a subframe.

For a UE configured in transmission mode 1-9, for a given activated serving cell

- if the PDSCH is assigned by EPDCCH received in the same serving cell, or if the UE is configured to monitor EPDCCH in the subframe and the PDSCH is not assigned by a PDCCH/EPDCCH, and if the UE is configured with the higher layer parameter *epdcch-StartSymbol-r11*
  - o $l_{\mathrm{DataStart}}$ is given by the higher-layer parameter *epdcch-StartSymbol-r11*.
- else if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells
  - o $l_{\mathrm{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received,
- Otherwise
  - o $l_{\mathrm{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, and $l_{\mathrm{DataStart}}$ is given by the CFI value + 1 in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 10$.

For a UE configured in transmission mode 10, for a given activated serving cell

- if the PDSCH is assigned by a PDCCH with DCI format 1C or by a PDCCH with DCI format 1A and with CRC scrambled with P-RNTI/RA-RNTI/SI-RNTI/Temporary C-RNTI
  - o $l_{\mathrm{DataStart}}$ is given by the span of the DCI given by the CFI value in the subframe of the given serving cell according to clause 5.3.4 of [4].
- if the PDSCH is assigned by a PDCCH/EPDCCH with DCI format 1A and with CRC scrambled with C-RNTI and if the PDSCH transmission is on antenna ports 0 - 3
  - o if the PDSCH is assigned by EPDCCH received in the same serving cell

        - $l_{\text{DataStart}}$ is given by $l_{\text{EPDCCHStart}}$ for the EPDCCH-PRB-set where EPDCCH with the DCI format 1A was received ($l_{\text{EPDCCHStart}}$ as defined in clause 9.1.4.1),
    - else if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells
        - $l_{\text{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received.
    - otherwise
        - $l_{\text{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{DataStart}}$ is given by the CFI value+1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \leq 10$.
- if the PDSCH is assigned by or semi-statically scheduled by a PDCCH/EPDCCH with DCI format 1A and if the PDSCH transmission is on antenna port 7
    - if the value of the higher layer parameter *pdsch-Start-r11* determined from parameter set 1 in table 7.1.9-1 for the serving cell on which PDSCH is received belongs to {1,2,3,4},
        - $l'_{\text{DataStart}}$ is given by the higher layer parameter *pdsch-Start-r11* determined from parameter set 1 in table 7.1.9-1 for the serving cell on which PDSCH is received.
    - else,
        - if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells,
            - $l'_{\text{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received
        - otherwise
            - $l'_{\text{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{DataStart}}$ is given by the CFI value + 1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \leq 10$.
    - if the subframe on which PDSCH is received is indicated by the higher layer parameter *mbsfn-SubframeConfigList-r11* determined from parameter set 1 in table 7.1.9-1 for the serving cell on which PDSCH is received, or if the PDSCH is received on subframe 1 or 6 for the frame structure type 2,
        - $l_{\text{DataStart}} = \min(2, l'_{\text{DataStart}})$,
    - otherwise
        - $l_{\text{DataStart}} = l'_{\text{DataStart}}$.
- if the PDSCH is assigned by or semi-persistently scheduled by a PDCCH/EPDCCH with DCI format 2D,
    - if the value of the higher layer parameter *pdsch-Start-r11* determined from the DCI (according to clause 7.1.9) for the serving cell on which PDSCH is received belongs to {1,2,3,4},
        - $l'_{\text{DataStart}}$ is given by parameter *pdsch-Start-r11* determined from the DCI (according to clause 7.1.9) for the serving cell on which PDSCH is received
    - else,
        - if PDSCH and the corresponding PDCCH/EPDCCH are received on different serving cells,
            - $l'_{\text{DataStart}}$ is given by the higher-layer parameter *pdsch-Start-r10* for the serving cell on which PDSCH is received
        - Otherwise

- $l'_{\mathrm{DataStart}}$ is given by the CFI value in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, and $l_{\mathrm{DataStart}}$ is given by the CFI value+1 in the subframe of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 10$.

– if the subframe on which PDSCH is received is indicated by the higher layer parameter *mbsfn-SubframeConfigList-r11* determined from the DCI (according to clause 7.1.9) for the serving cell on which PDSCH is received, or if the PDSCH is received on subframe 1 or 6 for frame structure type 2,

  o $l_{\mathrm{DataStart}} = \min(2, l'_{\mathrm{DataStart}})$,

– otherwise

  o $l_{\mathrm{DataStart}} = l'_{\mathrm{DataStart}}$.

7.1.6.5 Physical Resource Block (PRB) bundling

A UE configured for transmission mode 9 for a given serving cell *c* may assume that precoding granularity is multiple resource blocks in the frequency domain when PMI/RI reporting is configured.

For a given serving cell c, if a UE is configured for transmission mode 10

- if PMI/RI reporting is configured for all configured CSI processes for the serving cell *c*, the UE may assume that precoding granularity is multiple resource blocks in the frequency domain,
- otherwise, the UE shall assume the precoding granularity is one resource block in the frequency domain.

Fixed system bandwidth dependent Precoding Resource block Groups (PRGs) of size P' partition the system bandwidth and each PRG consists of consecutive PRBs. If $N_{\mathrm{RB}}^{\mathrm{DL}} \bmod P' > 0$ then one of the PRGs is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - P' \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / P' \rfloor$. The PRG size is non-increasing starting at the lowest frequency. The UE may assume that the same precoder applies on all scheduled PRBs within a PRG.

The PRG size a UE may assume for a given system bandwidth is given by:

Table 7.1.6.5-1

System Bandwidth ($N_{\mathrm{RB}}^{\mathrm{DL}}$)	PRG Size (P') (PRBs)
≤10	1
11 – 26	2
27 – 63	3
64 – 110	2

7.1.7 Modulation order and transport block size determination

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

- read the 5-bit "modulation and coding scheme" field (I_{MCS}) in the DCI

and second if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A:
    - o set the Table 7.1.7.2.1-1 column indicator N_{PRB} to $N_{\mathrm{PRB}}^{\mathrm{1A}}$ from clause 5.3.3.1.3 in [4]
- for DCI format 1C:
    - o use Table 7.1.7.2.3-1 for determining its transport block size.

else

- set N'_{PRB} to the total number of allocated PRBs based on the procedure defined in clause 7.1.6.

  if the transport block is transmitted in DwPTS of the special subframe in frame structure type 2, then

    - o for special subframe configuration 9 with normal cyclic prefix or special subframe configuration 7 with extended cyclic prefix:
        - ■ set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = \max\left\{\left\lfloor N'_{\mathrm{PRB}} \times 0.375 \right\rfloor, \quad 1\right\}$
    - o for other special subframe configurations:
        - ■ set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = \max\left\{\left\lfloor N'_{\mathrm{PRB}} \times 0.75 \right\rfloor, \quad 1\right\}$,

  else, set the Table 7.1.7.2.1-1 column indicator $N_{PRB} = N'_{PRB}$.

The UE may skip decoding a transport block in an initial transmission if the effective channel code rate is higher than 0.930, where the effective channel code rate is defined as the number of downlink information bits (including CRC bits) divided by the number of physical channel bits on PDSCH. If the UE skips decoding, the physical layer indicates to higher layer that the transport block is not successfully decoded. For the special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP, shown in Table 4.2-1 of [3], there shall be no PDSCH transmission in DwPTS of the special subframe.

7.1.7.1 Modulation order determination

The UE shall use Q_m = 2 if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI, otherwise, the UE shall use I_{MCS} and Table 7.1.7.1-1 to determine the modulation order (Q_m) used in the physical downlink shared channel.

Table 7.1.7.1-1: Modulation and TBS index table for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
0	2	0
1	2	1
2	2	2
3	2	3
4	2	4
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	4	9
11	4	10
12	4	11
13	4	12
14	4	13
15	4	14
16	4	15
17	6	15
18	6	16
19	6	17
20	6	18
21	6	19
22	6	20
23	6	21
24	6	22
25	6	23
26	6	24
27	6	25
28	6	26
29	2	reserved
30	4	
31	6	

7.1.7.2 Transport block size determination

If the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A:
  - o the UE shall set the TBS index (I_{TBS}) equal to I_{MCS} and determine its TBS by the procedure in clause 7.1.7.2.1.
- for DCI format 1C:
  - o the UE shall set the TBS index (I_{TBS}) equal to I_{MCS} and determine its TBS from Table 7.1.7.2.3-1.

else

- for $0 \le I_{MCS} \le 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 7.1.7.1-1 except if the transport block is disabled in DCI formats 2, 2A, 2B, 2C and 2D as specified below. For a transport block that is not mapped to more than single-layer spatial multiplexing, the TBS is determined by the procedure in clause 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in clause 7.1.7.2.2. For a transport block that is mapped to three-layer spatial multiplexing, the TBS is determined by the procedure in clause 7.1.7.2.4. For a transport block that is mapped to four-layer spatial multiplexing, the TBS is determined by the procedure in clause 7.1.7.2.5.

- for $29 \le I_{MCS} \le 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH/EPDCCH for the same transport block using $0 \le I_{MCS} \le 28$. If there is no PDCCH/EPDCCH for the same transport block using $0 \le I_{MCS} \le 28$, and if the initial PDSCH for the same transport block is semi-persistently scheduled, the TBS shall be determined from the most recent semi-persistent scheduling assignment PDCCH/EPDCCH.

- In DCI formats 2, 2A, 2B, 2C and 2D a transport block is disabled if $I_{MCS} = 0$ and if $rv_{idx} = 1$ otherwise the transport block is enabled.

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

7.1.7.2.1 Transport blocks not mapped to two or more layer spatial multiplexing

For $1 \le N_{PRB} \le 110$, the TBS is given by the (I_{TBS}, N_{PRB}) entry of Table 7.1.7.2.1-1.

Table 7.1.7.2.1-1: Transport block size table (dimension 27×110)

I_{TBS}	N_{PRB}									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	16	32	56	88	120	152	176	208	224	256
1	24	56	88	144	176	208	224	256	328	344
2	32	72	144	176	208	256	296	328	376	424
3	40	104	176	208	256	328	392	440	504	568
4	56	120	208	256	328	408	488	552	632	696
5	72	144	224	328	424	504	600	680	776	872
6	328	176	256	392	504	600	712	808	936	1032
7	104	224	328	472	584	712	840	968	1096	1224
8	120	256	392	536	680	808	968	1096	1256	1384
9	136	296	456	616	776	936	1096	1256	1416	1544
10	144	328	504	680	872	1032	1224	1384	1544	1736
11	176	376	584	776	1000	1192	1384	1608	1800	2024
12	208	440	680	904	1128	1352	1608	1800	2024	2280
13	224	488	744	1000	1256	1544	1800	2024	2280	2536
14	256	552	840	1128	1416	1736	1992	2280	2600	2856
15	280	600	904	1224	1544	1800	2152	2472	2728	3112
16	328	632	968	1288	1608	1928	2280	2600	2984	3240
17	336	696	1064	1416	1800	2152	2536	2856	3240	3624
18	376	776	1160	1544	1992	2344	2792	3112	3624	4008
19	408	840	1288	1736	2152	2600	2984	3496	3880	4264
20	440	904	1384	1864	2344	2792	3240	3752	4136	4584
21	488	1000	1480	1992	2472	2984	3496	4008	4584	4968
22	520	1064	1608	2152	2664	3240	3752	4264	4776	5352
23	552	1128	1736	2280	2856	3496	4008	4584	5160	5736
24	584	1192	1800	2408	2984	3624	4264	4968	5544	5992
25	616	1256	1864	2536	3112	3752	4392	5160	5736	6200
26	712	1480	2216	2984	3752	4392	5160	5992	6712	7480

I_{TBS}	N_{PRB}									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
0	288	328	344	376	392	424	456	488	504	536
1	376	424	456	488	520	568	600	632	680	712
2	472	520	568	616	648	696	744	776	840	872
3	616	680	744	808	872	904	968	1032	1096	1160
4	776	840	904	1000	1064	1128	1192	1288	1352	1416
5	968	1032	1128	1224	1320	1384	1480	1544	1672	1736
6	1128	1224	1352	1480	1544	1672	1736	1864	1992	2088
7	1320	1480	1608	1672	1800	1928	2088	2216	2344	2472
8	1544	1672	1800	1928	2088	2216	2344	2536	2664	2792
9	1736	1864	2024	2216	2344	2536	2664	2856	2984	3112
10	1928	2088	2280	2472	2664	2792	2984	3112	3368	3496
11	2216	2408	2600	2792	2984	3240	3496	3624	3880	4008
12	2472	2728	2984	3240	3368	3624	3880	4136	4392	4584
13	2856	3112	3368	3624	3880	4136	4392	4584	4968	5160
14	3112	3496	3752	4008	4264	4584	4968	5160	5544	5736
15	3368	3624	4008	4264	4584	4968	5160	5544	5736	6200

16	3624	3880	4264	4584	4968	5160	5544	5992	6200	6456
17	4008	4392	4776	5160	5352	5736	6200	6456	6712	7224
18	4392	4776	5160	5544	5992	6200	6712	7224	7480	7992
19	4776	5160	5544	5992	6456	6968	7224	7736	8248	8504
20	5160	5544	5992	6456	6968	7480	7992	8248	8760	9144
21	5544	5992	6456	6968	7480	7992	8504	9144	9528	9912
22	5992	6456	6968	7480	7992	8504	9144	9528	10296	10680
23	6200	6968	7480	7992	8504	9144	9912	10296	11064	11448
24	6712	7224	7992	8504	9144	9912	10296	11064	11448	12216
25	6968	7480	8248	8760	9528	10296	10680	11448	12216	12576
26	8248	8760	9528	10296	11064	11832	12576	13536	14112	14688

I_{TBS}	N_{PRB}									
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
0	568	600	616	648	680	712	744	776	776	808
1	744	776	808	872	904	936	968	1000	1032	1064
2	936	968	1000	1064	1096	1160	1192	1256	1288	1320
3	1224	1256	1320	1384	1416	1480	1544	1608	1672	1736
4	1480	1544	1608	1736	1800	1864	1928	1992	2088	2152
5	1864	1928	2024	2088	2216	2280	2344	2472	2536	2664
6	2216	2280	2408	2472	2600	2728	2792	2984	2984	3112
7	2536	2664	2792	2984	3112	3240	3368	3368	3496	3624
8	2984	3112	3240	3368	3496	3624	3752	3880	4008	4264
9	3368	3496	3624	3752	4008	4136	4264	4392	4584	4776
10	3752	3880	4008	4264	4392	4584	4776	4968	5160	5352
11	4264	4392	4584	4776	4968	5352	5544	5736	5992	5992
12	4776	4968	5352	5544	5736	5992	6200	6456	6712	6712
13	5352	5736	5992	6200	6456	6712	6968	7224	7480	7736
14	5992	6200	6456	6968	7224	7480	7736	7992	8248	8504
15	6456	6712	6968	7224	7736	7992	8248	8504	8760	9144
16	6712	7224	7480	7736	7992	8504	8760	9144	9528	9912
17	7480	7992	8248	8760	9144	9528	9912	10296	10296	10680
18	8248	8760	9144	9528	9912	10296	10680	11064	11448	11832
19	9144	9528	9912	10296	10680	11064	11448	12216	12576	12960
20	9912	10296	10680	11064	11448	12216	12576	12960	13536	14112
21	10680	11064	11448	12216	12576	12960	13536	14112	14688	15264
22	11448	11832	12576	12960	13536	14112	14688	15264	15840	16416
23	12216	12576	12960	13536	14112	14688	15264	15840	16416	16992
24	12960	13536	14112	14688	15264	15840	16416	16992	17568	18336
25	13536	14112	14688	15264	15840	16416	16992	17568	18336	19080
26	15264	16416	16992	17568	18336	19080	19848	20616	21384	22152

I_{TBS}	N_{PRB}									
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
0	840	872	904	936	968	1000	1032	1032	1064	1096
1	1128	1160	1192	1224	1256	1288	1352	1384	1416	1416
2	1384	1416	1480	1544	1544	1608	1672	1672	1736	1800
3	1800	1864	1928	1992	2024	2088	2152	2216	2280	2344
4	2216	2280	2344	2408	2472	2600	2664	2728	2792	2856
5	2728	2792	2856	2984	3112	3112	3240	3368	3496	3496
6	3240	3368	3496	3496	3624	3752	3880	4008	4136	4136
7	3752	3880	4008	4136	4264	4392	4584	4584	4776	4968
8	4392	4584	4584	4776	4968	4968	5160	5352	5544	5544
9	4968	5160	5160	5352	5544	5736	5736	5992	6200	6200
10	5544	5736	5736	5992	6200	6200	6456	6712	6712	6968
11	6200	6456	6712	6968	6968	7224	7480	7736	7736	7992
12	6968	7224	7480	7736	7992	8248	8504	8760	8760	9144
13	7992	8248	8504	8760	9144	9144	9528	9912	9912	10296
14	8760	9144	9528	9912	9912	10296	10680	11064	11064	11448
15	9528	9912	10296	10296	10680	11064	11448	11832	11832	12216
16	9912	10296	10680	11064	11448	11832	12216	12216	12576	12960
17	11064	11448	11832	12216	12576	12960	13536	13536	14112	14688
18	12216	12576	12960	13536	14112	14112	14688	15264	15264	15840
19	13536	13536	14112	14688	15264	15264	15840	16416	16992	16992
20	14688	14688	15264	15840	16416	16992	16992	17568	18336	18336
21	15840	15840	16416	16992	17568	18336	18336	19080	19848	19848
22	16992	16992	17568	18336	19080	19080	19848	20616	21384	21384
23	17568	18336	19080	19848	19848	20616	21384	22152	22152	22920
24	19080	19848	19848	20616	21384	22152	22920	22920	23688	24496
25	19848	20616	20616	21384	22152	22920	23688	24496	24496	25456
26	22920	23688	24496	25456	25456	26416	27376	28336	29296	29296

I_{TBS}	N_{PRB}									
	41	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
0	1128	1160	1192	1224	1256	1256	1288	1320	1352	1384
1	1480	1544	1544	1608	1608	1672	1736	1736	1800	1800
2	1800	1864	1928	1992	2024	2088	2088	2152	2216	2216
3	2408	2472	2536	2536	2600	2664	2728	2792	2856	2856
4	2984	2984	3112	3112	3240	3240	3368	3496	3496	3624
5	3624	3752	3752	3880	4008	4008	4136	4264	4392	4392
6	4264	4392	4584	4584	4776	4776	4968	4968	5160	5160
7	4968	5160	5352	5352	5544	5736	5736	5992	5992	6200
8	5736	5992	5992	6200	6200	6456	6456	6712	6968	6968
9	6456	6712	6712	6968	6968	7224	7480	7480	7736	7992
10	7224	7480	7480	7736	7992	7992	8248	8504	8504	8760
11	8248	8504	8760	8760	9144	9144	9528	9528	9912	9912
12	9528	9528	9912	9912	10296	10680	10680	11064	11064	11448
13	10680	10680	11064	11448	11448	11832	12216	12216	12576	12960
14	11832	12216	12216	12576	12960	12960	13536	13536	14112	14112
15	12576	12960	12960	13536	13536	14112	14688	14688	15264	15264
16	13536	13536	14112	14112	14688	14688	15264	15840	15840	16416
17	14688	15264	15264	15840	16416	16416	16992	17568	17568	18336
18	16416	16416	16992	17568	17568	18336	18336	19080	19080	19848
19	17568	18336	18336	19080	19080	19848	20616	20616	21384	21384
20	19080	19848	19848	20616	20616	21384	22152	22152	22920	22920
21	20616	21384	21384	22152	22920	22920	23688	24496	24496	25456
22	22152	22920	22920	23688	24496	24496	25456	25456	26416	27376
23	23688	24496	24496	25456	25456	26416	27376	27376	28336	28336
24	25456	25456	26416	26416	27376	28336	28336	29296	29296	30576
25	26416	26416	27376	28336	28336	29296	29296	30576	31704	31704
26	30576	30576	31704	32856	32856	34008	35160	35160	36696	36696

I_{TBS}	N_{PRB}									
	51	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
0	1416	1416	1480	1480	1544	1544	1608	1608	1608	1672
1	1864	1864	1928	1992	1992	2024	2088	2088	2152	2152
2	2280	2344	2344	2408	2472	2536	2536	2600	2664	2664
3	2984	2984	3112	3112	3240	3240	3368	3368	3496	3496
4	3624	3752	3752	3880	4008	4008	4136	4136	4264	4264
5	4584	4584	4776	4776	4776	4968	4968	5160	5160	5352
6	5352	5352	5544	5736	5736	5992	5992	5992	6200	6200
7	6200	6456	6456	6712	6712	6712	6968	6968	7224	7224
8	7224	7224	7480	7480	7736	7736	7992	7992	8248	8504
9	7992	8248	8248	8504	8760	8760	9144	9144	9144	9528
10	9144	9144	9144	9528	9528	9912	9912	10296	10296	10680
11	10296	10680	10680	11064	11064	11448	11448	11832	11832	12216
12	11832	11832	12216	12216	12576	12576	12960	12960	13536	13536
13	12960	13536	13536	14112	14112	14688	14688	14688	15264	15264
14	14688	14688	15264	15264	15840	15840	16416	16416	16992	16992
15	15840	15840	16416	16416	16992	16992	17568	17568	18336	18336
16	16416	16992	16992	17568	17568	18336	18336	19080	19080	19848
17	18336	19080	19080	19848	19848	20616	20616	20616	21384	21384
18	19848	20616	21384	21384	22152	22152	22920	22920	23688	23688
19	22152	22152	22920	22920	23688	24496	24496	25456	25456	25456
20	23688	24496	24496	25456	25456	26416	26416	27376	27376	28336
21	25456	26416	26416	27376	27376	28336	28336	29296	29296	30576
22	27376	28336	28336	29296	29296	30576	30576	31704	31704	32856
23	29296	29296	30576	30576	31704	31704	32856	32856	34008	34008
24	31704	31704	32856	32856	34008	34008	35160	35160	36696	36696
25	32856	32856	34008	34008	35160	35160	36696	36696	37888	37888
26	37888	37888	39232	40576	40576	40576	42368	42368	43816	43816

I_{TBS}	N_{PRB}									
	61	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**
0	1672	1736	1736	1800	1800	1800	1864	1864	1928	1928
1	2216	2280	2280	2344	2344	2408	2472	2472	2536	2536
2	2728	2792	2856	2856	2856	2984	2984	3112	3112	3112
3	3624	3624	3624	3752	3752	3880	3880	4008	4008	4136
4	4392	4392	4584	4584	4584	4776	4776	4968	4968	4968
5	5352	5544	5544	5736	5736	5736	5992	5992	5992	6200
6	6456	6456	6456	6712	6712	6968	6968	6968	7224	7224
7	7480	7480	7736	7736	7992	7992	8248	8248	8504	8504

8	8504	8760	8760	9144	9144	9144	9528	9528	9528	9912
9	9528	9912	9912	10296	10296	10296	10680	10680	11064	11064
10	10680	11064	11064	11448	11448	11448	11832	11832	12216	12216
11	12216	12576	12576	12960	12960	13536	13536	13536	14112	14112
12	14112	14112	14112	14688	14688	15264	15264	15264	15840	15840
13	15840	15840	16416	16416	16992	16992	16992	17568	17568	18336
14	17568	17568	18336	18336	18336	19080	19080	19848	19848	19848
15	18336	19080	19080	19848	19848	20616	20616	20616	21384	21384
16	19848	19848	20616	20616	21384	21384	22152	22152	22152	22920
17	22152	22152	22920	22920	23688	23688	24496	24496	24496	25456
18	24496	24496	24496	25456	25456	26416	26416	27376	27376	27376
19	26416	26416	27376	27376	28336	28336	29296	29296	29296	30576
20	28336	29296	29296	29296	30576	30576	31704	31704	31704	32856
21	30576	31704	31704	31704	32856	32856	34008	34008	35160	35160
22	32856	34008	34008	34008	35160	35160	36696	36696	36696	37888
23	35160	35160	36696	36696	37888	37888	37888	39232	39232	40576
24	36696	37888	37888	39232	39232	40576	40576	42368	42368	42368
25	39232	39232	40576	40576	40576	42368	42368	43816	43816	43816
26	45352	45352	46888	46888	48936	48936	48936	51024	51024	52752

I_{TBS}	N_{PRB}									
	71	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
0	1992	1992	2024	2088	2088	2088	2152	2152	2216	2216
1	2600	2600	2664	2728	2728	2792	2792	2856	2856	2856
2	3240	3240	3240	3368	3368	3368	3496	3496	3496	3624
3	4136	4264	4264	4392	4392	4392	4584	4584	4584	4776
4	5160	5160	5160	5352	5352	5544	5544	5544	5736	5736
5	6200	6200	6456	6456	6712	6712	6712	6968	6968	6968
6	7480	7480	7736	7736	7736	7992	7992	8248	8248	8248
7	8760	8760	8760	9144	9144	9144	9528	9528	9528	9912
8	9912	9912	10296	10296	10680	10680	10680	11064	11064	11064
9	11064	11448	11448	11832	11832	11832	12216	12216	12576	12576
10	12576	12576	12960	12960	12960	13536	13536	13536	14112	14112
11	14112	14688	14688	14688	15264	15264	15840	15840	15840	16416
12	16416	16416	16416	16992	16992	17568	17568	17568	18336	18336
13	18336	18336	19080	19080	19080	19848	19848	19848	20616	20616
14	20616	20616	20616	21384	21384	22152	22152	22152	22920	22920
15	22152	22152	22152	22920	22920	23688	23688	23688	24496	24496
16	22920	23688	23688	24496	24496	24496	25456	25456	25456	26416
17	25456	26416	26416	26416	27376	27376	27376	28336	28336	29296
18	28336	28336	29296	29296	29296	30576	30576	30576	31704	31704
19	30576	30576	31704	31704	32856	32856	32856	34008	34008	34008
20	32856	34008	34008	34008	35160	35160	35160	36696	36696	36696
21	35160	36696	36696	36696	37888	37888	39232	39232	39232	40576
22	37888	39232	39232	40576	40576	40576	42368	42368	42368	43816
23	40576	40576	42368	42368	43816	43816	43816	45352	45352	45352
24	43816	43816	45352	45352	45352	46888	46888	46888	48936	48936
25	45352	45352	46888	46888	46888	48936	48936	48936	51024	51024
26	52752	52752	55056	55056	55056	55056	57336	57336	57336	59256

I_{TBS}	N_{PRB}									
	81	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
0	2280	2280	2280	2344	2344	2408	2408	2472	2472	2536
1	2984	2984	2984	3112	3112	3112	3240	3240	3240	3240
2	3624	3624	3752	3752	3880	3880	3880	4008	4008	4008
3	4776	4776	4776	4968	4968	4968	5160	5160	5160	5352
4	5736	5992	5992	5992	5992	6200	6200	6200	6456	6456
5	7224	7224	7224	7480	7480	7480	7736	7736	7736	7992
6	8504	8504	8760	8760	8760	9144	9144	9144	9144	9528
7	9912	9912	10296	10296	10296	10680	10680	10680	11064	11064
8	11448	11448	11448	11832	11832	12216	12216	12216	12576	12576
9	12960	12960	12960	13536	13536	13536	13536	14112	14112	14112
10	14112	14688	14688	14688	14688	15264	15264	15264	15840	15840
11	16416	16416	16992	16992	16992	17568	17568	17568	18336	18336
12	18336	19080	19080	19080	19080	19848	19848	19848	20616	20616
13	20616	21384	21384	21384	22152	22152	22152	22920	22920	22920
14	22920	23688	23688	24496	24496	24496	25456	25456	25456	25456
15	24496	25456	25456	25456	26416	26416	26416	27376	27376	27376
16	26416	26416	27376	27376	27376	28336	28336	28336	29296	29296
17	29296	29296	30576	30576	30576	30576	31704	31704	31704	32856
18	31704	32856	32856	32856	34008	34008	34008	35160	35160	35160
19	35160	35160	35160	36696	36696	36696	37888	37888	37888	39232

20	37888	37888	39232	39232	39232	40576	40576	40576	42368	42368
21	40576	40576	42368	42368	42368	43816	43816	43816	45352	45352
22	43816	43816	45352	45352	45352	46888	46888	46888	48936	48936
23	46888	46888	46888	48936	48936	48936	51024	51024	51024	51024
24	48936	51024	51024	51024	52752	52752	52752	52752	55056	55056
25	51024	52752	52752	52752	55056	55056	55056	55056	57336	57336
26	59256	59256	61664	61664	61664	63776	63776	63776	66592	66592

I_{TBS}	N_{PRB}									
	91	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**
0	2536	2536	2600	2600	2664	2664	2728	2728	2728	2792
1	3368	3368	3368	3496	3496	3496	3496	3624	3624	3624
2	4136	4136	4136	4264	4264	4264	4392	4392	4392	4584
3	5352	5352	5352	5544	5544	5544	5736	5736	5736	5736
4	6456	6456	6712	6712	6712	6968	6968	6968	6968	7224
5	7992	7992	8248	8248	8248	8504	8504	8760	8760	8760
6	9528	9528	9528	9912	9912	9912	10296	10296	10296	10296
7	11064	11448	11448	11448	11448	11832	11832	11832	12216	12216
8	12576	12960	12960	12960	13536	13536	13536	13536	14112	14112
9	14112	14688	14688	14688	15264	15264	15264	15264	15840	15840
10	15840	16416	16416	16416	16992	16992	16992	16992	17568	17568
11	18336	18336	19080	19080	19080	19080	19848	19848	19848	19848
12	20616	21384	21384	21384	21384	22152	22152	22152	22920	22920
13	23688	23688	23688	24496	24496	24496	25456	25456	25456	25456
14	26416	26416	26416	27376	27376	27376	28336	28336	28336	28336
15	28336	28336	28336	29296	29296	29296	29296	30576	30576	30576
16	29296	30576	30576	30576	30576	31704	31704	31704	31704	32856
17	32856	32856	34008	34008	34008	35160	35160	35160	35160	36696
18	36696	36696	36696	37888	37888	37888	37888	39232	39232	39232
19	39232	39232	40576	40576	40576	40576	42368	42368	42368	43816
20	42368	42368	43816	43816	43816	45352	45352	45352	46888	46888
21	45352	46888	46888	46888	46888	48936	48936	48936	48936	51024
22	48936	48936	51024	51024	51024	51024	52752	52752	52752	55056
23	52752	52752	52752	55056	55056	55056	55056	57336	57336	57336
24	55056	57336	57336	57336	57336	59256	59256	59256	61664	61664
25	57336	59256	59256	59256	61664	61664	61664	61664	63776	63776
26	66592	68808	68808	68808	71112	71112	71112	73712	73712	75376

I_{TBS}	N_{PRB}									
	101	**102**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**
0	2792	2856	2856	2856	2984	2984	2984	2984	2984	3112
1	3752	3752	3752	3752	3880	3880	3880	4008	4008	4008
2	4584	4584	4584	4584	4776	4776	4776	4776	4968	4968
3	5992	5992	5992	5992	6200	6200	6200	6200	6456	6456
4	7224	7224	7480	7480	7480	7480	7736	7736	7736	7992
5	8760	9144	9144	9144	9144	9528	9528	9528	9528	9528
6	10680	10680	10680	10680	11064	11064	11064	11448	11448	11448
7	12216	12576	12576	12576	12960	12960	12960	12960	13536	13536
8	14112	14112	14688	14688	14688	14688	15264	15264	15264	15264
9	15840	16416	16416	16416	16416	16992	16992	16992	16992	17568
10	17568	18336	18336	18336	18336	18336	19080	19080	19080	19080
11	20616	20616	20616	21384	21384	21384	21384	22152	22152	22152
12	22920	23688	23688	23688	23688	24496	24496	24496	24496	25456
13	26416	26416	26416	26416	27376	27376	27376	27376	28336	28336
14	29296	29296	29296	29296	30576	30576	30576	30576	31704	31704
15	30576	31704	31704	31704	31704	32856	32856	32856	34008	34008
16	32856	32856	34008	34008	34008	34008	35160	35160	35160	35160
17	36696	36696	36696	37888	37888	37888	39232	39232	39232	39232
18	40576	40576	40576	40576	42368	42368	42368	42368	43816	43816
19	43816	43816	43816	45352	45352	45352	46888	46888	46888	46888
20	46888	46888	48936	48936	48936	48936	48936	51024	51024	51024
21	51024	51024	51024	52752	52752	52752	52752	55056	55056	55056
22	55056	55056	55056	57336	57336	57336	57336	59256	59256	59256
23	57336	59256	59256	59256	59256	61664	61664	61664	61664	63776
24	61664	61664	63776	63776	63776	63776	66592	66592	66592	66592
25	63776	63776	66592	66592	66592	66592	68808	68808	68808	71112
26	75376	75376	75376	75376	75376	75376	75376	75376	75376	75376

7.1.7.2.2 Transport blocks mapped to two-layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 55$, the TBS is given by the (I_{TBS} , $2 \cdot N_{\mathrm{PRB}}$) entry of Table 7.1.7.2.1-1.

For $56 \le N_{\mathrm{PRB}} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS} , N_{PRB}) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L2 using the mapping rule shown in Table 7.1.7.2.2-1. The TBS is given by TBS_L2.

Table 7.1.7.2.2-1: One-layer to two-layer TBS translation table

TBS_L1	TBS_L2	TBS_L1	TBS_L2	TBS_L1	TBS_L2	TBS_L1	TBS_L2
1544	3112	3752	7480	10296	20616	28336	57336
1608	3240	3880	7736	10680	21384	29296	59256
1672	3368	4008	7992	11064	22152	30576	61664
1736	3496	4136	8248	11448	22920	31704	63776
1800	3624	4264	8504	11832	23688	32856	66592
1864	3752	4392	8760	12216	24496	34008	68808
1928	3880	4584	9144	12576	25456	35160	71112
1992	4008	4776	9528	12960	25456	36696	73712
2024	4008	4968	9912	13536	27376	37888	76208
2088	4136	5160	10296	14112	28336	39232	78704
2152	4264	5352	10680	14688	29296	40576	81176
2216	4392	5544	11064	15264	30576	42368	84760
2280	4584	5736	11448	15840	31704	43816	87936
2344	4776	5992	11832	16416	32856	45352	90816
2408	4776	6200	12576	16992	34008	46888	93800
2472	4968	6456	12960	17568	35160	48936	97896
2536	5160	6712	13536	18336	36696	51024	101840
2600	5160	6968	14112	19080	37888	52752	105528
2664	5352	7224	14688	19848	39232	55056	110136
2728	5544	7480	14688	20616	40576	57336	115040
2792	5544	7736	15264	21384	42368	59256	119816
2856	5736	7992	15840	22152	43816	61664	124464
2984	5992	8248	16416	22920	45352	63776	128496
3112	6200	8504	16992	23688	46888	66592	133208
3240	6456	8760	17568	24496	48936	68808	137792
3368	6712	9144	18336	25456	51024	71112	142248
3496	6968	9528	19080	26416	52752	73712	146856
3624	7224	9912	19848	27376	55056	75376	149776

7.1.7.2.3 Transport blocks mapped for DCI Format 1C

The TBS is given by the I_{TBS} entry of Table 7.1.7.2.3-1.

Table 7.1.7.2.3-1: Transport Block Size (TBS) table for DCI format 1C

I_{TBS}	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TBS	40	56	72	120	136	144	176	208	224	256	280	296	328	336	392	488
I_{TBS}	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TBS	552	600	632	696	776	840	904	1000	1064	1128	1224	1288	1384	1480	1608	1736

7.1.7.2.4 Transport blocks mapped to three-layer spatial multiplexing

For $1 \le N_{PRB} \le 36$, the TBS is given by the (I_{TBS} , $3 \cdot N_{PRB}$) entry of Table 7.1.7.2.1-1.

For $37 \le N_{PRB} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS} , N_{PRB}) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L3 using the mapping rule shown in Table 7.1.7.2.4-1. The TBS is given by TBS_L3.

Table 7.1.7.2.4-1: One-layer to three-layer TBS translation table

TBS_L1	TBS_L3	TBS_L1	TBS_L3	TBS_L1	TBS_L3	TBS_L1	TBS_L3
1032	3112	2664	7992	8248	24496	26416	78704
1064	3240	2728	8248	8504	25456	27376	81176
1096	3240	2792	8248	8760	26416	28336	84760
1128	3368	2856	8504	9144	27376	29296	87936
1160	3496	2984	8760	9528	28336	30576	90816
1192	3624	3112	9144	9912	29296	31704	93800
1224	3624	3240	9528	10296	30576	32856	97896
1256	3752	3368	9912	10680	31704	34008	101840
1288	3880	3496	10296	11064	32856	35160	105528
1320	4008	3624	10680	11448	34008	36696	110136
1352	4008	3752	11064	11832	35160	37888	115040
1384	4136	3880	11448	12216	36696	39232	119816
1416	4264	4008	11832	12576	37888	40576	119816
1480	4392	4136	12576	12960	39232	42368	128496
1544	4584	4264	12960	13536	40576	43816	133208
1608	4776	4392	12960	14112	42368	45352	137792
1672	4968	4584	13536	14688	43816	46888	142248
1736	5160	4776	14112	15264	45352	48936	146856
1800	5352	4968	14688	15840	46888	51024	152976
1864	5544	5160	15264	16416	48936	52752	157432
1928	5736	5352	15840	16992	51024	55056	165216
1992	5992	5544	16416	17568	52752	57336	171888
2024	5992	5736	16992	18336	55056	59256	177816
2088	6200	5992	18336	19080	57336	61664	185728
2152	6456	6200	18336	19848	59256	63776	191720
2216	6712	6456	19080	20616	61664	66592	199824
2280	6712	6712	19848	21384	63776	68808	205880
2344	6968	6968	20616	22152	66592	71112	214176
2408	7224	7224	21384	22920	68808	73712	221680
2472	7480	7480	22152	23688	71112	75376	226416
2536	7480	7736	22920	24496	73712		
2600	7736	7992	23688	25456	76208		

7.1.7.2.5 Transport blocks mapped to four-layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 27$, the TBS is given by the (I_{TBS} , $4 \cdot N_{\mathrm{PRB}}$) entry of Table 7.1.7.2.1-1.

For $28 \le N_{\mathrm{PRB}} \le 110$, a baseline TBS_L1 is taken from the (I_{TBS} , N_{PRB}) entry of Table 7.1.7.2.1-1, which is then translated into TBS_L4 using the mapping rule shown in Table 7.1.7.2.5-1. The TBS is given by TBS_L4.

Table 7.1.7.2.5-1: One-layer to four-layer TBS translation table

TBS_L1	TBS_L4	TBS_L1	TBS_L4	TBS_L1	TBS_L4	TBS_L1	TBS_L4
776	3112	2280	9144	7224	29296	24496	97896
808	3240	2344	9528	7480	29296	25456	101840
840	3368	2408	9528	7736	30576	26416	105528
872	3496	2472	9912	7992	31704	27376	110136
904	3624	2536	10296	8248	32856	28336	115040
936	3752	2600	10296	8504	34008	29296	115040
968	3880	2664	10680	8760	35160	30576	124464
1000	4008	2728	11064	9144	36696	31704	128496
1032	4136	2792	11064	9528	37888	32856	133208
1064	4264	2856	11448	9912	39232	34008	137792
1096	4392	2984	11832	10296	40576	35160	142248
1128	4584	3112	12576	10680	42368	36696	146856
1160	4584	3240	12960	11064	43816	37888	151376
1192	4776	3368	13536	11448	45352	39232	157432
1224	4968	3496	14112	11832	46888	40576	161760
1256	4968	3624	14688	12216	48936	42368	169544
1288	5160	3752	15264	12576	51024	43816	175600
1320	5352	3880	15264	12960	51024	45352	181656
1352	5352	4008	15840	13536	55056	46888	187712
1384	5544	4136	16416	14112	57336	48936	195816
1416	5736	4264	16992	14688	59256	51024	203704
1480	5992	4392	17568	15264	61664	52752	211936
1544	6200	4584	18336	15840	63776	55056	220296
1608	6456	4776	19080	16416	66592	57336	230104
1672	6712	4968	19848	16992	68808	59256	236160
1736	6968	5160	20616	17568	71112	61664	245648
1800	7224	5352	21384	18336	73712	63776	254328
1864	7480	5544	22152	19080	76208	66592	266440
1928	7736	5736	22920	19848	78704	68808	275376
1992	7992	5992	23688	20616	81176	71112	284608
2024	7992	6200	24496	21384	84760	73712	293736
2088	8248	6456	25456	22152	87936	75376	299856
2152	8504	6712	26416	22920	90816		
2216	8760	6968	28336	23688	93800		

7.1.7.3 Redundancy Version determination for Format 1C

If the DCI Format 1C CRC is scrambled by P-RNTI or RA-RNTI, then

- the UE shall set the Redundancy Version to 0

Else if the DCI Format 1C CRC is scrambled by SI-RNTI, then

- the UE shall set the Redundancy Version as defined in [8].

7.1.8 Storing soft channel bits

Both for FDD and TDD, if the UE is configured with more than one serving cell, then for each serving cell, for at least $K_{\mathrm{MIMO}} \cdot \min\left(M_{\mathrm{DL\_HARQ}}, M_{\mathrm{limit}}\right)$ transport blocks, upon decoding failure of a code block of a transport block, the UE shall store received soft channel bits corresponding to a range of at least $w_k \; w_{k+1}, \ldots, w_{\mathrm{mod}(k+n_{SB}-1, N_{cb})}$, where:

$$n_{SB} = \min\left(N_{cb}, \left\lfloor \frac{N'_{soft}}{C \cdot N_{cells}^{DL} \cdot K_{\mathrm{MIMO}} \cdot \min\left(M_{\mathrm{DL\_HARQ}}, M_{\mathrm{limit}}\right)} \right\rfloor\right),$$

w_k, C, N_{cb}, K_{MIMO}, ,and M_{limit} are defined in clause 5.1.4.1.2 of [4].

$M_{\mathrm{DL\_HARQ}}$ is the maximum number of DL HARQ processes.

N_{cells}^{DL} is the number of configured serving cells.

If the UE signals *ue-Category-v1020*, N'_{soft} is the total number of soft channel bits [12] according to the UE category indicated by *ue-Category-v1020* [11]. Otherwise, N'_{soft} is the total number of soft channel bits [12] according to the UE category indicated by *ue-Category*[11].

In determining *k*, the UE should give priority to storing soft channel bits corresponding to lower values of *k*. w_k shall correspond to a received soft channel bit. The range $w_k \; w_{k+1}, \ldots, w_{\mathrm{mod}(k+n_{SB}-1, N_{cb})}$ may include subsets not containing received soft channel bits.

7.1.9 PDSCH resource mapping parameters

A UE configured in transmission mode 10 for a given serving cell can be configured with up to 4 parameter sets by higher layer signaling to decode PDSCH according to a detected PDCCH/EPDCCH with DCI format 2D intended for the UE and the given serving cell. The UE shall use the parameter set according to the value of the 'PDSCH RE Mapping and Quasi-Co-Location indicator' field (mapping defined in Table 7.1.9-1) in the detected PDCCH/EPDCCH with DCI format 2D for determining the PDSCH RE mapping (defined in clause 6.4 of [3]), and for determining PDSCH antenna port quasi co-location (defined in clause 7.1.10) if the UE is configured with Type B quasi co-location type (defined in clause 7.1.10). For PDSCH without a corresponding PDCCH/EPDCCH, the UE shall use the parameter set indicated in the PDCCH/EPDCCH with DCI format 2D corresponding to the associated SPS activation for determining the PDSCH RE mapping (defined in clause 6.4 of [3]) and PDSCH antenna port quasi co-location (defined in clause 7.1.10).

Table 7.1.9-1: PDSCH RE Mapping and Quasi-Co-Location Indicator field in DCI format 2D

Value of 'PDSCH RE Mapping and Quasi-Co-Location Indicator' field	Description
'00'	Parameter set 1 configured by higher layers
'01'	Parameter set 2 configured by higher layers
'10'	Parameter set 3 configured by higher layers
'11'	Parameter set 4 configured by higher layers

The following parameters for determining PDSCH RE mapping and PDSCH antenna port quasi co-location are configured via higher layer signaling for each parameter set:

- *crs-PortsCount-r11*.
- *crs-FreqShift-r11*.
- *mbsfn-SubframeConfigList-r11*.
- *csi-RS-ConfigZPId-r11*.
- *pdsch-Start-r11*.
- *qcl-CSI-RS-ConfigNZPId-r11*.

To decode PDSCH according to a detected PDCCH/EPDCCH with DCI format 1A with CRC scrambled with C-RNTI intended for the UE and the given serving cell and for PDSCH transmission on antenna port 7, a UE configured in transmission mode 10 for a given serving cell shall use the parameter set 1 in table 7.1.9-1 for determining the PDSCH

RE mapping (defined in clause 6.4 of [3]), and for determining PDSCH antenna port quasi co-location (defined in clause 7.1.10) if the UE is configured with Type B quasi co-location type (defined in clause 7.1.10).

To decode PDSCH corresponding to detected PDCCH/EPDCCH with DCI format 1A with CRC scrambled with SPS C-RNTI and PDSCH without a corresponding PDCCH/EPDCCH associated with SPS activation indicated in PDCCH/EPDCCH with DCI format 1A, a UE configured in transmission mode 10 for a given serving cell shall use the parameter set 1 in table 7.1.9-1 for determining the PDSCH RE mapping (defined in clause 6.4 of [3]), and for determining PDSCH antenna port quasi co-location (defined in clause 7.1.10) if the UE is configured with Type B quasi co-location type (defined in clause 7.1.10).

To decode PDSCH according to a detected PDCCH/EPDCCH with DCI format 1A intended for the UE on a given serving cell and for PDSCH transmission on antenna port 0 – 3, a UE configured in transmission mode 10 for the given serving cell shall determine the PDSCH RE mapping (as described in clause 6.4 of [3]) using the lowest indexed zero-power CSI-RS resource.

7.1.10 Antenna ports quasi co-location for PDSCH

A UE configured in transmission mode 8-10 for a serving cell may assume the antenna ports 7 – 14 of the serving cell are quasi co-located (as defined in [3]) for a given subframe with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

A UE configured in transmission mode 1-9 for a serving cell may assume the antenna ports 0 – 3, 5, 7 – 22 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

A UE configured in transmission mode 10 for a serving cell is configured with one of two quasi co-location types for the serving cell by higher layer parameter *qcl-Operation* to decode PDSCH according to transmission scheme associated with antenna ports 7-14:

- Type A: The UE may assume the antenna ports 0 – 3, 7 – 22 of a serving cell are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, and average delay.
- Type B: The UE may assume the antenna ports 15 – 22 corresponding to the CSI-RS resource configuration identified by the higher layer parameter *qcl-CSI-RS-ConfigNZPId-r11* (defined in clause 7.1.9) and the antenna ports 7 – 14 associated with the PDSCH are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

7.2 UE procedure for reporting Channel State Information (CSI)

The time and frequency resources that can be used by the UE to report CSI which consists of Channel Quality Indicator (CQI), precoding matrix indicator (PMI), precoding type indicator (PTI), and/or rank indication (RI) are controlled by the eNB. For spatial multiplexing, as given in [3], the UE shall determine a RI corresponding to the number of useful transmission layers. For transmit diversity as given in [3], RI is equal to one.

A UE in transmission mode 8 or 9 is configured with or without PMI/RI reporting by the higher layer parameter *pmi-RI-Report*.

A UE in transmission mode 10 can be configured with one or more CSI processes per serving cell by higher layers. Each CSI process is associated with a CSI-RS resource (defined in clause 7.2.5) and a CSI-interference measurement (CSI-IM) resource (defined in clause 7.2.6). A CSI reported by the UE corresponds to a CSI process configured by higher layers. Each CSI process can be configured with or without PMI/RI reporting by higher layer signalling.

A UE is configured with resource-restricted CSI measurements if the subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers.

CSI reporting is periodic or aperiodic.

If the UE is configured with more than one serving cell, it transmits CSI for activated serving cell(s) only.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUCCH as defined hereafter in subframes with no PUSCH allocation.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUSCH of the serving cell with smallest *ServCellIndex* as defined hereafter in subframes with a PUSCH allocation, where the UE shall use the same PUCCH-based periodic CSI reporting format on PUSCH.

A UE shall transmit aperiodic CSI reporting on PUSCH if the conditions specified hereafter are met. For aperiodic CQI/PMI reporting, RI reporting is transmitted only if the configured CSI feedback type supports RI reporting.

The CSI transmissions on PUCCH and PUSCH for various scheduling modes are summarized in the following table:

Table 7.2-1: Physical Channels for Aperiodic or Periodic CSI reporting

Scheduling Mode	Periodic CSI reporting channels	Aperiodic CSI reporting channel
Frequency non-selective	PUCCH	
Frequency selective	PUCCH	PUSCH

In case both periodic and aperiodic CSI reporting would occur in the same subframe, the UE shall only transmit the aperiodic CSI report in that subframe.

When reporting RI the UE reports a single instance of the number of useful transmission layers. For each RI reporting interval when the UE is configured in transmission modes 4 or when the UE is configured in transmission mode 8, 9 or 10 with PMI/RI reporting, a UE shall determine a RI from the supported set of RI values as defined in clause 5.2.2.6 of [4] and report the number in each RI report. For each RI reporting interval when the UE is configured in transmission mode 3, a UE shall determine RI as defined in clause 5.2.2.6 of [4] in each reporting interval and report the detected number in each RI report to support selection between transmit diversity and large delay CDD.

When reporting PMI the UE reports either a single or a multiple PMI report. The number of RBs represented by a single UE PMI report can be $N_{\text{RB}}^{\text{DL}}$ or a smaller subset of RBs. The number of RBs represented by a single PMI report is semi-statically configured by higher layer signalling. A UE is restricted to report PMI, RI and PTI within a precoder codebook subset specified by a bitmap parameter *codebookSubsetRestriction* configured by higher layer signalling. For a UE configured in transmission mode 10, the bitmap parameter *codebookSubsetRestriction* is configured for each CSI process and each subframe sets (if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers) by higher layer signaling. For a specific precoder codebook and associated transmission mode, the bitmap can specify all possible precoder codebook subsets from which the UE can assume the eNB may be using when the UE is configured in the relevant transmission mode. Codebook subset restriction is supported for transmission modes 3, 4, 5, 6 and for transmission modes 8, 9 and 10 with PMI/RI reporting. The resulting number of bits for each transmission mode is given in Table 7.2-1b. The bitmap forms the bit sequence $a_{A_c-1},...,a_3,a_2,a_1,a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that the PMI and RI reporting is not allowed to correspond to precoder(s) associated with the bit. The association of bits to precoders for the relevant transmission modes are given as follows:

1. Transmission mode 3

    a. 2 antenna ports: bit $a_{\upsilon-1}, \upsilon=2$ is associated with the precoder in Table 6.3.4.2.3-1 of [3] corresponding to υ layers and codebook index 0 while bit a_0 is associated with the precoder for 2 antenna ports in clause 6.3.4.3 of [3].

    b. 4 antenna ports: bit $a_{\upsilon-1}, \upsilon=2,3,4$ is associated with the precoders in Table 6.3.4.2.3-2 of [3] corresponding to υ layers and codebook indices 12, 13, 14, and 15 while bit a_0 is associated with the precoder for 4 antenna ports in clause 6.3.4.3 of [3].

2. Transmission mode 4

    a. 2 antenna ports: see Table 7.2-1c

    b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].

3. Transmission modes 5 and 6

    a. 2 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon=1$ layer with codebook index i_c in Table 6.3.4.2.3-1 of [3].

    b. 4 antenna ports: bit a_{i_c} is associated with the precoder for $\upsilon=1$ layer with codebook index i_c in Table 6.3.4.2.3-2 of [3].

4. Transmission mode 8

    a. 2 antenna ports: see Table 7.2-1c

    b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3], $\upsilon=1,2$.

5. Transmission modes 9 and 10

    a. 2 antenna ports: see Table 7.2-1c

    b. 4 antenna ports: bit $a_{16(\upsilon-1)+i_c}$ is associated with the precoder for υ layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].

    c. 8 antenna ports: bit $a_{f1(\upsilon-1)+i_{c1}}$ is associated with the precoder for υ layers ($\upsilon\in\{1,2,3,4,5,6,7,8\}$) and codebook index i_{c1} where $f1(\cdot)=\{0,16,32,36,40,44,48,52\}$ and bit $a_{53+g1(\upsilon-1)+i_{c2}}$ is associated with the precoder for υ layers ($\upsilon\in\{1,2,3,4\}$) and codebook index i_{c2} where $g1(\cdot)=\{0,16,32,48\}$. Codebook indices i_{c1} and i_{c2} are given in Table 7.2.4-1, 7.2.4-2, 7.2.4-3, 7.2.4-4, 7.2.4-5, 7.2.4-6, 7.2.4-7, or 7.2.4-8, for υ=1,2,3,4,5,6,7, or 8 respectively.

Table 7.2-1b: Number of bits in codebook subset restriction bitmap for applicable transmission modes

	Number of bits A_c		
	2 antenna ports	4 antenna ports	8 antenna ports
Transmission mode 3	2	4	
Transmission mode 4	6	64	
Transmission mode 5	4	16	
Transmission mode 6	4	16	
Transmission mode 8	6	32	
Transmission modes 9 and 10	6	64	109

Table 7.2-1c: Association of bits in *codebookSubSetRestriction* bitmap to precoders in the 2 antenna port codebook of Table 6.3.4.2.3-1 in [3]

Codebook index i_c	Number of layers υ	
	1	2
0	a_0	-
1	a_1	a_4
2	a_2	a_5
3	a_3	-

The set of subbands (S) a UE shall evaluate for CQI reporting spans the entire downlink system bandwidth. A subband is a set of k contiguous PRBs where k is a function of system bandwidth. Note the last subband in set S may have fewer than k contiguous PRBs depending on N_{RB}^{DL} . The number of subbands for system bandwidth given by N_{RB}^{DL} is defined by $N = \lceil N_{RB}^{DL} / k \rceil$. The subbands shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

- For transmission modes 1, 2, 3 and 5, as well as transmission modes 8, 9 and 10 without PMI/RI reporting, transmission mode 4 with RI=1, and transmission modes 8, 9 and 10 with PMI/RI reporting and RI=1, a single 4-bit wideband CQI is reported according to Table 7.2.3-1.
- For transmission modes 3 and 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, CQI is calculated assuming transmission of one codeword for RI=1 and two codewords for RI > 1.
- For RI > 1 with transmission mode 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, PUSCH based triggered reporting includes reporting a wideband CQI which comprises:
    - A 4-bit wideband CQI for codeword 0 according to Table 7.2.3-1
    - A 4-bit wideband CQI for codeword 1 according to Table 7.2.3-1
- For RI > 1 with transmission mode 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting, PUCCH based reporting includes reporting a 4-bit wideband CQI for codeword 0 according to Table 7.2.3-1 and a wideband spatial differential CQI. The wideband spatial differential CQI value comprises:
    - A 3-bit wideband spatial differential CQI value for codeword 1 offset level
        - Codeword 1 offset level = wideband CQI index for codeword 0 – wideband CQI index for codeword 1.
    - The mapping from the 3-bit wideband spatial differential CQI value to the offset level is shown in Table 7.2-2.

Table 7.2-2 Mapping spatial differential CQI value to offset level

Spatial differential CQI value	Offset level
0	0
1	1
2	2
3	≥3
4	≤-4
5	-3
6	-2
7	-1

7.2.1 Aperiodic CSI Reporting using PUSCH

A UE shall perform aperiodic CSI reporting using the PUSCH in subframe $n+k$ on serving cell c, upon decoding in subframe n either:

- an uplink DCI format [4], or
- a Random Access Response Grant,

for serving cell c if the respective CSI request field is set to trigger a report and is not reserved.

If the CSI request field is 1 bit and the UE is configured in transmission mode 1-9, a report is triggered for serving cell c, if the CSI request field is set to '1'. If the CSI request field is 1 bit and the UE is configured in transmission mode 10, a report is triggered for a set of CSI process(es) for serving cell c corresponding to the higher layer configured set of CSI process(es) associated with the value of CSI request field of '01' in Table 7.2.1-1B, if the CSI request field is set to '1'.

If the CSI request field size is 2 bits and the UE is configured in transmission mode 1-9 for all serving cells, a report is triggered according to the value in Table 7.2.1-1A corresponding to aperiodic CSI reporting. If the CSI request field size is 2 bits and the UE is configured in transmission mode 10 for at least one serving cell, a report is triggered according to the value in Table 7.2.1-1B corresponding to aperiodic CSI reporting. For a given serving cell, if the UE is configured in transmission modes 1-9, the "CSI process" in Table 7.2.1-1B refers to the aperiodic CSI configured for the UE on the given serving cell. A UE is not expected to be configured by higher layers with more than 5 CSI processes in each of the 1st and 2nd set of CSI process(es) in Table 7.2.1-1B.

A UE is not expected to receive more than one aperiodic CSI report request for a given subframe.

If a UE is configured with more than one CSI process for a serving cell, the UE on reception of an aperiodic CSI report request triggering a CSI report according to Table 7.2.1-1B is not expected to update CSI corresponding to the CSI reference resource (defined in clause 7.2.3) for all CSI processes except $\max(N_x - N_u, 0)$ lowest-indexed CSI processes for the serving cell associated with the request when the UE has other N_u unreported CSI processes associated with other aperiodic CSI requests for the serving cell, where N_{CSI-P} is the maximum number of CSI processes supported by the UE for the serving cell and:

- for FDD $N_x = N_{CSI-P}$;
- for TDD
  - if the UE is configured with four CSI processes for the serving cell , $N_x = N_{CSI-P}$
  - if the UE is configured with two or three CSI processes for the serving cell, $N_x = 3$.

If more than one value of N_{CSI-P} is included in the *UE-EUTRA-Capability*, the UE assumes a value of N_{CSI-P} that is consistent with its CSI process configuration. If more than one consistent value of N_{CSI-P} exists, the UE may assume any one of the consistent values.

Table 7.2.1-1A: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for serving cell c
'10'	Aperiodic CSI report is triggered for a 1st set of serving cells configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2nd set of serving cells configured by higher layers

Table 7.2.1-1B: CSI Request field for PDCCH/EPDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for a set of CSI process(es) configured by higher layers for serving cell c
'10'	Aperiodic CSI report is triggered for a 1st set of CSI process(es) configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2nd set of CSI process(es) configured by higher layers

NOTE: PDCCH/EPDCCH with DCI formats used to grant PUSCH transmissions as given by DCI format 0 and DCI format 4 are herein referred to as uplink DCI format when common behaviour is addressed.

When the CSI request field from an uplink DCI format is set to trigger a report, for FDD *k=4,* and for TDD UL/DL configuration 1-6, *k* is given in Table 8-2. For TDD UL/DL configuration 0, if the MSB of the UL index is set to 1 and LSB of the UL index is set to 0, *k* is given in Table 8-2; or if MSB of the UL index is set to 0 and LSB of the UL index is set to 1, *k* is equal to 7; or if both MSB and LSB of the UL index is set to 1, *k* is given in Table 8-2. . For TDD, if a UE is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different, the "TDD UL/DL Configuration" given in Table 8-2 refers to the UL-reference UL/DL configuration (defined in clause 8.0).

When the CSI request field from a Random Access Response Grant is set to trigger a report and is not reserved, *k* is equal to k_1 if the UL delay field in clause 6.2 is set to zero, where k_1 is given in clause 6.1.1. The UE shall postpone aperiodic CSI reporting to the next available UL subframe if the UL delay field is set to 1.

The minimum reporting interval for aperiodic reporting of CQI and PMI and RI is 1 subframe. The subband size for CQI shall be the same for transmitter-receiver configurations with and without precoding.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, when aperiodic CSI report with no transport block associated as defined in clause 8.6.2 and positive SR is transmitted in the same subframe, the UE shall transmit SR, and, if applicable, HARQ-ACK, on PUCCH resources as described in clause 10.1

A UE is semi-statically configured by higher layers to feed back CQI and PMI and corresponding RI on the same PUSCH using one of the following CSI reporting modes given in Table 7.2.1-1 and described below.

Table 7.2.1-1: CQI and PMI Feedback Types for PUSCH CSI reporting Modes

		PMI Feedback Type		
		No PMI	Single PMI	Multiple PMI
PUSCH CQI Feedback Type	Wideband (wideband CQI)			Mode 1-2
	UE Selected (subband CQI)	Mode 2-0		Mode 2-2
	Higher Layer-configured (subband CQI)	Mode 3-0	Mode 3-1	

For each of the transmission modes defined in clause 7.1, the following reporting modes are supported on PUSCH:

Transmission mode 1 : Modes 2-0, 3-0
Transmission mode 2 : Modes 2-0, 3-0

Transmission mode 3 : Modes 2-0, 3-0
Transmission mode 4 : Modes 1-2, 2-2, 3-1
Transmission mode 5 : Mode 3-1
Transmission mode 6 : Modes 1-2, 2-2, 3-1
Transmission mode 7 : Modes 2-0, 3-0
Transmission mode 8 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting
Transmission mode 9 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1
Transmission mode 10 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1.

The aperiodic CSI reporting mode is given by the parameter *cqi-ReportModeAperiodic* which is configured by higher-layer signalling.

For a serving cell with $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 7$, PUSCH reporting modes are not supported for that serving cell.
RI is only reported for transmission modes 3 and 4, as well as transmission modes 8, 9 and 10 with PMI/RI reporting.

For serving cell c, a UE configured in transmission mode 10 with PMI/RI reporting for a CSI process can be configured with a 'RI-reference CSI process' for the CSI process. If the UE is configured with a 'RI-reference CSI process' for the CSI process, the reported RI for the CSI process shall be the same as the reported RI for the configured 'RI-reference CSI process'. The RI for the 'RI-reference CSI process' is not based on any other configured CSI process other than the 'RI-reference CSI process'. The UE is not expected to receive an aperiodic CSI report request for a given subframe triggering a CSI report including CSI associated with the CSI process and not including CSI associated with the configured 'RI-reference CSI process'. If the UE is configured with a 'RI-reference CSI process' for a CSI process and if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers for only one of the CSI processes then the UE is not expected to receive configuration for the CSI process configured with the subframe subsets that have a different set of restricted RIs with precoder codebook subset restriction between the two subframe sets. The UE is not expected to receive configurations for the CSI process and the 'RI-reference CSI process' that have a different:

- Aperiodic CSI reporting mode, and/or
- number of CSI-RS antenna ports, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are not configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for each subframe set if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers for only one of the CSI processes, and the set of restricted RIs for the two subframe sets are the same.

A RI report for a serving cell on an aperiodic reporting mode is valid only for CQI/PMI report for that serving cell on that aperiodic reporting mode

- Wideband feedback
  - Mode 1-2 description:
    - For each subband a preferred precoding matrix is selected from the codebook subset assuming transmission only in the subband
    - A UE shall report one wideband CQI value per codeword which is calculated assuming the use of the corresponding selected precoding matrix in each subband and transmission on set *S* subbands.
    - The UE shall report the selected precoding matrix indicator for each set *S* subband except with 8 CSI-RS ports configured for transmission modes 9 and 10 in which case a first precoding matrix indicator i_1 is reported for the set *S* subbands and a second precoding matrix indicator i_2 is reported for each set *S* subband.

- Subband size is given by Table 7.2.1-3.
- For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.

- Higher Layer-configured subband feedback
  - Mode 3-0 description:
    - A UE shall report a wideband CQI value which is calculated assuming transmission on set *S* subbands
    - The UE shall also report one subband CQI value for each set *S* subband. The subband CQI value is calculated assuming transmission only in the subband
    - Both the wideband and subband CQI represent channel quality for the first codeword, even when RI>1.
    - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - Mode 3-1 description:
    - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
    - A UE shall report one subband CQI value per codeword for each set *S* subband which are calculated assuming the use of the single precoding matrix in all subbands and assuming transmission in the corresponding subband.
    - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
    - The UE shall report the selected single precoding matrix indicator except with 8 CSI-RS ports configured for transmission modes 9 and 10 in which case a first and second precoding matrix indicator are reported corresponding to the selected single precoding matrix.
    - For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - Subband CQI value for each codeword are encoded differentially with respect to their respective wideband CQI using 2-bits as defined by
    - Subband differential CQI offset level = subband CQI index – wideband CQI index. The mapping from the 2-bit subband differential CQI value to the offset level is shown in Table 7.2.1-2.

Table 7.2.1-2: Mapping subband differential CQI value to offset level

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

  - Supported subband size (*k*) is given in Table 7.2.1-3.

Table 7.2.1-3: Subband Size (*k*) vs. System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	Subband Size (*k*)
6 - 7	NA
8 - 10	4
11 - 26	4
27 - 63	6
64 - 110	8

- UE-selected subband feedback
  - Mode 2-0 description:
    - The UE shall select a set of *M* preferred subbands of size *k* (where *k* and *M* are given in Table 7.2.1-5 for each system bandwidth range) within the set of subbands *S*.
    - The UE shall also report one CQI value reflecting transmission only over the *M* selected subbands determined in the previous step. The CQI represents channel quality for the first codeword, even when RI>1.
    - Additionally, the UE shall also report one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
    - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - Mode 2-2 description:
    - The UE shall perform joint selection of the set of *M* preferred subbands of size *k* within the set of subbands *S* and a preferred single precoding matrix selected from the codebook subset that is preferred to be used for transmission over the *M* selected subbands.
    - The UE shall report one CQI value per codeword reflecting transmission only over the selected *M* preferred subbands and using the same selected single precoding matrix in each of the *M* subbands.
    - Except with 8 CSI-RS ports configured for transmission modes 9 and 10, the UE shall also report the selected single precoding matrix indicator preferred for the M selected subbands. A UE shall also report the selected single precoding matrix indicator for all set *S* subbands.
    - For transmission modes 9 and 10, and with 8 CSI-RS ports configured, a UE shall report a first precoding matrix indicator for all set *S* subbands. A UE shall also report a second precoding matrix indicator for all set *S* subbands and another second precoding matrix indicator for the M selected subbands.
    - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
    - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands
    - For transmission modes 4, 8, 9 and 10, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
  - For all UE-selected subband feedback modes the UE shall report the positions of the *M* selected subbands using a combinatorial index *r* defined as

- $r = \sum_{i=0}^{M-1} \left\langle \begin{matrix} N - s_i \\ M - i \end{matrix} \right\rangle$

- where the set $\{s_i\}_{i=0}^{M-1}$, $(1 \le s_i \le N,\quad s_i < s_{i+1})$ contains the M sorted subband indices and $\left\langle \begin{matrix} x \\ y \end{matrix} \right\rangle = \begin{cases} \binom{x}{y} & x \ge y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label $r \in \left\{0, \cdots, \binom{N}{M} - 1\right\}$.

- The CQI value for the M selected subbands for each codeword is encoded differentially using 2-bits relative to its respective wideband CQI as defined by
  - Differential CQI offset level = M selected subbands CQI index – wideband CQI index
  - The mapping from the 2-bit differential CQI value to the offset level is shown in Table 7.2.1-4.

Table 7.2.1-4: Mapping differential CQI value to offset level

Differential CQI value	Offset level
0	≤1
1	2
2	3
3	≥4

- Supported subband size k and M values include those shown in Table 7.2.1-5. In Table 7.2.1-5 the k and M values are a function of system bandwidth.

- The number of bits to denote the position of the M selected subbands is $L = \left\lceil \log_2 \binom{N}{M} \right\rceil$.

Table 7.2.1-5: Subband Size (*k*) and Number of Subbands (*M*) in S vs. Downlink System Bandwidth

System Bandwidth N_{RB}^{DL}	Subband Size *k* (RBs)	*M*
6 – 7	NA	NA
8 – 10	2	1
11 – 26	2	3
27 – 63	3	5
64 – 110	4	6

7.2.2 Periodic CSI Reporting using PUCCH

A UE is semi-statically configured by higher layers to periodically feed back different CSI components (CQI, PMI, PTI, and/or RI) on the PUCCH using the reporting modes given in Table 7.2.2-1 and described below. A UE in transmission mode 10 can be configured by higher layers for multiple periodic CSI reports corresponding to one or more CSI processes per serving cell on PUCCH.

Table 7.2.2-1: CQI and PMI Feedback Types for PUCCH CSI reporting Modes

		PMI Feedback Type	
		No PMI	**Single PMI**
PUCCH CQI Feedback Type	**Wideband (wideband CQI)**	Mode 1-0	Mode 1-1
	UE Selected (subband CQI)	Mode 2-0	Mode 2-1

For each of the transmission modes defined in clause 7.1, the following periodic CSI reporting modes are supported on PUCCH:

Transmission mode 1 : Modes 1-0, 2-0
Transmission mode 2 : Modes 1-0, 2-0
Transmission mode 3 : Modes 1-0, 2-0
Transmission mode 4 : Modes 1-1, 2-1
Transmission mode 5 : Modes 1-1, 2-1
Transmission mode 6 : Modes 1-1, 2-1
Transmission mode 7 : Modes 1-0, 2-0
Transmission mode 8 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting
Transmission mode 9 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports>1; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1.
Transmission mode 10 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports>1; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1.

For a UE configured in transmission mode 1-9, one periodic CSI reporting mode for each serving cell is configured by higher-layer signalling.

For a UE configured in transmission mode 10, one or more periodic CSI reporting modes for each serving cell are configured by higher-layer signalling.

For a UE configured with transmission mode 9 or 10, and with 8 CSI-RS ports, mode 1-1 is configured to be either submode 1 or submode 2 via higher-layer signaling using the parameter *PUCCH_format1-1_CSI_reporting_mode*.

For the UE-selected subband CQI, a CQI report in a certain subframe of a certain serving cell describes the channel quality in a particular part or in particular parts of the bandwidth of that serving cell described subsequently as bandwidth part (BP) or parts. The bandwidth parts shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

For each serving cell

- There are a total of *N* subbands for a serving cell system bandwidth given by $N_{\mathrm{RB}}^{\mathrm{DL}}$ where $\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / k \rfloor$ subbands are of size *k.* If $\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k \rceil - \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / k \rfloor > 0$ then one of the subbands is of size $N_{\mathrm{RB}}^{\mathrm{DL}} - k \cdot \lfloor N_{\mathrm{RB}}^{\mathrm{DL}} / k \rfloor$.
- A bandwidth part *j* is frequency-consecutive and consists of N_{j} subbands where *J* bandwidth parts span *S* or $N_{\mathrm{RB}}^{\mathrm{DL}}$ as given in Table 7.2.2-2. If $J = 1$ then N_{j} is $\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \rceil$. If *J>1* then N_{j} is either $\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \rceil$ or $\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \rceil - 1$, depending on $N_{\mathrm{RB}}^{\mathrm{DL}}$, *k* and *J*.

- Each bandwidth part *j*, where $0 \le j \le J$-1, is scanned in sequential order according to increasing frequency.
- For UE selected subband feedback a single subband out of N_j subbands of a bandwidth part is selected along with a corresponding *L*-bit label indexed in the order of increasing frequency, where $L = \left\lceil \log_2 \left\lceil N_{RB}^{DL} / k / J \right\rceil \right\rceil$.

The CQI and PMI payload sizes of each PUCCH CSI reporting mode are given in Table 7.2.2-3.

The following CQI/PMI and RI reporting types with distinct periods and offsets are supported for the PUCCH CSI reporting modes given in Table 7.2.2-3:

- Type 1 report supports CQI feedback for the UE selected sub-bands
- Type 1a report supports subband CQI and second PMI feedback
- Type 2, Type 2b, and Type 2c report supports wideband CQI and PMI feedback
- Type 2a report supports wideband PMI feedback
- Type 3 report supports RI feedback
- Type 4 report supports wideband CQI
- Type 5 report supports RI and wideband PMI feedback
- Type 6 report supports RI and PTI feedback

For a UE configured in transmission mode 1-9 and for each serving cell, or for a UE configured in transmission mode 10 and for each CSI process in each serving cell, the periodicity N_{pd} (in subframes) and offset $N_{OFFSET,CQI}$ (in subframes) for CQI/PMI reporting are determined based on the parameter *cqi-pmi-ConfigIndex* ($I_{CQI/PMI}$) given in Table 7.2.2-1A for FDD and Table 7.2.2-1C for TDD. The periodicity M_{RI} and relative offset $N_{OFFSET,RI}$ for RI reporting are determined based on the parameter *ri-ConfigIndex* (I_{RI}) given in Table 7.2.2-1B. Both *cqi-pmi-ConfigIndex* and *ri-ConfigIndex* are configured by higher layer signalling. The relative reporting offset for RI $N_{OFFSET,RI}$ takes values from the set $\{0,-1,...,-(N_{pd}-1)\}$. If a UE is configured to report for more than one CSI subframe set then parameter *cqi-pmi-ConfigIndex* and *ri-ConfigIndex* respectively correspond to the CQI/PMI and RI periodicity and relative reporting offset for subframe set 1 and *cqi-pmi-ConfigIndex2* and *ri-ConfigIndex*2 respectively correspond to the CQI/PMI and RI periodicity and relative reporting offset for subframe set 2. For a UE configured with transmission mode 10, the parameters *cqi-pmi-ConfigIndex* , *ri-ConfigIndex*, *cqi-pmi-ConfigIndex2* and *ri-ConfigIndex*2 can be configured for each CSI process.

In the case where wideband CQI/PMI reporting is configured:

- The reporting instances for wideband CQI/PMI are subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}\right) \bmod \left(N_{pd}\right) = 0$.
- In case RI reporting is configured, the reporting interval of the RI reporting is an integer multiple M_{RI} of period N_{pd} (in subframes).
    - o The reporting instances for RI are subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}\right) \bmod \left(N_{pd} \cdot M_{RI}\right) = 0$.

In the case where both wideband CQI/PMI and subband CQI reporting are configured:

- o The reporting instances for wideband CQI/PMI and subband CQI are subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}\right) \bmod N_{pd} = 0$.
    - ▪ When PTI is not transmitted (due to not being configured) or the most recently transmitted PTI is equal to 1 for a UE configured in transmission mode 9 or for a UE configured in transmission mode 10 without a 'RI-reference CSI process' for a CSI process, or the transmitted PTI is equal to 1 reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for the CSI process, or the transmitted PTI is equal to 1 for a 'RI-reference CSI process' reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with the 'RI-reference CSI process' for the CSI process, and the most recent type 6 report for the CSI process is dropped:
        - ▪ The wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission modes 9 and 10) report has period $H \cdot N_{pd}$, and is reported on the

subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}\right)\bmod\left(H\cdot N_{pd}\right)=0$. The integer H is defined as $H=J\cdot K+1$, where J is the number of bandwidth parts.

  - Between every two consecutive wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission modes 9 and 10) reports, the remaining $J\cdot K$ reporting instances are used in sequence for subband CQI reports on K full cycles of bandwidth parts except when the gap between two consecutive wideband CQI/PMI reports contains less than $J\cdot K$ reporting instances due to a system frame number transition to 0, in which case the UE shall not transmit the remainder of the subband CQI reports which have not been transmitted before the second of the two wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission modes 9 and 10) reports. Each full cycle of bandwidth parts shall be in increasing order starting from bandwidth part 0 to bandwidth part $J-1$. The parameter K is configured by higher-layer signalling.

- When the most recently transmitted PTI is 0 for a UE configured in transmission mode 9 or for a UE configured in transmission mode 10 without a 'RI-reference CSI process' for a CSI process, or the transmitted PTI is 0 reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for the CSI process, or the transmitted PTI is 0 for a 'RI-reference CSI process' reported in the most recent RI reporting instance for a CSI process when a UE is configured in transmission mode 10 with the 'RI-reference CSI process' for the CSI process, and the most recent type 6 report for the CSI process is dropped:

  - The wideband first precoding matrix indicator report has period $H'\cdot N_{pd}$, and is reported on the subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}\right)\bmod\left(H'\cdot N_{pd}\right)=0$, where H' is signalled by higher layers.

  - Between every two consecutive wideband first precoding matrix indicator reports, the remaining reporting instances are used for a wideband second precoding matrix indicator with wideband CQI as described below

- In case RI reporting is configured, the reporting interval of RI is M_{RI} times the wideband CQI/PMI period $H\cdot N_{pd}$, and RI is reported on the same PUCCH cyclic shift resource as both the wideband CQI/PMI and subband CQI reports.

  - The reporting instances for RI are subframes satisfying $\left(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,CQI}-N_{OFFSET,RI}\right)\bmod\left(H\cdot N_{pd}\cdot M_{RI}\right)=0$

In case of collision of a CSI report with PUCCH reporting type 3, 5, or 6 of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2a, 2b, 2c, or 4 of the same serving cell the latter CSI report with PUCCH reporting type (1, 1a, 2, 2a, 2b, 2c, or 4) has lower priority and is dropped.

For a serving cell and UE configured in transmission mode 10, in case of collision between CSI reports of same serving cell with PUCCH reporting type of the same priority, and the CSI reports corresponding to different CSI processes, the CSI reports corresponding to all CSI processes except the CSI process with the lowest *CSIProcessIndex* are dropped.

If the UE is configured with more than one serving cell, the UE transmits a CSI report of only one serving cell in any given subframe. For a given subframe, in case of collision of a CSI report with PUCCH reporting type 3, 5, 6, or 2a of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2b, 2c, or 4 of another serving cell, the latter CSI with PUCCH reporting type (1, 1a, 2, 2b, 2c, or 4) has lower priority and is dropped. For a given subframe, in case of collision of CSI report with PUCCH reporting type 2, 2b, 2c, or 4 of one serving cell with CSI report with PUCCH reporting type 1 or 1a of another serving cell, the latter CSI report with PUCCH reporting type 1, or 1a has lower priority and is dropped.
For a given subframe and serving cells with UE configured in transmission mode 1-9, in case of collision between CSI reports of these different serving cells with PUCCH reporting type of the same priority, the CSI reports for all these serving cells except the serving cell with lowest *ServCellIndex* are dropped.

For a given subframe and serving cells with UE configured in transmission mode 10, in case of collision between CSI reports of different serving cells with PUCCH reporting type of the same priority and the CSI reports corresponding to CSI processes with same *csi-ProcessId-r11*, the CSI reports of all serving cells except the serving cell with lowest *ServCellIndex* are dropped.

For a given subframe and serving cells with UE configured in transmission mode 10, in case of collision between CSI reports of different serving cells with PUCCH reporting type of the same priority and the CSI reports corresponding to CSI processes with different *csi-ProcessId-r11*, the CSI reports of all serving cells except the serving cell with CSI reports corresponding to CSI process with the lowest *csi-ProcessId-r11* are dropped.

For a given subframe, in case of collision between CSI report of a given serving cell with UE configured in transmission mode 1-9, and CSI report(s) corresponding to CSI process(es) of a different serving cell with the UE configured in transmission mode 10, and the CSI reports of the serving cells with PUCCH reporting type of the same priority, the CSI report(s) corresponding to CSI process(es) with *csi-ProcessId-r11* > 1 of the different serving cell are dropped.

For a given subframe, in case of collision between CSI report of a given serving cell with UE configured in transmission mode 1-9, and CSI report corresponding to CSI process with *csi-ProcessId-r11* = 1 of a different serving cell with the UE configured in transmission mode 10, and the CSI reports of the serving cells with PUCCH reporting type of the same priority, the CSI report of the serving cell with highest *ServCellIndex* is dropped.

See clause 10.1 for UE behaviour regarding collision between CSI and HARQ-ACK and the corresponding PUCCH format assignment.

The CSI report of a given PUCCH reporting type shall be transmitted on the PUCCH resource $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$ as defined in [3], where $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$ is UE specific and configured by higher layers for each serving cell.

If the UE is not configured for simultaneous PUSCH and PUCCH transmission or, if the UE is configured for simultaneous PUSCH and PUCCH transmission and not transmitting PUSCH, in case of collision between CSI and positive SR in a same subframe, CSI is dropped.

Table 7.2.2-1A: Mapping of $I_{CQI/PMI}$ to N_{pd} and $N_{OFFSET,CQI}$ for FDD

$I_{CQI/PMI}$	Value of N_{pd}	Value of $N_{OFFSET,CQI}$
$0 \le I_{CQI/PMI} \le 1$	2	$I_{CQI/PMI}$
$2 \le I_{CQI/PMI} \le 6$	5	$I_{CQI/PMI} - 2$
$7 \le I_{CQI/PMI} \le 16$	10	$I_{CQI/PMI} - 7$
$17 \le I_{CQI/PMI} \le 36$	20	$I_{CQI/PMI} - 17$
$37 \le I_{CQI/PMI} \le 76$	40	$I_{CQI/PMI} - 37$
$77 \le I_{CQI/PMI} \le 156$	80	$I_{CQI/PMI} - 77$
$157 \le I_{CQI/PMI} \le 316$	160	$I_{CQI/PMI} - 157$
$I_{CQI/PMI} = 317$	Reserved	
$318 \le I_{CQI/PMI} \le 349$	32	$I_{CQI/PMI} - 318$
$350 \le I_{CQI/PMI} \le 413$	64	$I_{CQI/PMI} - 350$
$414 \le I_{CQI/PMI} \le 541$	128	$I_{CQI/PMI} - 414$
$542 \le I_{CQI/PMI} \le 1023$	Reserved	

Table 7.2.2-1B: Mapping of I_{RI} to M_{RI} and $N_{OFFSET,RI}$.

I_{RI}	Value of M_{RI}	Value of $N_{OFFSET,RI}$
0 ≤ I_{RI} ≤ 160	1	$-I_{RI}$
161 ≤ I_{RI} ≤ 321	2	$-(I_{RI}$ – 161)
322 ≤ I_{RI} ≤ 482	4	$-(I_{RI}$ – 322)
483 ≤ I_{RI} ≤ 643	8	$-(I_{RI}$ – 483)
644 ≤ I_{RI} ≤ 804	16	$-(I_{RI}$ – 644)
805 ≤ I_{RI} ≤ 965	32	$-(I_{RI}$ – 805)
966 ≤ I_{RI} ≤ 1023	Reserved	

Table 7.2.2-1C: Mapping of $I_{CQI/PMI}$ to N_{pd} and $N_{OFFSET,CQI}$ for TDD

$I_{CQI/PMI}$	Value of N_{pd}	Value of $N_{OFFSET,CQI}$
$I_{CQI/PMI}$ = 0	1	$I_{CQI/PMI}$
1 ≤ $I_{CQI/PMI}$ ≤ 5	5	$I_{CQI/PMI}$ – 1
6 ≤ $I_{CQI/PMI}$ ≤ 15	10	$I_{CQI/PMI}$ – 6
16 ≤ $I_{CQI/PMI}$ ≤ 35	20	$I_{CQI/PMI}$ – 16
36 ≤ $I_{CQI/PMI}$ ≤ 75	40	$I_{CQI/PMI}$ – 36
76 ≤ $I_{CQI/PMI}$ ≤ 155	80	$I_{CQI/PMI}$ – 76
156 ≤ $I_{CQI/PMI}$ ≤ 315	160	$I_{CQI/PMI}$ – 156
316 ≤ $I_{CQI/PMI}$ ≤ 1023	Reserved	

For TDD periodic CQI/PMI reporting, the following periodicity values apply for a serving cell *c* depending on the TDD UL/DL configuration of the primary cell [3]:

- The reporting period of $N_{pd} = 1$ is applicable for the serving cell *c* only if TDD UL/DL configuration of the primary cell belongs to {0, 1, 3, 4, 6}, and where all UL subframes of the primary cell in a radio frame are used for CQI/PMI reporting.
- The reporting period of $N_{pd} = 5$ is applicable for the serving cell *c* only if TDD UL/DL configuration of the primary cell belongs to {0, 1, 2, 6}.
- The reporting periods of $N_{pd} = \{10,20,40,80,160\}$ are applicable for the serving cell c for any TDD UL/DL configuration of the primary cell.

For a serving cell with $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 7$, Mode 2-0 and Mode 2-1 are not supported for that serving cell.

The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1D for first and second precoding matrix indicator i_1 and i_2. Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1F for PUCCH Reporting Type 1a.

Table 7.2.2-1D: PUCCH mode 1-1 submode 2 codebook subsampling

RI	Relationship between the first PMI value and codebook index i_1		Relationship between the second PMI value and codebook index i_2		total
	Value of the first PMI I_{PMI1}	Codebook index i_1	Value of the second PMI I_{PMI2}	Codebook index i_2	#bits
1	0-7	$2I_{PMI1}$	0-1	$2I_{PMI2}$	4
2	0-7	$2I_{PMI1}$	0-1	I_{PMI2}	4
3	0-1	$2I_{PMI1}$	0-7	$4\lfloor I_{PMI2}/4 \rfloor + I_{PMI2}$	4
4	0-1	$2I_{PMI1}$	0-7	I_{PMI2}	4
5	0-3	I_{PMI1}	0	0	2
6	0-3	I_{PMI1}	0	0	2
7	0-3	I_{PMI1}	0	0	2
8	0	0	0	0	0

Table 7.2.2-1E: Joint encoding of RI and i_1 for PUCCH mode 1-1 submode 1

Value of joint encoding of RI and the first PMI $I_{RI/PMI1}$	RI	Codebook index i_1
0-7	1	$2I_{RI/PMI1}$
8-15	2	2($I_{RI/PMI1}$-8)
16-17	3	2($I_{RI/PMI1}$-16)
18-19	4	2($I_{RI/PMI1}$-18)
20-21	5	2($I_{RI/PMI1}$-20)
22-23	6	2($I_{RI/PMI1}$-22)
24-25	7	2($I_{RI/PMI1}$-24)
26	8	0
27-31	reserved	NA

Table 7.2.2-1F: PUCCH mode 2-1 codebook subsampling.

RI	Relationship between the second PMI value and codebook index i_2	
	Value of the second PMI I_{PMI2}	Codebook index i_2
1	0-15	I_{PMI2}
2	0-3	$2I_{PMI2}$
3	0-3	$8 \cdot \lfloor I_{PMI2}/2 \rfloor + (I_{PMI2} \bmod 2) + 2$
4	0-3	$2I_{PMI2}$
5	0	0
6	0	0
7	0	0
8	0	0

An RI or PTI or any precoding matrix indicator reported for a serving cell in a periodic reporting mode is valid only for CSI reports for that serving cell on that periodic CSI reporting mode.

For serving cell c, a UE configured in transmission mode 10 with PMI/RI reporting for a CSI process can be configured with a 'RI-reference CSI process'. The RI for the 'RI-reference CSI process' is not based on any other configured CSI process other than the 'RI-reference CSI process'. If the UE is configured with a 'RI-reference CSI process' for a CSI process and if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for only one of the CSI processes then the UE is not expected to receive configuration for the CSI process configured with the subframe subsets that have a different set of restricted RIs with precoder codebook subset restriction between the two subframe sets.The UE is not expected to receive configurations for the CSI process and the 'RI-reference CSI process' that have a different:

- periodic CSI reporting mode (including sub-mode if configured), and/or
- number of CSI-RS antenna ports, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are not configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction for each subframe set if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for both CSI processes, and/or
- set of restricted RIs with precoder codebook subset restriction if subframe sets $C_{\text{CSI},0}$ and $C_{\text{CSI},1}$ are configured by higher layers for only one of the CSI processes, and the set of restricted RIs for the two subframe sets are the same.

For the calculation of CQI/PMI conditioned on the last reported RI, in the absence of a last reported RI the UE shall conduct the CQI/PMI calculation conditioned on the lowest possible RI as given by the bitmap parameter *codebookSubsetRestriction* . If reporting for more than one CSI subframe set is configured, CQI/PMI is conditioned on the last reported RI linked to the same subframe set as the CSI report.

- Wideband feedback
  - Mode 1-0 description:
    - In the subframe where RI is reported (only for transmission mode 3):
      - A UE shall determine a RI assuming transmission on set *S* subbands.
      - The UE shall report a type 3 report consisting of one RI.
    - In the subframe where CQI is reported:
      - A UE shall report a type 4 report consisting of one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
      - For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1.
  - Mode 1-1 description:
    - In the subframe where RI is reported (only for transmission modes 4, 8, 9 and 10):
      - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.
      - The UE shall report a type 3 report consisting of one RI.
    - In the subframe where RI and a first PMI are reported (only for transmission modes 9 and 10, and configured with submode 1 and 8 CSI-RS ports)
      - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.

- The UE shall report a type 5 report consisting of jointly coded RI and a first PMI corresponding to a set of precoding matrices selected from the codebook subset assuming transmission on set *S* subbands.

- If the UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process and in case of collision of type 5 report for the CSI process with type 5 report for the 'RI-reference CSI process', the wideband first PMI for the CSI process shall be the same as the wideband first PMI in the most recent type 5 report for the configured 'RI-reference CSI process'; otherwise, the wideband first PMI value is calculated conditioned on the reported periodic RI.

▪ In the subframe where CQI/PMI is reported for all transmission modes except with 8 CSI-RS ports configured for transmission modes 9 and 10:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2 report consisting of
    - o A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
    - o The selected single PMI (wideband PMI).
    - o When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - For transmission modes 4, 8, 9 and 10,
    - o If a UE is configured in transmission mode 10 with a ‘'RI-reference CSI process’' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the ‘'RI-reference CSI process’' is reported in the most recent RI reporting instance for the CSI process, the PMI and CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured ‘'RI-reference CSI process’' in the most recent RI reporting instance for the CSI process; otherwise the PMI and CQI are calculated conditioned on the last reported periodic RI.
  - For other transmission modes the PMI and CQI are calculated conditioned on transmission rank 1.

▪ In the subframe where wideband CQI/second PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured to submode 1 only:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2b report consisting of
    - o A single wideband CQI value which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set *S* subbands.
    - o The wideband second PMI corresponding to the selected single precoding matrix.
    - o When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 5 report for the CSI process is dropped, and a type 5 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process,
    - o The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI and the wideband first PMI

for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.

- The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.

- Otherwise,
  - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI.
  - The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.

- In the subframe where wideband CQI/first PMI/second PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured to submode 2 only:
  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2c report consisting of
    - A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.
    - The wideband first PMI and the wideband second PMI corresponding to the selected single precoding matrix as defined in clause 7.2.4.
    - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the wideband first PMI, the wideband second PMI and the wideband CQI for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise the wideband first PMI, the wideband second PMI and the wideband CQI are calculated conditioned on the last reported periodic RI.

- UE Selected subband feedback
  - Mode 2-0 description:
    - In the subframe where RI is reported (only for transmission mode 3):
      - A UE shall determine a RI assuming transmission on set *S* subbands.
      - The UE shall report a type 3 report consisting of one RI.
    - In the subframe where wideband CQI is reported:
      - The UE shall report a type 4 report on each respective successive reporting opportunity consisting of one wideband CQI value which is calculated assuming transmission on set *S* subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
      - For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1.
    - In the subframe where CQI for the selected subbands is reported:

- The UE shall select the preferred subband within the set of N_j subbands in each of the *J* bandwidth parts where *J* is given in Table 7.2.2-2.

- The UE shall report a type 1 report consisting of one CQI value reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband *L*-bit label. A type 1 report for each bandwidth part will in turn be reported in respective successive reporting opportunities. The CQI represents channel quality for the first codeword, even when RI>1.

- For transmission mode 3 the preferred subband selection and CQI values are calculated conditioned on the last reported periodic RI. For other transmission modes they are calculated conditioned on transmission rank 1.

- Mode 2-1 description:
  - In the subframe where RI is reported (only for transmission modes 4 and 8 and with 2 or 4 CSI-RS ports configured for transmission modes 9 and 10):
    - Ifa UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.
    - The UE shall report a type 3 report consisting of one RI.
  - In the subframe where RI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured then:
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the RI for the CSI process shall be the same as the RI in the most recent CSI report comprising RI for the configured 'RI-reference CSI process' irrespective of subframe sets if configured; otherwise, the UE shall determine a RI assuming transmission on set *S* subbands.
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, the PTI for the CSI process shall be the same as the PTI in the most recent type 6 report for the configured 'RI-reference CSI process'; otherwise, the UE shall determine a precoder type indication (PTI).
    - The UE shall report a type 6 report consisting of one RI and the PTI.
  - In the subframe where wideband CQI/PMI is reported for all transmission modes except with 8 CSI-RS ports configured for transmission modes 9 and 10:
    - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.

    - A UE shall report a type 2 report on each respective successive reporting opportunity consisting of:

      - A wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set *S* subbands.

      - The selected single PMI (wideband PMI).

      - When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.

    - For transmission modes 4, 8, 9 and 10,

      - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the PMI and CQI values for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise the PMI and CQI values are calculated conditioned on the last reported periodic RI.

- For other transmission modes the PMI and CQI values are calculated conditioned on transmission rank 1.

▪ In the subframe where the wideband first PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured:

  - A set of precoding matrices corresponding to the wideband first PMI is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2a report on each respective successive reporting opportunity consisting of the wideband first PMI corresponding to the selected set of precoding matrices.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=0 is reported in the most recent RI reporting instance for the CSI process, the wideband first PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise with the last reported PTI=0, the wideband first PMI value is calculated conditioned on the last reported periodic RI.

▪ In the subframe where wideband CQI/second PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured:

  - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands.
  - A UE shall report a type 2b report on each respective successive reporting opportunity consisting of:
    - o A wideband CQI value which is calculated assuming the use of the selected single precoding matrix in all subbands and transmission on set *S* subbands.
    - o The wideband second PMI corresponding to the selected single precoding matrix.
    - o When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
  - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=1 is reported in the most recent RI reporting instance for the CSI process,
    - o The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process,
    - o The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
  - Otherwise, with the last reported PTI=1,

        - o The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI.
        - o The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.
    - If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.
- ▪ In the subframe where CQI for the selected subband is reported for all transmission modes except with 8 CSI-RS ports configured for transmission modes 9 and 10:
    - The UE shall select the preferred subband within the set of N_j subbands in each of the J bandwidth parts where J is given in Table 7.2.2-2.
    - The UE shall report a type 1 report per bandwidth part on each respective successive reporting opportunity consisting of:
        - o CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband L-bit label.
        - o When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
            - ▪ Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
            - ▪ Assuming the use of the most recently reported single precoding matrix in all subbands and transmission on the selected subband within the applicable bandwidth part.
        - o The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
    - For transmission modes 4, 8, 9 and 10,
        - o If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 3 report for the CSI process is dropped, and a type 3 report for the 'RI-reference CSI process' is reported in the most recent RI reporting instance for the CSI process, the subband selection and CQI values for the CSI process are calculated conditioned on the last reported periodic wideband PMI for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process; otherwise the subband selection and CQI values are calculated conditioned on the last reported periodic wideband PMI and RI.
    - For other transmission modes the subband selection and CQI values are calculated conditioned on the last reported PMI and transmission rank 1.
- ▪ In the subframe where wideband CQI/second PMI is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured:
    - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands.
    - The UE shall report a type 2b report on each respective successive reporting opportunity consisting of:
        - o A wideband CQI value which is calculated assuming the use of the selected single precoding matrix in all subbands and transmission on set S subbands.

        - o The wideband second PMI corresponding to the selected single precoding matrix.
        - o When RI>1, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
    - If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=0 is reported in the most recent RI reporting instance for the CSI process,
        - o The wideband second PMI value for the CSI process is calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process.
        - o The wideband CQI value is calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
    - Otherwise, with the last reported PTI=0,
        - o The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI. The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.
    - If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.
- ▪ In the subframe where subband CQI/second PMI for the selected subband is reported for transmission modes 9 and 10, and with 8 CSI-RS ports configured:
    - The UE shall select the preferred subband within the set of N_j subbands in each of the J bandwidth parts where J is given in Table 7.2.2-2.
    - The UE shall report a type 1a report per bandwidth part on each respective successive reporting opportunity consisting of:
        - o CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband L-bit label.
        - o When RI>1, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
            - ▪ Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
            - ▪ Assuming the use of the precoding matrix corresponding to the selected second PMI and the most recently reported first PMI and transmission on the selected subband within the applicable bandwidth part.
        - o The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
        - o A second PMI of the preferred precoding matrix selected from the codebook subset assuming transmission only over the selected subband within the applicable bandwidth part determined in the previous step.

- If a UE is configured in transmission mode 10 with a 'RI-reference CSI process' for a CSI process, and the most recent type 6 report for the CSI process is dropped, and a type 6 report for the 'RI-reference CSI process' with PTI=1 is reported in the most recent RI reporting instance for the CSI process,
    - The subband second PMI values for the CSI process are calculated conditioned on the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process and the last reported wideband first PMI for the CSI process.
    - The subband selection and CQI values are calculated conditioned on the selected precoding matrix for the CSI process and the reported periodic RI for the configured 'RI-reference CSI process' in the most recent RI reporting instance for the CSI process.
- Otherwise, with the last reported PTI=1
    - The subband second PMI values are calculated conditioned on the last reported periodic RI and the wideband first PMI.
    - The subband selection and CQI values are calculated conditioned on the selected precoding matrix and the last reported periodic RI.
- If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.

Table 7.2.2-2: Subband Size (*k*) and Bandwidth Parts *(J)* vs. Downlink System Bandwidth

System Bandwidth $N_{\mathrm{RB}}^{\mathrm{DL}}$	**Subband Size *k* (RBs)**	**Bandwidth Parts (*J*)**
6 – 7	NA	NA
8 – 10	4	1
11 – 26	4	2
27 – 63	6	3
64 – 110	8	4

If parameter *ttiBundling* provided by higher layers is set to *TRUE* and if an UL-SCH in subframe bundling operation collides with a periodic CSI reporting instance, then the UE shall drop the periodic CSI report of a given PUCCH reporting type in that subframe and shall not multiplex the periodic CSI report payload in the PUSCH transmission in that subframe. A UE is not expected to be configured with simultaneous PUCCH and PUSCH transmission when UL-SCH subframe bundling is configured.

Table 7.2.2-3: PUCCH Reporting Type Payload size per PUCCH Reporting Mode and Mode State

PUCCH Reporting Type	Reported	Mode State	PUCCH Reporting Modes			
			Mode 1-1 (bits/BP)	Mode 2-1 (bits/BP)	Mode 1-0 (bits/BP)	Mode 2-0 (bits/BP)
1	Sub-band CQI	RI = 1	NA	4+L	NA	4+L
		RI > 1	NA	7+L	NA	4+L
1a	Sub-band CQI / second PMI	8 antenna ports RI = 1	NA	8+L	NA	NA
		8 antenna ports 1 < RI < 5	NA	9+L	NA	NA
		8 antenna ports RI > 4	NA	7+L	NA	NA
2	Wideband CQI/PMI	2 antenna ports RI = 1	6	6	NA	NA
		4 antenna ports RI = 1	8	8	NA	NA
		2 antenna ports RI > 1	8	8	NA	NA
		4 antenna ports RI > 1	11	11	NA	NA
2a	Wideband first PMI	8 antenna ports RI < 3	NA	4	NA	NA
		8 antenna ports 2 < RI < 8	NA	2	NA	NA
		8 antenna ports RI = 8	NA	0	NA	NA
2b	Wideband CQI / second PMI	8 antenna ports RI = 1	8	8	NA	NA
		8 antenna ports 1 < RI < 4	11	11	NA	NA
		8 antenna ports RI = 4	10	10	NA	NA
		8 antenna ports RI > 4	7	7	NA	NA
2c	Wideband CQI / first PMI / second PMI	8 antenna ports RI = 1	8	NA	NA	NA
		8 antenna ports 1 < RI ≤ 4	11	NA	NA	NA
		8 antenna ports 4 < RI ≤ 7	9	NA	NA	NA
		8 antenna ports RI = 8	7	NA	NA	NA
3	RI	2/4 antenna ports, 2-layer spatial multiplexing	1	1	1	1
		8 antenna ports, 2-layer spatial multiplexing	1	NA	NA	NA
		4 antenna ports, 4-layer spatial multiplexing	2	2	2	2
		8 antenna ports, 4-layer spatial multiplexing	2	NA	NA	NA
		8-layer spatial multiplexing	3	NA	NA	NA
4	Wideband CQI	RI = 1 or RI>1	NA	NA	4	4
5	RI/ first PMI	8 antenna ports, 2-layer spatial multiplexing	4	NA	NA	NA
		8 antenna ports, 4 and 8-layer spatial multiplexing	5			
6	RI/PTI	8 antenna ports, 2-layer spatial multiplexing	NA	2	NA	NA
		8 antenna ports, 4-layer spatial multiplexing	NA	3	NA	NA
		8 antenna ports, 8-layer spatial multiplexing	NA	4	NA	NA

7.2.3 Channel Quality Indicator (CQI) definition

The CQI indices and their interpretations are given in Table 7.2.3-1.

Based on an unrestricted observation interval in time and frequency, the UE shall derive for each CQI value reported in uplink subframe *n* the highest CQI index between 1 and 15 in Table 7.2.3-1 which satisfies the following condition, or CQI index 0 if CQI index 1 does not satisfy the condition:

- A single PDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding 0.1.

If CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers, each CSI reference resource belongs to either $C_{\mathrm{CSI},0}$ or $C_{\mathrm{CSI},1}$ but not to both. When CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers a UE is not expected to receive a trigger for which the CSI reference resource is in subframe that does not belong to either subframe set. For a UE in transmission mode 10 and periodic CSI reporting, the CSI subframe set for the CSI reference resource is configured by higher layers for each CSI process.

For a UE in transmission mode 9 when parameter *pmi-RI-Report* is configured by higher layers, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe *n* based on only the Channel-State Information (CSI) reference signals (CSI-RS) defined in [3] for which the UE is configured to assume non-zero power for the CSI-RS. For a UE in transmission mode 9 when the parameter *pmi-RI-Report* is not configured by higher layers or in transmission modes 1-8 the UE shall derive the channel measurements for computing CQI based on CRS.

For a UE in transmission mode 10, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe *n* and corresponding to a CSI process, based on only the non-zero power CSI-RS (defined in [3]) within a configured CSI-RS resource associated with the CSI process.

For a UE in transmission mode 10 , the UE shall derive the interference measurements for computing the CQI value reported in uplink subframe *n* and corresponding to a CSI process, based on only the zero power CSI-RS (defined in [3]) within the configured CSI-IM resource associated with the CSI process. If the UE in transmission mode 10 is configured by higher layers for CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ for the CSI process, the configured CSI-IM resource within the subframe subset belonging to the CSI reference resource is used to derive the interference measurement.

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

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

The CSI reference resource for a serving cell is defined as follows:

- In the frequency domain, the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the derived CQI value relates.
- In the time domain,
    - o for a UE configured in transmission mode 1-9 or transmission mode 10 with a single configured CSI process for the serving cell, the CSI reference resource is defined by a single downlink subframe $n-n_{CQI\_ref}$,
        - where for periodic CSI reporting n_{CQI_ref} is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink subframe;

  - where for aperiodic CSI reporting n_{CQI_ref} is such that the reference resource is in the same valid downlink subframe as the corresponding CSI request in an uplink DCI format.
  - where for aperiodic CSI reporting n_{CQI_ref} is equal to 4 and downlink subframe n-n_{CQI_ref} corresponds to a valid downlink subframe, where downlink subframe n-n_{CQI_ref} is received after the subframe with the corresponding CSI request in a Random Access Response Grant.

- for a UE configured in transmission mode 10 with multiple configured CSI processes for the serving cell, the CSI reference resource for a given CSI process is defined by a single downlink subframe n-n_{CQI_ref},
  - where for FDD and periodic or aperiodic CSI reporting n_{CQI_ref} is the smallest value greater than or equal to 5, such that it corresponds to a valid downlink subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for FDD and aperiodic CSI reporting n_{CQI_ref} is equal to 5 and downlink subframe n-n_{CQI_ref} corresponds to a valid downlink subframe, where downlink subframe n-n_{CQI_ref} is received after the subframe with the corresponding CSI request in a Random Access Response Grant.
  - where for TDD, and 2 or 3 configured CSI processes, and periodic or aperiodic CSI reporting, n_{CQI_ref} is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for TDD, and 2 or 3 configured CSI processes, and aperiodic CSI reporting, n_{CQI_ref} is equal to 4 and downlink subframe n-n_{CQI_ref} corresponds to a valid downlink subframe, where downlink subframe n-n_{CQI_ref} is received after the subframe with the corresponding CSI request in a Random Access Response Grant;
  - where for TDD, and 4 configured CSI processes, and periodic or aperiodic CSI reporting, n_{CQI_ref} is the smallest value greater than or equal to 5, such that it corresponds to a valid downlink subframe, and for aperiodic CSI reporting the corresponding CSI request is in an uplink DCI format;
  - where for TDD, and 4 configured CSI processes, and aperiodic CSI reporting, n_{CQI_ref} is equal to 5 and downlink subframe n-n_{CQI_ref} corresponds to a valid downlink subframe, where downlink subframe n-n_{CQI_ref} is received after the subframe with the corresponding CSI request in a Random Access Response Grant.

A downlink subframe in a serving cell shall be considered to be valid if:

  - it is configured as a downlink subframe for that UE, and
  - in case multiple cells with different uplink-downlink configurations are aggregated and the UE is not capable of simultaneous reception and transmission in the aggregated cells, the subframe in the primary cell is a downlink subframe or a special subframe with the length of DwPTS more than $7680 \cdot T_s$, and
  - except for transmission mode 9 or 10, it is not an MBSFN subframe, and
  - it does not contain a DwPTS field in case the length of DwPTS is $7680 \cdot T_s$ and less, and
  - it does not fall within a configured measurement gap for that UE, and
  - for periodic CSI reporting, it is an element of the CSI subframe set linked to the periodic CSI report when that UE is configured with CSI subframe sets, and
  - for a UE configured in transmission mode 10 with multiple configured CSI processes, and aperiodic CSI reporting for a CSI process, it is an element of the CSI subframe set linked to the downlink subframe with the corresponding CSI request in an uplink DCI format, when that UE is configured with CSI subframe sets for the CSI process.

If there is no valid downlink subframe for the CSI reference resource in a serving cell, CSI reporting is omitted for the serving cell in uplink subframe *n*.

- In the layer domain, the CSI reference resource is defined by any RI and PMI on which the CQI is conditioned.

In the CSI reference resource, the UE shall assume the following for the purpose of deriving the CQI index, and if also configured, PMI and RI:

- The first 3 OFDM symbols are occupied by control signalling
- No resource elements used by primary or secondary synchronization signals or PBCH or EPDCCH
- CP length of the non-MBSFN subframes
- Redundancy Version 0
- If CSI-RS is used for channel measurements, the ratio of PDSCH EPRE to CSI-RS EPRE is as given in clause 7.2.5
- For transmission mode 9 CSI reporting:
    - CRS REs are as in non-MBSFN subframes;
    - If the UE is configured for PMI/RI reporting, the UE-specific reference signal overhead is consistent with the most recent reported rank if more than one CSI-RS port is configured, and is consistent with rank 1 transmission if only one CSI-RS port is configured; and PDSCH signals on antenna ports $\{7\ldots 6+\upsilon\}$ for υ layers would result in signals equivalent to corresponding symbols transmitted on antenna ports $\{15\ldots 14+P\}$, as given by $\begin{bmatrix} y^{(15)}(i) \\ \vdots \\ y^{(14+P)}(i) \end{bmatrix} = W(i)\begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$, where $x(i) = \begin{bmatrix} x^{(0)}(i) & \ldots & x^{(\upsilon-1)}(i) \end{bmatrix}^T$ is a vector of symbols from the layer mapping in clause 6.3.3.2 of [3], $P \in \{1,2,4,8\}$ is the number of CSI-RS ports configured, and if only one CSI-RS port is configured, $W(i)$ is 1, otherwise $W(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$. The corresponding PDSCH signals transmitted on antenna ports $\{15\ldots 14+P\}$ would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in clause 7.2.5.

- For transmission mode 10 CSI reporting, if a CSI process is configured without PMI/RI reporting:
    - If the number of antenna ports of the associated CSI-RS resource is one, a PDSCH transmission is on single-antenna port, port 7. The channel on antenna port {7} is inferred from the channel on antenna port {15} of the associated CSI-RS resource.
        - CRS REs are as in non-MBSFN subframes. The CRS overhead is assumed to be the same as the CRS overhead corresponding to the number of CRS antenna ports of the serving cell;
        - The UE-specific reference signal overhead is 12 REs per PRB pair.
    - Otherwise,
        - If the number of antenna ports of the associated CSI-RS resource is 2, the PDSCH transmission scheme assumes the transmit diversity scheme defined in clause 7.1.2 on antenna ports {0,1} except that the channels on antenna ports {0,1} are inferred from the channels on antenna port {15, 16} of the associated CSI resource respectively.
        - If the number of antenna ports of the associated CSI-RS resource is 4, the PDSCH transmission scheme assumes the transmit diversity scheme defined in clause 7.1.2 on antenna ports {0,1,2,3} except that the channels on antenna ports {0,1,2,3} are inferred from the channels on antenna ports {15, 16, 17, 18} of the associated CSI-RS resource respectively.
        - The UE is not expected to be configured with more than 4 antenna ports for the CSI-RS resource associated with the CSI process configured without PMI/RI reporting.
        - The overhead of CRS REs is assuming the same number of antenna ports as that of the associated CSI-RS resource.
        - UE-specific reference signal overhead is zero.
- For transmission mode 10 CSI reporting, if a CSI process is configured with PMI/RI reporting:
    - CRS REs are as in non-MBSFN subframes. The CRS overhead is assumed to be the same as the CRS overhead corresponding to the number of CRS antenna ports of the serving cell;
    - The UE-specific reference signal overhead is consistent with the most recent reported rank for the CSI process if more than one CSI-RS port is configured, and is consistent with rank 1 transmission if only one CSI-RS port is configured; and PDSCH signals on antenna ports $\{7\ldots 6+\upsilon\}$ for υ layers would result in signals equivalent to corresponding symbols transmitted on antenna ports

$\{15 \ldots 14+P\}$, as given by $\begin{bmatrix} y^{(15)}(i) \\ \vdots \\ y^{(14+P)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$, where

$x(i) = \left[x^{(0)}(i) \quad \ldots \quad x^{(\upsilon-1)}(i)\right]^T$ is a vector of symbols from the layer mapping in clause 6.3.3.2 of [3], $P \in \{1,2,4,8\}$ is the number of antenna ports of the associated CSI-RS resource, and if P=1, $W(i)$ is 1, otherwise $W(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$. The corresponding PDSCH signals transmitted on antenna ports $\{15 \ldots 14+P\}$ would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in clause 7.2.5

- Assume no REs allocated for CSI-RS and zero-power CSI-RS
- Assume no REs allocated for PRS
- The PDSCH transmission scheme given by Table 7.2.3-0 depending on the transmission mode currently configured for the UE (which may be the default mode).
- If CRS is used for channel measurements, the ratio of PDSCH EPRE to cell-specific RS EPRE is as given in clause 5.2 with the exception of ρ_A which shall be assumed to be
  - o $\rho_A = P_A + \Delta_{offset} + 10\log_{10}(2)$ [dB] for any modulation scheme, if the UE is configured with transmission mode 2 with 4 cell-specific antenna ports, or transmission mode 3 with 4 cell-specific antenna ports and the associated RI is equal to one;
  - o $\rho_A = P_A + \Delta_{offset}$ [dB] for any modulation scheme and any number of layers, otherwise.

The shift Δ_{offset} is given by the parameter *nomPDSCH-RS-EPRE-Offset* which is configured by higher-layer signalling.

Table 7.2.3-0: PDSCH transmission scheme assumed for CSI reference resource

Transmission mode	Transmission scheme of PDSCH
1	Single-antenna port, port 0
2	Transmit diversity
3	Transmit diversity if the associated rank indicator is 1, otherwise large delay CDD
4	Closed-loop spatial multiplexing
5	Multi-user MIMO
6	Closed-loop spatial multiplexing with a single transmission layer
7	If the number of PBCH antenna ports is one, Single-antenna port, port 0; otherwise Transmit diversity
8	If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity If the UE is configured with PMI/RI reporting: closed-loop spatial multiplexing
9	If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity If the UE is configured with PMI/RI reporting: if the number of CSI-RS ports is one, single-antenna port, port 7; otherwise up to 8 layer transmission, ports 7-14 (see clause 7.1.5B)
10	If a CSI process of the UE is configured without PMI/RI reporting: if the number of CSI-RS ports is one, single-antenna port, port7; otherwise transmit diversity If a CSI process of the UE is configured with PMI/RI reporting: if the number of CSI-RS ports is one, single-antenna port, port 7; otherwise up to 8 layer transmission, ports 7-14 (see clause 7.1.5B)

Table 7.2.3-1: 4-bit CQI Table

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

7.2.4 Precoding Matrix Indicator (PMI) definition

For transmission modes 4, 5 and 6, precoding feedback is used for channel dependent codebook based precoding and relies on UEs reporting precoding matrix indicator (PMI). For transmission mode 8, the UE shall report PMI if configured with PMI/RI reporting. For transmission modes 9 and 10, the UE shall report PMI if configured with PMI/RI reporting and the number of CSI-RS ports is larger than 1. A UE shall report PMI based on the feedback modes described in 7.2.1 and 7.2.2. For other transmission modes, PMI reporting is not supported.

For 2 and 4 antenna ports, each PMI value corresponds to a codebook index given in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [3] as follows:

- For 2 antenna ports $\{0,1\}$ or {15,16} and an associated RI value of 1, a PMI value of $n \in \{0,1,2,3\}$ corresponds to the codebook index n given in Table 6.3.4.2.3-1 of [3] with $\upsilon = 1$.
- For 2 antenna ports $\{0,1\}$ or {15,16} and an associated RI value of 2, a PMI value of $n \in \{0,1\}$ corresponds to the codebook index $n+1$ given in Table 6.3.4.2.3-1 of [3] with $\upsilon = 2$.
- For 4 antenna ports $\{0,1,2,3\}$ or {15,16,17,18}, a PMI value of $n \in \{0,1,\cdots,15\}$ corresponds to the codebook index n given in Table 6.3.4.2.3-2 of [3] with υ equal to the associated RI value.

For 8 antenna ports, each PMI value corresponds to a pair of codebook indices given in Table 7.2.4-1, 7.2.4-2, 7.2.4-3, 7.2.4-4, 7.2.4-5, 7.2.4-6, 7.2.4-7, or 7.2.4-8, where the quantities φ_n and v_m are given by

$$\varphi_n = e^{j\pi n/2}$$
$$v_m = \begin{bmatrix} 1 & e^{j2\pi m/32} & e^{j4\pi m/32} & e^{j6\pi m/32} \end{bmatrix}^T$$

- as follows:For 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, a first PMI value of $n_1 \in \{0,1,\cdots, f(\upsilon)-1\}$ and a second PMI value of $n_2 \in \{0,1,\cdots, g(\upsilon)-1\}$ corresponds to the codebook indices n_1 and n_2 given in Table 7.2.4-j with υ equal to the associated RI value and where $j = \upsilon$, $f(\upsilon) = \{16,16,4,4,4,4,4,1\}$ and $g(\upsilon) = \{16,16,16,8,1,1,1,1\}$.
- In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1D for first and second precoding matrix indicator i_1 and i_2. Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1F for PUCCH Reporting Type 1.

Table 7.2.4-1: Codebook for 1-layer CSI reporting using antenna ports 15 to 22

i_1	i_2							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0 – 15	$W^{(1)}_{2i_1,0}$	$W^{(1)}_{2i_1,1}$	$W^{(1)}_{2i_1,2}$	$W^{(1)}_{2i_1,3}$	$W^{(1)}_{2i_1+1,0}$	$W^{(1)}_{2i_1+1,1}$	$W^{(1)}_{2i_1+1,2}$	$W^{(1)}_{2i_1+1,3}$
i_1	i_2							
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0 - 15	$W^{(1)}_{2i_1+2,0}$	$W^{(1)}_{2i_1+2,1}$	$W^{(1)}_{2i_1+2,2}$	$W^{(1)}_{2i_1+2,3}$	$W^{(1)}_{2i_1+3,0}$	$W^{(1)}_{2i_1+3,1}$	$W^{(1)}_{2i_1+3,2}$	$W^{(1)}_{2i_1+3,3}$
where $W^{(1)}_{m,n} = \frac{1}{\sqrt{8}}\begin{bmatrix} v_m \\ \varphi_n v_m \end{bmatrix}$								

Table 7.2.4-2: Codebook for 2-layer CSI reporting using antenna ports 15 to 22

i_1	i_2			
	0	**1**	**2**	**3**
0 – 15	$W^{(2)}_{2i_1,2i_1,0}$	$W^{(2)}_{2i_1,2i_1,1}$	$W^{(2)}_{2i_1+1,2i_1+1,0}$	$W^{(2)}_{2i_1+1,2i_1+1,1}$
i_1	i_2			
	4	**5**	**6**	**7**
0 – 15	$W^{(2)}_{2i_1+2,2i_1+2,0}$	$W^{(2)}_{2i_1+2,2i_1+2,1}$	$W^{(2)}_{2i_1+3,2i_1+3,0}$	$W^{(2)}_{2i_1+3,2i_1+3,1}$
i_1	i_2			
	8	**9**	**10**	**11**
0 – 15	$W^{(2)}_{2i_1,2i_1+1,0}$	$W^{(2)}_{2i_1,2i_1+1,1}$	$W^{(2)}_{2i_1+1,2i_1+2,0}$	$W^{(2)}_{2i_1+1,2i_1+2,1}$
i_1	i_2			
	12	**13**	**14**	**15**
0 – 15	$W^{(2)}_{2i_1,2i_1+3,0}$	$W^{(2)}_{2i_1,2i_1+3,1}$	$W^{(2)}_{2i_1+1,2i_1+3,0}$	$W^{(2)}_{2i_1+1,2i_1+3,1}$
where $W^{(2)}_{m,m',n} = \frac{1}{4}\begin{bmatrix} v_m & v_{m'} \\ \varphi_n v_m & -\varphi_n v_{m'} \end{bmatrix}$				

Table 7.2.4-3: Codebook for 3-layer CSI reporting using antenna ports 15 to 22

i_1	i_2			
	0	**1**	**2**	**3**
0 - 3	$W^{(3)}_{8i_1,8i_1,8i_1+8}$	$W^{(3)}_{8i_1+8,8i_1,8i_1+8}$	$\tilde{W}^{(3)}_{8i_1,8i_1+8,8i_1+8}$	$\tilde{W}^{(3)}_{8i_1+8,8i_1,8i_1}$
i_1	i_2			
	4	**5**	**6**	**7**
0 - 3	$W^{(3)}_{8i_1+2,8i_1+2,8i_1+10}$	$W^{(3)}_{8i_1+10,8i_1+2,8i_1+10}$	$\tilde{W}^{(3)}_{8i_1+2,8i_1+10,8i_1+10}$	$\tilde{W}^{(3)}_{8i_1+10,8i_1+2,8i_1+2}$
i_1	i_2			
	8	**9**	**10**	**11**
0 - 3	$W^{(3)}_{8i_1+4,8i_1+4,8i_1+12}$	$W^{(3)}_{8i_1+12,8i_1+4,8i_1+12}$	$\tilde{W}^{(3)}_{8i_1+4,8i_1+12,8i_1+12}$	$\tilde{W}^{(3)}_{8i_1+12,8i_1+4,8i_1+4}$
i_1	i_2			
	12	**13**	**14**	**15**
0 - 3	$W^{(3)}_{8i_1+6,8i_1+6,8i_1+14}$	$W^{(3)}_{8i_1+14,8i_1+6,8i_1+14}$	$\tilde{W}^{(3)}_{8i_1+6,8i_1+14,8i_1+14}$	$\tilde{W}^{(3)}_{8i_1+14,8i_1+6,8i_1+6}$
where $W^{(3)}_{m,m',m''} = \frac{1}{\sqrt{24}}\begin{bmatrix} v_m & v_{m'} & v_{m''} \\ v_m & -v_{m'} & -v_{m''} \end{bmatrix}$, $\tilde{W}^{(3)}_{m,m',m''} = \frac{1}{\sqrt{24}}\begin{bmatrix} v_m & v_{m'} & v_{m''} \\ v_m & v_{m'} & -v_{m''} \end{bmatrix}$				

Table 7.2.4-4: Codebook for 4-layer CSI reporting using antenna ports 15 to 22

i_1	i_2			
	0	**1**	**2**	**3**
0 - 3	$W^{(4)}_{8i_1,8i_1+8,0}$	$W^{(4)}_{8i_1,8i_1+8,1}$	$W^{(4)}_{8i_1+2,8i_1+10,0}$	$W^{(4)}_{8i_1+2,8i_1+10,1}$
i_1	i_2			
	4	**5**	**6**	**7**
0 - 3	$W^{(4)}_{8i_1+4,8i_1+12,0}$	$W^{(4)}_{8i_1+4,8i_1+12,1}$	$W^{(4)}_{8i_1+6,8i_1+14,0}$	$W^{(4)}_{8i_1+6,8i_1+14,1}$
where $W^{(4)}_{m,m',n} = \frac{1}{\sqrt{32}}\begin{bmatrix} v_m & v_{m'} & v_m & v_{m'} \\ \varphi_n v_m & \varphi_n v_{m'} & -\varphi_n v_m & -\varphi_n v_{m'} \end{bmatrix}$				

Table 7.2.4-5: Codebook for 5-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0 - 3	$W_{i_1}^{(5)} = \frac{1}{\sqrt{40}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} \end{bmatrix}$

Table 7.2.4-6: Codebook for 6-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0 - 3	$W_{i_1}^{(6)} = \frac{1}{\sqrt{48}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} \end{bmatrix}$

Table 7.2.4-7: Codebook for 7-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0 - 3	$W_{i_1}^{(7)} = \frac{1}{\sqrt{56}}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} & v_{2i_1+24} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} & v_{2i_1+24} \end{bmatrix}$

Table 7.2.4-8: Codebook for 8-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0	$W_{i_1}^{(8)} = \frac{1}{8}\begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} & v_{2i_1+24} & v_{2i_1+24} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} & v_{2i_1+24} & -v_{2i_1+24} \end{bmatrix}$

7.2.5 Channel-State Information – Reference Signal (CSI-RS) definition

For a serving cell and UE configured in transmission mode 9, the UE can be configured with one CSI-RS resource configuration. For a serving cell and UE configured in transmission mode 10, the UE can be configured with one or more CSI-RS resource configuration(s). The following parameters for which the UE shall assume non-zero transmission power for CSI-RS are configured via higher layer signaling for each CSI-RS resource configuration:

- CSI-RS resource configuration identity, if the UE is configured in transmission mode 10,
- Number of CSI-RS ports. The allowable values and port mapping are given in clause 6.10.5 of [3].
- CSI RS Configuration (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3])
- CSI RS subframe configuration $I_{\mathrm{CSI-RS}}$. The allowable values are given in clause 6.10.5.3 of [3].
- UE assumption on reference PDSCH transmitted power for CSI feedback P_c, if the UE is configured in transmission mode 9.
- UE assumption on reference PDSCH transmitted power for CSI feedback P_c for each CSI process, if the UE is configured in transmission mode 10. If CSI subframe sets $C_{\mathrm{CSI},0}$ and $C_{\mathrm{CSI},1}$ are configured by higher layers for a CSI process, P_c is configured for each CSI subframe set of the CSI process.
- Pseudo-random sequence generator parameter, n_{ID}. The allowable values are given in [11].
- Higher layer parameter *qcl-CRS-Info-r11* for Quasi co-location type B UE assumption of CRS antenna ports and CSI-RS antenna ports with the following parameters, if the UE is configured in transmission mode 10:
  - *qcl-ScramblingIdentity-r11*.
  - *crs-PortsCount-r11*.
  - *mbsfn-SubframeConfigList-r11*.

P_c is the assumed ratio of PDSCH EPRE to CSI-RS EPRE when UE derives CSI feedback and takes values in the range of [-8, 15] dB with 1 dB step size, where the PDSCH EPRE corresponds to the symbols for which the ratio of the PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A, as specified in Table 5.2-2 and Table 5.2-3.

A UE should not expect the configuration of CSI-RS and PMCH in the same subframe of a serving cell.

For frame structure type 2 and 4 CRS ports, the UE is not expected to receive a CSI RS Configuration index (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3]) belonging to the set [20-31] for the normal CP case or the set [16-27] for the extended CP case.

A UE may assume the CSI-RS antenna ports of a CSI-RS resource configuration are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

A UE configured in transmission mode 10 and with quasi co-location type B, may assume the antenna ports 0 – 3 associated with *qcl-CRS-Info-r11* corresponding to a CSI-RS resource configuration and antenna ports 15 – 22 corresponding to the CSI-RS resource configuration are quasi co-located (as defined in [3]) with respect to Doppler shift, and Doppler spread.

7.2.6 Channel-State Information – Interference Measurement (CSI-IM) Resource definition

For a serving cell and UE configured in transmission mode 10, the UE can be configured with one or more CSI-IM resource configuration(s). The following parameters are configured via higher layer signaling for each CSI-IM resource configuration:

- Zero-power CSI RS Configuration (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3])
- Zero-power CSI RS subframe configuration $I_{\mathrm{CSI-RS}}$. The allowable values are given in clause 6.10.5.3 of [3].

A UE is not expected to receive CSI-IM resource configuration(s) that are not all completely overlapping with one zero-power CSI-RS resource configuration which can be configured for the UE. A UE is not expected to receive a CSI-IM resource configuration that is not completely overlapping with one of the zero-power CSI-RS resource configurations defined in clause 7.2.7.

A UE should not expect the configuration of CSI-IM resource and PMCH in the same subframe of a serving cell.

7.2.7 Zero Power CSI-RS Resource definition

For a serving cell and UE configured in transmission mode 1-9, the UE can be configured with one zero-power CSI-RS resource configuration. For a serving cell and UE configured in transmission mode 10, the UE can be configured with one or more zero-power CSI-RS resource configuration(s).
The following parameters are configured via higher layer signaling for each zero-power CSI-RS resource configuration:

- Zero-power CSI RS Configuration list (16-bit bitmap *ZeroPowerCSI-RS* in [3])
- Zero-power CSI RS subframe configuration $I_{\mathrm{CSI-RS}}$. *T*he allowable values are given in clause 6.10.5.3 of [3].

A UE should not expect the configuration of zero-power CSI-RS and PMCH in the same subframe of a serving cell.

For frame structure type 1, the UE is not expected to receive the 16-bit bitmap *ZeroPowerCSI-RS* with any one of the 6 LSB bits set to 1 for the normal CP case, or with any one of the 8 LSB bits set to 1 for the extended CP case.

For frame structure type 2 and 4 CRS ports, the UE is not expected to receive the 16-bit bitmap *ZeroPowerCSI-RS* with any one of the 6 LSB bits set to 1 for the normal CP case, or with any one of the 8 LSB bits set to 1 for the extended CP case.

7.3 UE procedure for reporting HARQ-ACK

The UE procedure for HARQ-ACK reporting for frame structure type 1 is given in clause 7.3.1.

The UE procedure for HARQ-ACK reporting for frame structure type 2 is given in clause 7.3.2.

7.3.1 FDD HARQ-ACK reporting procedure

For FDD with PUCCH format 1a/1b transmission, when both HARQ-ACK and SR are transmitted in the same sub-frame, a UE shall transmit the HARQ-ACK on its assigned HARQ-ACK PUCCH format 1a/1b resource for a negative SR transmission and transmit the HARQ-ACK on its assigned SR PUCCH resource for a positive SR transmission.

For FDD with PUCCH format 1b with channel selection, when both HARQ-ACK and SR are transmitted in the same sub-frame a UE shall transmit the HARQ-ACK on its assigned HARQ-ACK PUCCH resource with channel selection as defined in clause 10.1.2.2.1 for a negative SR transmission and transmit one HARQ-ACK bit per serving cell on its assigned SR PUCCH resource for a positive SR transmission according to the following:

- if only one transport block or a PDCCH/EPDCCH indicating downlink SPS release is detected on a serving cell, the HARQ-ACK bit for the serving cell is the HARQ-ACK bit corresponding to the transport block or the PDCCH/EPDCCH indicating downlink SPS release;
- if two transport blocks are received on a serving cell, the HARQ-ACK bit for the serving cell is generated by spatially bundling the HARQ-ACK bits corresponding to the transport blocks;
- if neither PDSCH transmission for which HARQ-ACK response shall be provided nor PDCCH/EPDCCH indicating downlink SPS release is detected for a serving cell, the HARQ-ACK bit for the serving cell is set to NACK;

and the HARQ-ACK bits for the primary cell and the secondary cell are mapped to $b(0)$ and $b(1)$, respectively, where $b(0)$ and $b(1)$ are specified in clause 5.4.1 in [3].

For FDD, when a PUCCH format 3 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in clause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to a PDSCH transmission on the primary cell only or a PDCCH/EPDCCH indicating downlink SPS release on the primary cell only, in which case the SR shall be transmitted as for FDD with PUCCH format 1a/1b.

For FDD and for a PUSCH transmission, a UE shall not transmit HARQ-ACK on PUSCH in subframe n if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe $n-4$.

When only a positive SR is transmitted, a UE shall use PUCCH Format 1 for the SR resource as defined in clause 5.4.1 in [3].

7.3.2 TDD HARQ-ACK reporting procedure

For TDD, if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, UE procedure for reporting HARQ-ACK is given in clause 7.3.2.1.

For TDD, if a UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, UE procedure for reporting HARQ-ACK is given in clause 7.3.2.2.

When only a positive SR is transmitted, a UE shall use PUCCH Format 1 for the SR resource as defined in clause 5.4.1 in [3].

7.3.2.1 TDD HARQ-ACK reporting procedure for same UL/DL configuration

For TDD, the UE shall upon detection of a PDSCH transmission or a PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe n.

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK, for special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in a serving cell, shown in table 4.2-1 [3], the special subframe of the serving cell is excluded from the HARQ-ACK codebook size determination. In this case, if the serving cell is the primary cell, there is no PDCCH/EPDCCH indicating downlink SPS release in the special subframe.

For TDD UL/DL configurations 1-6 and one configured serving cell, if the UE is not configured with PUCCH format 3, the value of the Downlink Assignment Index (DAI) in DCI format 0/4, V_{DAI}^{UL}, detected by the UE according to Table 7.3-X in subframe $n-k'$, where k' is defined in Table 7.3-Y, represents the total number of subframes with PDSCH transmissions and with PDCCH/EPDCCH indicating downlink SPS release to the corresponding UE within all the subframe(s) $n-k$, where $k \in K$. The value V_{DAI}^{UL} includes all PDSCH transmission with and without corresponding PDCCH/EPDCCH within all the subframe(s) $n-k$. In case neither PDSCH transmission, nor PDCCH/EPDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of the DAI in DCI format 0/4, V_{DAI}^{UL}, if transmitted, is set to 4.

For TDD UL/DL configuration 1-6 and a UE configured with more than one serving cell, or for TDD UL/DL configuration 1-6 and a UE configured with one serving cell and PUCCH format 3, a value W_{DAI}^{UL} is determined by the Downlink Assignment Index (DAI) in DCI format 0/4 according to Table 7.3-Z in subframe $n-k'$, where k' is defined in Table 7.3-Y. In case neither PDSCH transmission, nor PDCCH/EPDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of W_{DAI}^{UL} is set to 4 by the DAI in DCI format 0/4 if transmitted.

For TDD UL/DL configurations 1-6, the value of the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release up to the present subframe within subframe(s) $n-k$ of each configured serving cell, where $k \in K$, and shall be updated from subframe to subframe. Denote $V_{DAI,c}^{DL}$ as the value of the DAI in PDCCH/EPDCCH with DCI format 1/1A/1B/1D/2/2A/2B/2C/2D detected by the UE according to Table 7.3-X in subframe $n-k_m$ in serving cell c, where k_m is the smallest value in the set K (defined in Table 10.1.3.1-1) such that the UE detects a DCI format 1/1A/1B/1D/2/2A/2B/2C/2D. When configured with one serving cell, the subscript of c in $V_{DAI,c}^{DL}$ can be omitted.

For all TDD UL/DL configurations, denote $U_{DAI,c}$ as the total number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release detected by the UE within the subframe(s) $n-k$ in serving cell c, where $k \in K$. When configured with one serving cell, the subscript of c in $U_{DAI,c}$ can be omitted. Denote N_{SPS}, which can be zero or one, as the number of PDSCH transmissions without a corresponding PDCCH/EPDCCH within the subframe(s) $n-k$, where $k \in K$.

For TDD HARQ-ACK bundling or HARQ-ACK multiplexing and a subframe n with $M=1$, the UE shall generate one or two HARQ-ACK bits by performing a logical AND operation per codeword across M DL subframes associated with a single UL subframe, of all the corresponding $U_{DAI}+N_{SPS}$ individual PDSCH transmission HARQ-ACKs and individual ACK in response to received PDCCH/EPDCCH indicating downlink SPS release, where M is the number of elements in the set K defined in Table 10.1.3.1-1. The UE shall detect if at least one downlink assignment has been missed, and for the case that the UE is transmitting on PUSCH the UE shall also determine the parameter N_{bundled}.

- For TDD UL/DL configuration 0, N_{bundled} shall be 1 if the UE detects the PDSCH transmission with or without corresponding PDCCH/EPDCCH, or detects PDCCH indicating downlink SPS release within the subframe $n-k$, where $k \in K$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release within the subframe(s) $n-k$, where $k \in K$.
- For the case that the UE is not transmitting on PUSCH in subframe *n* and TDD UL/DL configurations 1-6, if $U_{DAI}>0$ and $V_{DAI}^{DL} \neq (U_{DAI}-1) \bmod 4+1$, the UE detects that at least one downlink assignment has been missed.

- For the case that the UE is transmitting on PUSCH and the PUSCH transmission is adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE and TDD UL/DL configurations 1-6, if $V_{DAI}^{UL} \neq (U_{DAI} + N_{SPS} - 1) \bmod 4 + 1$ the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords where N_{bundled} is determined by the UE as $N_{\text{bundled}} = V_{DAI}^{UL} + 2$. If the UE does not detect any downlink assignment missing, N_{bundled} is determined by the UE as $N_{\text{bundled}} = V_{DAI}^{UL}$. UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$ and $V_{DAI}^{UL} = 4$.

- For the case that the UE is transmitting on PUSCH, and the PUSCH transmission is not based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE and TDD UL/DL configurations 1-6, if $U_{DAI} > 0$ and $V_{DAI}^{DL} \neq (U_{DAI} - 1) \bmod 4 + 1$, the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords. The UE determines $N_{\text{bundled}} = (U_{DAI} + N_{SPS})$ as the number of assigned subframes. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$.

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK, the HARQ-ACK feedback bits $o_{c,0}^{ACK}\ o_{c,1}^{ACK}, \ldots, o_{c,O_c^{ACK}-1}^{ACK}$ for the *c*-th serving cell configured by RRC are constructed as follows, where *c*≥0, $O_c^{ACK} = B_c^{DL}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied and $O_c^{ACK} = 2B_c^{DL}$ otherwise, where B_c^{DL} is the number of downlink subframes for which the UE needs to feedback HARQ-ACK bits for the *c*-th serving cell.

- For the case that the UE is transmitting on PUCCH, $B_c^{DL} = M$ where M is the number of elements in the set K defined in Table 10.1.3.1-1 associated with subframe *n* and the set K does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL} = M - 1$.

- For TDD UL/DL configuration 0 or for a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL} = M$ where M is the number of elements in the set K defined in Table 10.1.3.1-1 associated with subframe *n* and the set K does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL} = M - 1$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$, where $k \in K$.

- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL} = W_{DAI}^{UL}$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

- For TDD UL/DL configurations 5 and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, the UE shall assume $B_c^{DL} = W_{DAI}^{UL} + 4\left\lceil \left(U - W_{DAI}^{UL}\right)/4 \right\rceil$, where U denotes the maximum value of U_c among all the configured serving cells, U_c is the total number of received PDSCHs and PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ on the *c*-th serving cell, $k \in K$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK,

- for TDD UL/DL configurations 1-6, the HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,DAI(k)-1}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$

otherwise, where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$, $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to $o_{c,O_c^{ACK}-1}^{ACK}$ The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK;

- for TDD UL/DL configuration 0, the HARQ-ACK for a PDSCH transmission or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,0}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or associated with $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ otherwise, where $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK.

For TDD when format 1b with channel selection is configured for transmission of HARQ-ACK and for 2 configured serving cells, the HARQ-ACK feedback bits $o_0^{ACK}\ o_1^{ACK}, \ldots, o_{O^{ACK}-1}^{ACK}$ on PUSCH are constructed as follows.

- For TDD UL/DL configuration 0, o_j^{ACK} = HARQ-ACK(*j*), $0 \le j \le A-1$ as defined in clause 10.1.3.2.1. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with W_{DAI}^{UL} =1 or 2, o_j^{ACK} is determined as if PUCCH format 3 is configured for transmission of HARQ-ACK, except that spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed for all serving cells configured with a downlink transmission mode that supports up to two transport blocks in case W_{DAI}^{UL} =2.

- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with W_{DAI}^{UL} =3 or 4, $o_j^{ACK} = o(j)$, $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the value of M is replaced by W_{DAI}^{UL}. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 and a subframe n with M =1 or 2, o_j^{ACK} = HARQ-ACK(*j*), $0 \le j \le A-1$ as defined in clause 10.1.3.2.1. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

- For TDD UL/DL configurations {1, 2, 3, 4, 6} and a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 and a subframe n with M =3 or 4, $o_j^{ACK} = o(j)$, $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

For TDD HARQ-ACK bundling, when the UE is configured by transmission mode 3, 4, 8, 9 or 10 defined in clause 7.1 and HARQ-ACK bits are transmitted on PUSCH, the UE shall always generate 2 HARQ-ACK bits assuming both codeword 0 and 1 are enabled. For the case that the UE detects only the PDSCH transmission associated with codeword 0 within the bundled subframes, the UE shall generate NACK for codeword 1.

Table 7.3-X: Value of Downlink Assignment Index

DAI MSB, LSB	V_{DAI}^{UL} or V_{DAI}^{DL}	Number of subframes with PDSCH transmission and with PDCCH/EPDCCH indicating DL SPS release
0,0	1	1 or 5 or 9
0,1	2	2 or 6
1,0	3	3 or 7
1,1	4	0 or 4 or 8

Table 7.3-Y: Uplink association index *k'* for TDD

TDD UL/DL Configuration	subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
1			6	4				6	4	
2			4					4		
3			4	4	4					
4			4	4						
5			4							
6			7	7	5			7	7	

Table 7.3-Z: Value of W_{DAI}^{UL} determined by the DAI field in DCI format 0/4

DAI MSB, LSB	W_{DAI}^{UL}
0,0	1
0,1	2
1,0	3
1,1	4

For TDD HARQ-ACK multiplexing and a subframe n with $M > 1$, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. In case the UE is transmitting on PUSCH, the UE shall determine the number of HARQ-ACK feedback bits O^{ACK} and the HARQ-ACK feedback bits o_n^{ACK} , $n = 0,\ldots,O^{ACK} - 1$ to be transmitted in subframe *n*.

- If the PUSCH transmission is adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE, then $O^{ACK} = V_{DAI}^{UL}$ unless $V_{DAI}^{UL} = 4$ and $U_{DAI} + N_{SPS} = 0$ in which case the UE shall not transmit HARQ-ACK. The spatially bundled HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{DAI(k)-1}^{ACK}$ where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to $o_{O^{ACK}-1}^{ACK}$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK.

- If the PUSCH transmission is not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 intended for the UE, $O^{ACK} = M$, and o_i^{ACK} is associated with the spatially bundled HARQ-ACK for DL subframe $n-k_i$, where $k_i \in K$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$.

For TDD when a PUCCH format 3 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in clause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to one of the following cases

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1', or

- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$, or

- a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) in the subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1',

in which case the UE shall transmit the HARQ-ACK and scheduling request according to the procedure for PUCCH format 1b with channel selection in TDD.

For TDD when the UE is configured with HARQ-ACK bundling, HARQ-ACK multiplexing or PUCCH format 1b with channel selection, and when both HARQ-ACK and SR are transmitted in the same sub-frame, a UE shall transmit the bundled HARQ-ACK or the multiple HARQ-ACK responses (according to clause 10.1) on its assigned HARQ-ACK PUCCH resources for a negative SR transmission. For a positive SR, the UE shall transmit $b(0),b(1)$ on its assigned SR PUCCH resource using PUCCH format 1b according to clause 5.4.1 in [3]. The value of $b(0),b(1)$ are generated according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH/EPDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells N_{cells}^{DL}. For TDD UL/DL configurations 1-6, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq (U_{DAI,c} - 1) \bmod 4 + 1$ for a serving cell c, the UE detects that at least one downlink assignment has been missed.

Table 7.3-1: Mapping between multiple HARQ-ACK responses and $b(0),b(1)$

Number of ACK among multiple ($N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$) HARQ-ACK responses	$b(0),b(1)$
0 or None (UE detect at least one DL assignment is missed)	0, 0
1	1, 1
2	1, 0
3	0, 1
4	1, 1
5	1, 0
6	0, 1
7	1, 1
8	1, 0
9	0, 1

For TDD if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE,* and if the UE is configured with HARQ-ACK bundling, HARQ-ACK multiplexing or PUCCH format 1b with channel selection, and if the UE receives PDSCH and/or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell within subframe(s) $n-k$, where $k \in K$, a UE shall transmit the CSI and $b(0),b(1)$ using PUCCH format 2b for normal CP or PUCCH format 2 for extended CP, according to clause 5.2.3.4 in [4] with a''_0, a''_1 replaced by $b(0), b(1)$. The value of $b(0), b(1)$ are generated according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH/EPDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells N_{cells}^{DL}. For TDD UL/DL configurations 1-6, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq (U_{DAI,c} - 1) \bmod 4 + 1$ for a serving cell c, the UE detects that at least one downlink assignment has been missed.

For TDD if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, and if the UE is configured with PUCCH format 1b with channel selection and receives at least one PDSCH on the secondary cell within subframe(s) $n-k$, where $k \in K$, the UE shall drop the CSI and transmit HARQ-ACK according to clause 10.1.3.

For TDD and a UE is configured with PUCCH format 3,

if the parameter *simultaneousAckNackAndCQI* is set *TRUE* and if the UE receives,

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for TDD UL/DL configurations 1-6 the DAI value in the PDCCH/EPDCCH is equal to '1', or

- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$,

then the UE shall transmit the CSI and HARQ-ACK using PUCCH format 2/2a/2b according to clause 5.2.3.4 in [4]; else if

- the parameter *simultaneousAckNackAndCQI-Format3-r11* is set *TRUE* and if PUCCH format 3 resource is determined according to clause 10.1.3.1 or clause 10.1.3.2.2 and

    - o if the total number of bits in the subframe corresponding to HARQ-ACKs, SR (if any), and the CSI is not larger than 22, or

    - o if the total number of bits in the subframe corresponding to spatially bundled HARQ-ACKs, SR (if any), and the CSI is not larger than 22

then the UE shall transmit the HARQ-ACKs, SR (if any) and the CSI using the determined PUCCH format 3 resource according to [4];

else,

the UE shall drop the CSI and transmit the HARQ-ACK according to clause 10.1.3.

7.3.2.2 TDD HARQ-ACK reporting procedure for different UL/DL configurations

For a configured serving cell, the DL-reference UL/DL configuration as defined in clause 10.2 is referred to as the "DL-reference UL/DL configuration" in the rest of this clause.

For a configured serving cell, if the DL-reference UL/DL configuration is 0, then the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D is not used.

The UE shall upon detection of a PDSCH transmission or a PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$ for serving cell *c*, where $k \in K_c$ intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*, wherein set

K_c contains values of $k \in K$ such that subframe *n-k* corresponds to a DL subframe or a special subframe for serving cell *c*, K defined in Table 10.1.3.1-1 (where "UL/DL configuration" in Table 10.1.3.1-1 refers to the DL-reference UL/DL configuration) is associated with subframe *n*. M_c is the number of elements in set K_c associated with subframe *n* for serving cell *c*,

For the remainder of this clause $K = K_c$.

When PUCCH format 3 is configured for transmission of HARQ-ACK, for special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in a serving cell, shown in table 4.2-1 [3], the special subframe of the serving cell is excluded from the HARQ-ACK codebook size determination. In this case, if the serving cell is the primary cell, there is no PDCCH/EPDCCH indicating downlink SPS release in the special subframe.

If the UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1,2,3,4,5,6} for a serving cell, a value W_{DAI}^{UL} is determined by the Downlink Assignment Index (DAI) in DCI format 0/4 corresponding to a PUSCH on the serving cell according to Table 7.3-Z in subframe $n - k'$, where k' is defined in Table 7.3-Y and the "TDD UL/DL Configuration" in Table 7.3-Y refers to the UL-reference UL/DL configuration (defined in clause 8.0) for the serving cell. In case neither PDSCH transmission, nor PDCCH/EPDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of W_{DAI}^{UL} is set to 4 by the DAI in DCI format 0/4 if transmitted.

If the DL-reference UL/DL configuration belongs to {1,2,3,4,5,6}, the value of the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C/2D denotes the accumulative number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release up to the present subframe within subframe(s) $n-k$ of each configured serving cell, where $k \in K$, and shall be updated from subframe to subframe. Denote $V_{DAI,c}^{DL}$ as the value of the DAI in PDCCH/EPDCCH with DCI format 1/1A/1B/1D/2/2A/2B/2C/2D detected by the UE according to Table 7.3-X in subframe $n - k_m$ in serving cell c , where k_m is the smallest value in the set K such that the UE detects a DCI format 1/1A/1B/1D/2/2A/2B/2C/2D.

For all TDD UL/DL configurations, denote $U_{DAI,c}$ as the total number of PDCCH/EPDCCH (s) with assigned PDSCH transmission(s) and PDCCH/EPDCCH indicating downlink SPS release detected by the UE within the subframe(s) $n-k$ in serving cell c , where $k \in K$. Denote N_{SPS} , which can be zero or one, as the number of PDSCH transmissions without a corresponding PDCCH/EPDCCH within the subframe(s) $n-k$, where $k \in K$.

If PUCCH format 3 is configured for transmission of HARQ-ACK, the HARQ-ACK feedback bits $o_{c,0}^{ACK}\ o_{c,1}^{ACK},...,o_{c,O_c^{ACK}-1}^{ACK}$ for the *c*-th serving cell configured by RRC are constructed as follows, where *c*≥0, $O_c^{ACK} = B_c^{DL}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied and $O_c^{ACK} = 2B_c^{DL}$ otherwise, where B_c^{DL} is the number of downlink subframes for which the UE needs to feedback HARQ-ACK bits for the *c*-th serving cell.

- For the case that the UE is transmitting in subframe *n* on PUCCH or a PUSCH transmission not adjusted based on a detected DCI format 0/4 or a PUSCH transmission adjusted based on an associated detected DCI format 0/4 with UL-reference UL/DL configuration 0 (defined in Sec 8.0), then $B_c^{DL} = M_c$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$, where $k \in K$.
- If DL-reference UL/DL configuration of each of the configured serving cells belongs to {0, 1, 2, 3, 4, 6} and for a PUSCH transmission in a subframe *n* adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 using UL-reference UL/DL configuration belonging to {1,2,3,4,5,6} (defined in Sec 8.0), the UE shall assume $B_c^{DL} = \min\left(W_{DAI}^{UL}, M_c\right)$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.
- If DL-reference UL/DL configuration of at least one configured serving cell belongs to {5} and for a PUSCH transmission adjusted based on an associated detected PDCCH/EPDCCH with DCI format 0/4 using UL-

reference UL/DL configuration belonging to {1,2,3,4,5,6} (defined in Sec 8.0), the UE shall assume $B_c^{DL} = \min\left(W_{DAI}^{UL} + 4\left\lceil (U - W_{DAI}^{UL})/4 \right\rceil, M_c\right)$, where U denotes the maximum value of U_c among all the configured serving cells, U_c is the total number of received PDSCHs and PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ for the *c*-th serving cell, $k \in K$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

When PUCCH format 3 is configured for transmission of HARQ-ACK,

- if DL-reference UL/DL configuration belongs to {1,2,3,4,5,6}, the HARQ-ACK for a PDSCH transmission with a corresponding PDCCH/EPDCCH or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,DAI(k)-1}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ otherwise, where *DAI(k)* is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C/2D detected in subframe $n-k$, $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH/EPDCCH is mapped to $o_{c,O_c^{ACK}-1}^{ACK}$ The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK;

- if DL-reference UL/DL configuration is 0, the HARQ-ACK for a PDSCH transmission or for a PDCCH/EPDCCH indicating downlink SPS release in subframe $n-k$ is associated with $o_{c,0}^{ACK}$ if transmission mode configured in the *c*-th serving cell supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ otherwise, where $o_{c,0}^{ACK}$ and $o_{c,1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH/EPDCCH indicating downlink SPS release are set to NACK.

If DL-reference UL/DL configuration of each of the serving cells belongs to {0,1,2,3,4,6} and if PUCCH format 1b with channel selection is configured for transmission of HARQ-ACK and for two configured serving cells, the HARQ-ACK feedback bits $o_0^{ACK}\ o_1^{ACK}, \ldots, o_{O^{ACK}-1}^{ACK}$ on PUSCH are constructed as follows

- if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6}, for a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with W_{DAI}^{UL} =1 or 2, o_j^{ACK} is determined as if PUCCH format 3 is configured for transmission of HARQ-ACK, except that spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed for all serving cells configured with a downlink transmission mode that supports up to two transport blocks in case W_{DAI}^{UL} =2, where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission.

- if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6}, for a PUSCH transmission adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4 with W_{DAI}^{UL} =3 or 4, $o_j^{ACK} = o(j)$, $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the value of M is replaced by W_{DAI}^{UL} where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

- if UL-reference UL/DL configuration (defined in Sec 8.0) is 0, or if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6}, for a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, for a subframe n with M =1 or 2 (M defined in Sec 10.1.3.2.1),

o_j^{ACK} = HARQ-ACK(j), $0 \le j \le A-1$ as defined in clause 10.1.3.2.1, where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

- if UL-reference UL/DL configuration (defined in Sec 8.0) is 0, or if UL-reference UL/DL configuration (defined in Sec 8.0) belongs to {1, 2, 3, 4, 6} and, for a PUSCH transmission not adjusted based on a detected PDCCH/EPDCCH with DCI format 0/4, for a subframe n with M =3 or 4 (M defined in Sec 10.1.3.2.1), $o_j^{ACK} = o(j)$, $0 \le j \le 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the UL-reference UL/DL configuration is the UL-reference UL/DL configuration of the serving cell corresponding to the PUSCH transmission. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH/EPDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

When a PUCCH format 3 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in clause 5.2.3.1 in [4], unless the HARQ-ACK corresponds to one of the following cases

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6}, the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH/EPDCCH is equal to '1', or

- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$, or

- a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) in the subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH/EPDCCH equal to '1',

in which case the UE shall transmit the HARQ-ACK and scheduling request according to the procedure for PUCCH format 1b with channel selection in TDD.

If the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, and if the UE is configured with PUCCH format 1b with channel selection, and if the UE receives PDSCH and/or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell within subframe(s) $n-k$, where $k \in K$, a UE shall transmit the CSI and $b(0), b(1)$ using PUCCH format 2b for normal CP or PUCCH format 2 for extended CP, according to clause 5.2.3.4 in [4] with a_0'', a_1'' replaced by $b(0), b(1)$. The value of $b(0), b(1)$ are generated according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH/EPDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells N_{cells}^{DL}. If DL-reference UL/DL configuration belongs to {1,2,3,4,5,6} and, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \ne (U_{DAI,c}-1) \bmod 4 + 1$ for a serving cell c, the UE detects that at least one downlink assignment has been missed.

If the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, and if the UE is configured with PUCCH format 1b with channel selection and receives at least one PDSCH on the secondary cell within subframe(s) $n-k$, where $k \in K$, the UE shall drop the CSI and transmit HARQ-ACK according to clause 10.1.3.

When both HARQ-ACK and CSI are configured to be transmitted in the same sub-frame and if a UE is configured with PUCCH format 3,

if the parameter *simultaneousAckNackAndCQI* is set *TRUE* and if the UE receives

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH/EPDCCH is equal to '1' (defined in Table 7.3-X), or a PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH/EPDCCH is equal to '1', or

- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$,

then the UE shall transmit the CSI and HARQ-ACK using PUCCH format 2/2a/2b according to clause 5.2.3.4 in [4];

else if

- the parameter *simultaneousAckNackAndCQI-Format3-r11* is set *TRUE* and if PUCCH format 3 resource is determined according to clause 10.1.3.1 or clause 10.1.3.2.2 and
    - o if the total number of bits in the subframe corresponding to HARQ-ACKs, SR (if any), and the CSI is not larger than 22, or
    - o if the total number of bits in the subframe corresponding to spatially bundled HARQ-ACKs, SR (if any), and the CSI is not larger than 22

then the UE shall transmit the HARQ-ACKs, SR (if any) and the CSI using the determined PUCCH format 3 resource according to [4];

else,

the UE shall drop the CSI and transmit the HARQ-ACK according to clause 10.1.3.

8 Physical uplink shared channel related procedures

For FDD and transmission mode 1, there shall be 8 uplink HARQ processes per serving cell for non-subframe bundling operation, i.e. normal HARQ operation, and 4 uplink HARQ processes for subframe bundling operation. For FDD and transmission mode 2, there shall be 16 uplink HARQ processes per serving cell for non-subframe bundling operation and there are two HARQ processes associated with a given subframe as described in [8]. The subframe bundling operation is configured by the parameter *ttiBundling* provided by higher layers.

In case higher layers configure the use of subframe bundling for FDD and TDD, the subframe bundling operation is only applied to UL-SCH, such that four consecutive uplink subframes are used.

8.0 UE procedure for transmitting the physical uplink shared channel

For FDD and normal HARQ operation, the UE shall upon detection on a given serving cell of a PDCCH/EPDCCH with DCI format 0/4 and/or a PHICH transmission in subframe n intended for the UE, adjust the corresponding PUSCH transmission in subframe $n+4$ according to the PDCCH/EPDCCH and PHICH information.

For normal HARQ operation, if the UE detects a PHICH transmission and if the most recent PUSCH transmission for the same transport block was using spatial multiplexing according to clause 8.0.2 and the UE does not detect a PDCCH/EPDCCH with DCI format 4 in subframe n intended for the UE, the UE shall adjust the corresponding PUSCH retransmission in the associated subframe according to the PHICH information, and using the number of transmission layers and precoding matrix according to the most recent PDCCH/EPDCCH, if the number of negatively acknowledged transport blocks is equal to the number of transport blocks indicated in the most recent PDCCH/EPDCCH associated with the corresponding PUSCH.

For normal HARQ operation, if the UE detects a PHICH transmission and if the most recent PUSCH transmission for the same transport block was using spatial multiplexing according to clause 8.0.2 and the UE does not detect a PDCCH/EPDCCH with DCI format 4 in subframe n intended for the UE, and if the number of negatively acknowledged transport blocks is not equal to the number of transport blocks indicated in the most recent PDCCH/EPDCCH associated with the corresponding PUSCH then the UE shall adjust the corresponding PUSCH retransmission in the associated subframe according to the PHICH information, using the precoding matrix with codebook index 0 and the number of transmission layers equal to number of layers corresponding to the negatively acknowledged transport block from the most recent PDCCH/EPDCCH. In this case, the UL DMRS resources are calculated according to the cyclic shift field for DMRS [3] in the most recent PDCCH/EPDCCH with DCI format 4 associated with the corresponding PUSCH transmission and number of layers corresponding to the negatively acknowledged transport block.

If a UE is configured with the carrier indicator field for a given serving cell, the UE shall use the carrier indicator field value from the detected PDCCH/EPDCCH with uplink DCI format to determine the serving cell for the corresponding PUSCH transmission.

For FDD and normal HARQ operation, if a PDCCH/EPDCCH with CSI request field set to trigger an aperiodic CSI report, as described in clause 7.2.1, is detected by a UE on subframe n, then on subframe $n+4$ UCI is mapped on the corresponding PUSCH transmission, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

For TDD, if a UE is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different, if the serving cell is a primary cell or if the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, the serving cell UL/DL configuration is the UL-reference UL/DL configuration.

For TDD, if a UE is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different and if the serving cell is a secondary cell and if the UE is configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, then for the serving cell, the UL reference UL/DL configuration is given in Table 8-0A corresponding to the pair formed by (other serving cell UL/DL configuration, serving cell UL/DL configuration).

Table 8-0A: UL-reference UL/DL Configuration for serving cell based on the pair formed by (other serving cell UL/DL configuration, serving cell UL/DL configuration)

Set #	(other serving cell UL/DL configuration, serving cell UL/DL configuration)	UL-reference UL/DL configuration
Set 1	(1,1),(1,2),(1,4),(1,5)	1
	(2,2),(2,5)	2
	(3,3),(3,4),(3,5)	3
	(4,4),(4,5)	4
	(5,5)	5
Set 2	(1,0),(2,0),(3,0),(4,0),(5,0)	0
	(2,1),(4,1),(5,1)	1
	(5,2)	2
	(4,3),(5,3)	3
	(5,4)	4
	(1,6),(2,6),(3,6),(4,6),(5,6)	6
Set 3	(3,1)	1
	(3,2),(4,2)	2
	(1,3),(2,3)	3
	(2,4)	4
Set 4	(0,0),(6,0)	0
	(0,1),(0,2),(0,4),(0,5),(6,1),(6,2),(6,5)	1
	(0,3),(6,3)	3
	(6,4)	4
	(0,6),(6,6)	6

For TDD and normal HARQ operation, if a PDCCH/EPDCCH with CSI request field set to trigger an aperiodic CSI report, as described in clause 7.2.1, is detected by a UE on subframe n, then on subframe $n+k$ UCI is mapped on the corresponding PUSCH transmission where k is given by Table 8-2, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

For FDD and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe n intended for the UE, and/or a PHICH transmission in subframe $n-5$ intended for the UE, adjust the corresponding first PUSCH transmission in the bundle in subframe $n+4$ according to the PDCCH/EPDCCH and PHICH information.

For FDD and TDD, the NDI as signalled on PDCCH/EPDCCH, the RV as determined in clause 8.6.1, and the TBS as determined in clause 8.6.2, shall be delivered to higher layers.

For TDD and transmission mode 1, the number of HARQ processes per serving cell shall be determined by the DL/UL configuration (Table 4.2-2 of [3]), as indicated in Table 8-1. For TDD and transmission mode 2, the number of HARQ processes per serving cell for non-subframe bundling operation shall be twice the number determined by the DL/UL configuration (Table 4.2-2 of [3]) as indicated in Table 8-1 and there are two HARQ processes associated with a given subframe as described in [8].

Table 8-1: Number of synchronous UL HARQ processes for TDD

TDD UL/DL configuration	Number of HARQ processes for normal HARQ operation	Number of HARQ processes for subframe bundling operation
0	7	3
1	4	2
2	2	N/A
3	3	N/A
4	2	N/A
5	1	N/A
6	6	3

For TDD, if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same,

- For TDD UL/DL configurations 1-6 and normal HARQ operation, the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe n intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k*, with *k* given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information.

- For TDD UL/DL configuration 0 and normal HARQ operation the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k* if the MSB of the UL index in the PDCCH/EPDCCH with uplink DCI format is set to 1 or PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 0$, as defined in clause 9.1.2, with *k* given in Table 8-2. If, for TDD UL/DL configuration 0 and normal HARQ operation, the LSB of the UL index in the DCI format 0/4 is set to 1 in subframe *n* or a PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 1$, as defined in clause 9.1.2, or PHICH is received in subframe *n*=1 or 6, the UE shall adjust the corresponding PUSCH transmission in subframe *n+7*. If, for TDD UL/DL configuration 0, both the MSB and LSB of the UL index in the PDCCH/EPDCCH with uplink DCI format are set in subframe *n*, the UE shall adjust the corresponding PUSCH transmission in both subframes *n+ k* and *n+7*, with *k* given in Table 8-2.

For TDD, if a UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same,

- For a serving cell with an UL-reference UL/DL configurations belonging to {1,2,3,4,5,6} and normal HARQ operation, the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k* for the serving cell, with *k* given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information, where the "TDD UL/DL Configuration" given in Table 8-2 refers to the UL-reference UL/DL configuration.

- For a serving cell with UL-reference UL/DL configuration 0 and normal HARQ operation the UE shall upon detection of a PDCCH/EPDCCH with uplink DCI format and/or a PHICH transmission in subframe *n* intended for the UE, adjust the corresponding PUSCH transmission in subframe *n+k* for the serving cell if the MSB of the UL index in the PDCCH/EPDCCH with uplink DCI format is set to 1 or PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 0$, as defined in clause 9.1.2, with *k* given in Table 8-2. If, for a serving cell with UL-reference UL/DL configuration 0 and normal HARQ operation, the LSB of the UL index in the DCI format 0/4 is set to 1 in subframe *n* or a PHICH is received in subframe *n*=0 or 5 in the resource corresponding to $I_{PHICH} = 1$, as defined in clause 9.1.2, or PHICH is received in subframe *n*=1 or 6, the UE shall adjust the corresponding PUSCH transmission in subframe *n+7* for the serving cell. If, for a serving cell with UL-reference UL/DL configuration 0, both the MSB and LSB of the UL index in the PDCCH/EPDCCH with uplink DCI format are set in subframe *n*, the UE shall adjust the corresponding PUSCH transmission in both subframes *n+ k* and *n+7* for the serving cell, with *k* given in Table 8-2, where the TDD UL/DL Configuration" given in Table 8-2 refers to the UL-reference UL/DL configuration.

For TDD UL/DL configurations 1 and 6 and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission intended for the UE in subframe *n-l* with *l* given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+k*, with *k* given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information.

For TDD UL/DL configuration 0 and subframe bundling operation, the UE shall upon detection of a PDCCH/EPDCCH with DCI format 0 in subframe *n* intended for the UE, and/or a PHICH transmission intended for the UE in subframe *n-l* with *l* given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe *n+k*, if the MSB of the UL index in the DCI format 0 is set to 1 or if $I_{PHICH} = 0$, as defined in clause 9.1.2, with *k* given in Table 8-2, according to the PDCCH/EPDCCH and PHICH information. If, for TDD UL/DL configuration 0 and subframe bundling operation, the LSB of the UL index in the PDCCH/EPDCCH with DCI format 0 is set to 1 in subframe *n* or if $I_{PHICH} = 1$, as defined in clause 9.1.2, the UE shall adjust the corresponding first PUSCH transmission in the bundle in subframe *n+7*, according to the PDCCH/EPDCCH and PHICH information.

Table 8-2 *k* for TDD configurations 0-6

TDD UL/DL Configuration	subframe number *n*									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	4	6				4	6			
1		6			4		6			4
2				4					4	
3	4								4	4
4									4	4
5									4	
6	7	7				7	7			5

Table 8-2a *l* for TDD configurations 0, 1 and 6

TDD UL/DL Configuration	subframe number *n*									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	9	6				9	6			
1		2			3		2			3
6	5	5				6	6			8

A UE is semi-statically configured via higher layer signalling to transmit PUSCH transmissions signalled via PDCCH/EPDCCH according to one of two uplink transmission modes, denoted mode 1 - 2.

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-3 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and the PUSCH retransmission for the same transport block is by C-RNTI.

If a UE is configured by higher layers to decode EPDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the EPDCCH according to the combination defined in Table 8-3A and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these EPDCCHs and the PUSCH retransmission for the same transport block is by C-RNTI.

Transmission mode 1 is the default uplink transmission mode for a UE until the UE is assigned an uplink transmission mode by higher layer signalling.

When a UE configured in transmission mode 2 receives a DCI Format 0 uplink scheduling grant, it shall assume that the PUSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

Table 8-3: PDCCH and PUSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see clause 8.0.1)
Mode 2	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see clause 8.0.1)
	DCI format 4	UE specific by C-RNTI	Closed-loop spatial multiplexing (see clause 8.0.2)

Table 8-3A: EPDCCH and PUSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to EPDCCH
Mode 1	DCI format 0	UE specific by C-RNTI	Single-antenna port, port 10 (see clause 8.0.1)
Mode 2	DCI format 0	UE specific by C-RNTI	Single-antenna port, port 10 (see clause 8.0.1)
	DCI format 4	UE specific by C-RNTI	Closed-loop spatial multiplexing (see clause 8.0.2)

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI and is also configured to receive random access procedures initiated by "PDCCH orders", the UE shall decode the PDCCH according to the combination defined in Table 8-4.

If a UE is configured by higher layers to decode EPDCCHs with the CRC scrambled by the C-RNTI and is also configured to receive random access procedures initiated by "PDCCH orders", the UE shall decode the EPDCCH according to the combination defined in Table 8-4A.

Table 8-4: PDCCH configured as "PDCCH order" to initiate random access procedure

DCI format	Search Space
DCI format 1A	Common and UE specific by C-RNTI

Table 8-4A: EPDCCH configured as "PDCCH order" to initiate random access procedure

DCI format	Search Space
DCI format 1A	UE specific by C-RNTI

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-5 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and PUSCH retransmission for the same transport block is by SPS C-RNTI. The scrambling initialization of initial transmission of this PUSCH without a corresponding PDCCH and the PUSCH retransmission for the same transport block is by SPS C-RNTI.

If a UE is configured by higher layers to decode EPDCCHs with the CRC scrambled by the SPS C-RNTI, the UE shall decode the EPDCCH according to the combination defined in Table 8-5A and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these EPDCCHs and PUSCH retransmission for the same transport block is by SPS C-RNTI. The scrambling initialization of initial transmission of this PUSCH without a corresponding EPDCCH and the PUSCH retransmission for the same transport block is by SPS C-RNTI.

Table 8-5: PDCCH and PUSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see clause 8.0.1)
Mode 2	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see clause 8.0.1)

Table 8-5A: EPDCCH and PUSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	UE specific by C-RNTI	Single-antenna port, port 10 (see clause 8.0.1)
Mode 2	DCI format 0	UE specific by C-RNTI	Single-antenna port, port 10 (see clause 8.0.1)

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the Temporary C-RNTI regardless of whether UE is configured or not configured to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-6 and transmit the corresponding PUSCH. The scrambling initialization of PUSCH corresponding to these PDCCH is by Temporary C-RNTI.

If a Temporary C-RNTI is set by higher layers, the scrambling of PUSCH corresponding to the Random Access Response Grant in clause 6.2 and the PUSCH retransmission for the same transport block is by Temporary C-RNTI. Else, the scrambling of PUSCH corresponding to the Random Access Response Grant in clause 6.2 and the PUSCH retransmission for the same transport block is by C-RNTI.

Table 8-6: PDCCH configured by Temporary C-RNTI

DCI format	Search Space
DCI format 0	Common

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUCCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8-7. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

Table 8-7: PDCCH configured by TPC-PUCCH-RNTI

DCI format	Search Space
DCI format 3/3A	Common

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUSCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8.8. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

Table 8-8: PDCCH configured by TPC-PUSCH-RNTI

DCI format	Search Space
DCI format 3/3A	Common

8.0.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 10) of the PUSCH, the UE transmission on the PUSCH is performed according to clause 5.3.2A.1 of [3].

8.0.2 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PUSCH, the UE transmission on the PUSCH is performed according to the applicable number of transmission layers as defined in clause 5.3.2A.2 of [3].

8.1 Resource allocation for PDCCH/EPDCCH with uplink DCI format

Two resource allocation schemes Type 0 and Type 1 are supported for PDCCH/EPDCCH with uplink DCI format.

If the resource allocation type bit is not present in the uplink DCI format, only resource allocation type 0 is supported.

If the resource allocation type bit is present in the uplink DCI format, the selected resource allocation type for a decoded PDCCH/EPDCCH is indicated by a resource allocation type bit where type 0 is indicated by 0 value and type 1 is indicated otherwise. The UE shall interpret the resource allocation field depending on the resource allocation type bit in the PDCCH/EPDCCH with uplink DCI format detected.

8.1.1 Uplink resource allocation type 0

The resource allocation information for uplink resource allocation type 0 indicates to a scheduled UE a set of contiguously allocated virtual resource block indices denoted by n_{VRB}. A resource allocation field in the scheduling grant consists of a resource indication value (*RIV*) corresponding to a starting resource block (RB_{START}) and a length in terms of contiguously allocated resource blocks ($L_{\mathrm{CRBs}} \geq 1$). The resource indication value is defined by

if $(L_{\mathrm{CRBs}} - 1) \leq \lfloor N_{\mathrm{RB}}^{\mathrm{UL}} / 2 \rfloor$ then

$$RIV = N_{\mathrm{RB}}^{\mathrm{UL}}(L_{\mathrm{CRBs}} - 1) + RB_{\mathrm{START}}$$

else

$$RIV = N_{\mathrm{RB}}^{\mathrm{UL}}(N_{\mathrm{RB}}^{\mathrm{UL}} - L_{\mathrm{CRBs}} + 1) + (N_{\mathrm{RB}}^{\mathrm{UL}} - 1 - RB_{\mathrm{START}})$$

8.1.2 Uplink resource allocation type 1

The resource allocation information for uplink resource allocation type 1 indicates to a scheduled UE two sets of resource blocks with each set including one or more consecutive resource block groups of size *P* as given in table 7.1.6.1-1 assuming $N_{\mathrm{RB}}^{\mathrm{UL}}$ as the system bandwidth. A combinatorial index *r* consists of $\left\lceil \log_2 \left(\binom{\lceil N_{RB}^{UL} / P + 1 \rceil}{4} \right) \right\rceil$ bits.

The bits from the resource allocation field in the scheduling grant represent *r* unless the number of bits in the resource allocation field in the scheduling grant is

- smaller than required to fully represent *r*, in which case the bits in the resource allocation field in the scheduling grant occupy the LSBs of *r* and the value of the remaining bits of *r* shall be assumed to be 0; or

- larger than required to fully represent *r*, in which case *r* occupies the LSBs of the resource allocation field in the scheduling grant.

The combinatorial index *r* corresponds to a starting and ending RBG index of resource block set 1, s_0 and $s_1 - 1$, and resource block set 2, s_2 and $s_3 - 1$ respectively, where *r* is given by equation $r = \sum_{i=0}^{M-1} \left\langle {N - s_i \atop M - i} \right\rangle$ defined in clause 7.2.1 with *M*=4 and $N = \lceil N_{\mathrm{RB}}^{\mathrm{UL}} / P \rceil + 1$. clause 7.2.1 also defines ordering properties and range of values that s_i (RBG indices) map to. Only a single RBG is allocated for a set at the starting RBG index if the corresponding ending RBG index equals the starting RBG index.

8.2 UE sounding procedure

A UE shall transmit Sounding Reference Symbol (SRS) on per serving cell SRS resources based on two trigger types:

- trigger type 0: higher layer signalling

- trigger type 1: DCI formats 0/4/1A for FDD and TDD and DCI formats 2B/2C/2D for TDD.

In case both trigger type 0 and trigger type 1 SRS transmissions would occur in the same subframe in the same serving cell, the UE shall only transmit the trigger type 1 SRS transmission.

A UE may be configured with SRS parameters for trigger type 0 and trigger type 1 on each serving cell. The following SRS parameters are serving cell specific and semi-statically configurable by higher layers for trigger type 0 and for trigger type 1.

- Transmission comb $\bar{k}_{TC}$, as defined in clause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- Starting physical resource block assignment n_{RRC} , as defined in clause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- *duration*: single or indefinite (until disabled), as defined in [11] for trigger type 0
- *srs-ConfigIndex* I_{SRS} for SRS periodicity T_{SRS} and SRS subframe offset T_{offset} , as defined in Table 8.2-1 and Table 8.2-2 for trigger type 0 and SRS periodicity $T_{SRS,1}$ and SRS subframe offset $T_{offset,1}$, as defined in Table 8.2-4 and Table 8.2-5 trigger type 1
- SRS bandwidth B_{SRS} , as defined in clause 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- Frequency hopping bandwidth, b_{hop} , as defined in clause 5.5.3.2 of [3] for trigger type 0
- Cyclic shift n_{SRS}^{cs} , as defined in clause 5.5.3.1 of [3] for trigger type 0 and each configuration of trigger type 1
- Number of antenna ports N_p for trigger type 0 and each configuration of trigger type 1

For trigger type 1 and DCI format 4 three sets of SRS parameters, *srs-ConfigApDCI-Format4*, are configured by higher layer signalling. The 2-bit SRS request field [4] in DCI format 4 indicates the SRS parameter set given in Table 8.1-1. For trigger type 1 and DCI format 0, a single set of SRS parameters, *srs-ConfigApDCI-Format0*, is configured by higher layer signalling. For trigger type 1 and DCI formats 1A/2B/2C/2D, a single common set of SRS parameters, *srs-ConfigApDCI-Format1a2b2c*, is configured by higher layer signalling. The SRS request field is 1 bit [4] for DCI formats 0/1A/2B/2C/2D, with a type 1 SRS triggered if the value of the SRS request field is set to '1'.
A 1-bit SRS request field shall be included in DCI formats 0/1A for frame structure type 1 and 0/1A/2B/2C/2D for frame structure type 2 if the UE is configured with SRS parameters for DCI formats 0/1A/2B/2C/2D by higher-layer signalling.

Table 8.1-1: SRS request value for trigger type 1 in DCI format 4

Value of SRS request field	Description
'00'	No type 1 SRS trigger
'01'	The 1st SRS parameter set configured by higher layers
'10'	The 2nd SRS parameter set configured by higher layers
'11'	The 3rd SRS parameter set configured by higher layers

The serving cell specific SRS transmission bandwidths C_{SRS} are configured by higher layers. The allowable values are given in clause 5.5.3.2 of [3].

The serving cell specific SRS transmission sub-frames are configured by higher layers. The allowable values are given in clause 5.5.3.3 of [3].

When antenna selection is enabled for a given serving cell for a UE that supports transmit antenna selection, the index $a(n_{SRS})$, of the UE antenna that transmits the SRS at time n_{SRS} is given by

$a(n_{SRS}) = n_{SRS} \bmod 2$, for both partial and full sounding bandwidth, and when frequency hopping is disabled (i.e., $b_{hop} \geq B_{SRS}$),

$$a(n_{SRS}) = \begin{cases} \left(n_{SRS} + \lfloor n_{SRS}/2 \rfloor + \beta \cdot \lfloor n_{SRS}/K \rfloor\right) \bmod 2 & \text{when } K \text{ is even} \\ n_{SRS} \bmod 2 & \text{when } K \text{ is odd} \end{cases}, \quad \beta = \begin{cases} 1 & \text{where } K \bmod 4 = 0 \\ 0 & \text{otherwise} \end{cases}$$

when frequency hopping is enabled (i.e., $b_{hop} < B_{SRS}$),

where values B_{SRS}, b_{hop}, N_b, and n_{SRS} are given in clause 5.5.3.2 of [3], and $K = \prod_{b'=b_{hop}}^{B_{SRS}} N_{b'}$ (where $N_{b_{hop}} = 1$ regardless of the N_b value), except when a single SRS transmission is configured for the UE. If a UE is configured with more than one serving cell, the UE is not expected to transmit SRS on different antenna ports simultaneously.

A UE may be configured to transmit SRS on N_p antenna ports of a serving cell where N_p may be configured by higher layer signalling. For PUSCH transmission mode 1 $N_p \in \{0,1,2,4\}$ and for PUSCH transmission mode 2 $N_p \in \{0,1,2\}$ with two antenna ports configured for PUSCH and $N_p \in \{0,1,4\}$ with 4 antenna ports configured for PUSCH. A UE configured for SRS transmission on multiple antenna ports of a serving cell shall transmit SRS for all the configured transmit antenna ports within one SC-FDMA symbol of the same subframe of the serving cell. The SRS transmission bandwidth and starting physical resource block assignment are the same for all the configured antenna ports of a given serving cell.

A UE not configured with multiple TAGs shall not transmit SRS whenever SRS and PUSCH transmissions happen to overlap in the same symbol.

For TDD, when one SC-FDMA symbol exists in UpPTS of a given serving cell, it can be used for SRS transmission. When two SC-FDMA symbols exist in UpPTS of a given serving cell, both can be used for SRS transmission and both can be assigned to the same UE.

A UE not configured with multiple TAGs shall not transmit type 0 triggered SRS whenever type 0 triggered SRS and PUCCH format 2/2a/2b transmissions happen to coincide in the same subframe. A UE not configured with multiple TAGs shall not transmit type 1 triggered SRS whenever type 1 triggered SRS and PUCCH format 2a/2b or format 2 with HARQ-ACK transmissions happen to coincide in the same subframe. A UE not configured with multiple TAGs shall not transmit PUCCH format 2 without HARQ-ACK whenever type 1 triggered SRS and PUCCH format 2 without HARQ-ACK transmissions happen to coincide in the same subframe.

A UE not configured with multiple TAGs shall not transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACK and/or positive SR happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *FALSE*. A UE not configured with multiple TAGs shall transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACK and/or positive SR using shortened format as defined in clauses 5.4.1 and 5.4.2A of [3] happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *TRUE*.

A UE not configured with multiple TAGs shall not transmit SRS whenever SRS transmission on any serving cells and PUCCH transmission carrying HARQ-ACK and/or positive SR using normal PUCCH format as defined in clauses 5.4.1 and 5.4.2A of [3] happen to coincide in the same subframe.

In UpPTS, whenever SRS transmission instance overlaps with the PRACH region for preamble format 4 or exceeds the range of uplink system bandwidth configured in the serving cell, the UE shall not transmit SRS.

The parameter *ackNackSRS-SimultaneousTransmission* provided by higher layers determines if a UE is configured to support the transmission of HARQ-ACK on PUCCH and SRS in one subframe. If it is configured to support the transmission of HARQ-ACK on PUCCH and SRS in one subframe, then in the cell specific SRS subframes of the primary cell UE shall transmit HARQ-ACK and SR using the shortened PUCCH format as defined in clauses 5.4.1 and 5.4.2A of [3], where the HARQ-ACK or the SR symbol corresponding to the SRS location is punctured.
This shortened PUCCH format shall be used in a cell specific SRS subframe of the primary cell even if the UE does not transmit SRS in that subframe. The cell specific SRS subframes are defined in clause 5.5.3.3 of [3]. Otherwise, the UE shall use the normal PUCCH format 1/1a/1b as defined in clause 5.4.1 of [3] or normal PUCCH format 3 as defined in clause 5.4.2A of [3] for the transmission of HARQ-ACK and SR.

Trigger type 0 SRS configuration of a UE in a serving cell for SRS periodicity, T_{SRS}, and SRS subframe offset, T_{offset}, is defined in Table 8.2-1 and Table 8.2-2, for FDD and TDD, respectively. The periodicity T_{SRS} of the SRS transmission is serving cell specific and is selected from the set {2, 5, 10, 20, 40, 80, 160, 320} ms or subframes.
For the SRS periodicity T_{SRS} of 2 ms in TDD, two SRS resources are configured in a half frame containing UL subframe(s) of a given serving cell.

Type 0 triggered SRS transmission instances in a given serving cell for TDD with $T_{\text{SRS}} > 2$ and for FDD are the subframes satisfying $(10 \cdot n_f + k_{\text{SRS}} - T_{offset}) \bmod T_{\text{SRS}} = 0$, where for FDD $k_{\text{SRS}} = \{0,1,...,9\}$ is the subframe index within the frame, for TDD k_{SRS} is defined in Table 8.2-3. The SRS transmission instances for TDD with $T_{\text{SRS}} = 2$ are the subframes satisfying $(k_{\text{SRS}} - T_{offset}) \bmod 5 = 0$.

Trigger type 1 SRS configuration of a UE in a serving cell for SRS periodicity, $T_{\text{SRS},1}$, and SRS subframe offset, $T_{offset,1}$, is defined in Table 8.2-4 and Table 8.2-5, for FDD and TDD, respectively. The periodicity $T_{\text{SRS},1}$ of the SRS transmission is serving cell specific and is selected from the set {2, 5, 10} ms or subframes.
For the SRS periodicity $T_{\text{SRS},1}$ of 2 ms in TDD, two SRS resources are configured in a half frame containing UL subframe(s) of a given serving cell.

A UE configured for type 1 triggered SRS transmission in serving cell *c* and not configured with a carrier indicator field shall transmit SRS on serving cell *c* upon detection of a positive SRS request in PDCCH/EPDCCH scheduling PUSCH/PDSCH on serving cell *c*.

A UE configured for type 1 triggered SRS transmission in serving cell *c* and configured with a carrier indicator field shall transmit SRS on serving cell *c* upon detection of a positive SRS request in PDCCH/EPDCCH scheduling PUSCH/PDSCH with the value of carrier indicator field corresponding to serving cell *c*.

A UE configured for type 1 triggered SRS transmission on serving cell *c* upon detection of a positive SRS request in subframe *n* of serving cell *c* shall commence SRS transmission in the first subframe satisfying $n+k, k \geq 4$ and

$(10 \cdot n_f + k_{\text{SRS}} - T_{offset,1}) \bmod T_{\text{SRS},1} = 0$ for TDD with $T_{\text{SRS},1} > 2$ and for FDD,

$(k_{\text{SRS}} - T_{offset,1}) \bmod 5 = 0$ for TDD with $T_{\text{SRS},1} = 2$

where for FDD $k_{\text{SRS}} = \{0,1,...,9\}$ is the subframe index within the frame n_f, for TDD k_{SRS} is defined in Table 8.2-3.

A UE configured for type 1 triggered SRS transmission is not expected to receive type 1 SRS triggering events associated with different values of trigger type 1 SRS transmission parameters, as configured by higher layer signalling, for the same subframe and the same serving cell.

A UE shall not transmit SRS whenever SRS and a PUSCH transmission corresponding to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure coincide in the same subframe.

Table 8.2-1: UE Specific SRS Periodicity T_{SRS} and Subframe Offset Configuration T_{offset} for trigger type 0, FDD

SRS Configuration Index I_{SRS}	SRS Periodicity T_{SRS} (ms)	SRS Subframe Offset T_{offset}
0 – 1	2	I_{SRS}
2 – 6	5	I_{SRS} – 2
7 – 16	10	I_{SRS} – 7
17 – 36	20	I_{SRS} – 17
37 – 76	40	I_{SRS} – 37
77 – 156	80	I_{SRS} – 77
157 – 316	160	I_{SRS} – 157
317 – 636	320	I_{SRS} – 317
637 – 1023	reserved	reserved

Table 8.2-2: UE Specific SRS Periodicity T_{SRS} and Subframe Offset Configuration T_{offset} for trigger type 0, TDD

SRS Configuration Index I_{SRS}	SRS Periodicity T_{SRS} (ms)	SRS Subframe Offset T_{offset}
0	2	0, 1
1	2	0, 2
2	2	1, 2
3	2	0, 3
4	2	1, 3
5	2	0, 4
6	2	1, 4
7	2	2, 3
8	2	2, 4
9	2	3, 4
10 – 14	5	I_{SRS} – 10
15 – 24	10	I_{SRS} – 15
25 – 44	20	I_{SRS} – 25
45 – 84	40	I_{SRS} – 45
85 – 164	80	I_{SRS} – 85
165 – 324	160	I_{SRS} – 165
325 – 644	320	I_{SRS} – 325
645 – 1023	reserved	reserved

Table 8.2-3: k_{SRS} for TDD

	subframe index *n*										
	0	1		2	3	4	5	6		7	8	9
		1st symbol of UpPTS	2nd symbol of UpPTS					1st symbol of UpPTS	2nd symbol of UpPTS			
k_{SRS} in case UpPTS length of 2 symbols		0	1	2	3	4		5	6	7	8	9
k_{SRS} in case UpPTS length of 1 symbol		1		2	3	4		6		7	8	9

Table 8.2-4: UE Specific SRS Periodicity $T_{\mathrm{SRS},1}$ and Subframe Offset Configuration $T_{offset,1}$ for trigger type 1, FDD

SRS Configuration Index I_{SRS}	SRS Periodicity $T_{\mathrm{SRS},1}$ (ms)	SRS Subframe Offset $T_{offset,1}$
0 – 1	2	I_{SRS}
2 – 6	5	I_{SRS} – 2
7 – 16	10	I_{SRS} – 7
17 – 31	reserved	reserved

Table 8.2-5: UE Specific SRS Periodicity $T_{\mathrm{SRS},1}$ and Subframe Offset Configuration $T_{offset,1}$ for trigger type 1, TDD

SRS Configuration Index I_{SRS}	SRS Periodicity $T_{\mathrm{SRS},1}$ (ms)	SRS Subframe Offset $T_{offset,1}$
0	2	0, 1
1	2	0, 2
2	2	1, 2
3	2	0, 3
4	2	1, 3
5	2	0, 4
6	2	1, 4
7	2	2, 3
8	2	2, 4
9	2	3, 4
10 – 14	5	I_{SRS} – 10
15 – 24	10	I_{SRS} – 15
25 – 31	reserved	reserved

8.3 UE HARQ-ACK procedure

For Frame Structure type 1, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in subframe *i*-4.

For TDD, if a UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same,

- For Frame Structure type 2 UL/DL configuration 1-6, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* as indicated by the following table 8.3-1.

- For Frame Structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 0$, as defined in clause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* as indicated by the following table 8.3-1. For Frame Structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 1$, as defined in clause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-6.

For TDD, if a UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same,

– For serving cell with an UL-reference UL/DL configuration (defined in clause 8.0) belonging to {1,2,3,4,5,6}, an HARQ-ACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* for the serving cell as indicated by the following table 8.3-1, where "TDD UL/DL Configuration" in table 8.3-1 refers to the UL-reference UL/DL Configuration.

– For a serving cell with UL-reference UL/DL configuration 0 (defined in clause 8.0), an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 0$, as defined in clause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i-k* for the serving cell as indicated by the following table 8.3-1, where "TDD UL/DL Configuration" in table 8.3-1 refers to the UL-reference UL/DL configuration. For a serving cell with UL-reference UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{PHICH} = 1$, as defined in clause 9.1.2, assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe *i*-6 for the serving cell.

Table 8.3-1 *k* for TDD configurations 0-6

TDD UL/DL Configuration	subframe number *i*									
	0	1	2	3	4	5	6	7	8	9
0	7	4				7	4			
1		4			6		4			6
2				6					6	
3	6								6	6
4									6	6
5									6	
6	6	4				7	4			6

The physical layer in the UE shall deliver indications to the higher layers as follows:

For FDD, and for TDD with a UE configured with one serving cell, and for TDD with a UE configured with more than one serving cell and with TDD UL/DL configuration of all configured serving cells the same, for downlink subframe *i*, if a transport block was transmitted in the associated PUSCH subframe then:

- if ACK is decoded on the PHICH corresponding to that transport block in subframe *i*, or if that transport block is disabled by PDCCH/EPDCCH received in downlink subframe *i*, ACK for that transport block shall be delivered to the higher layers; else NACK for that transport block shall be delivered to the higher layers.

For TDD, if the UE is configured with more than one serving cell, and if at least two serving cells have different UL/DL configurations, for downlink subframe *i*, if a transport block was transmitted in the associated PUSCH subframe then:

- if ACK is decoded on the PHICH corresponding to that transport block in subframe i, or if that transport block is disabled by PDCCH/EPDCCH received in downlink subframe i, ACK for that transport block shall be delivered to the higher layers; or

- if a PHICH resource corresponding to that transport block is not present in subframe i or if UE is not expected to receive PHICH corresponding to that transport block in subframe i, ACK for that transport block shall be delivered to the higher layers.

- else NACK for that transport block shall be delivered to the higher layers.

8.4 UE PUSCH hopping procedure

The UE shall perform PUSCH frequency hopping if the single bit Frequency Hopping (FH) field in a corresponding PDCCH/EPDCCH with DCI format 0 is set to 1 and the uplink resource block assignment is type 0 otherwise no PUSCH frequency hopping is performed.

A UE performing PUSCH frequency hopping shall determine its PUSCH Resource Allocation (RA) for the first slot of a subframe (*S1*) including the lowest index PRB ($n_{PRB}^{S1}(n)$) in subframe *n* from the resource allocation field in the latest PDCCH/EPDCCH with DCI format 0 for the same transport block. If there is no PDCCH/EPDCCH for the same transport block, the UE shall determine its hopping type based on

- the hopping information in the most recent semi-persistent scheduling assignment PDCCH/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.

The resource allocation field in DCI format 0 excludes either 1 or 2 bits used for hopping information as indicated by Table 8.4-1 below where the number of PUSCH resource blocks is defined as

$$N_{RB}^{PUSCH}=\begin{cases} N_{RB}^{UL}-\tilde{N}_{RB}^{HO}-\left(N_{RB}^{UL} \bmod 2\right) & \text{Type 1 PUSCH hopping} \\ N_{RB}^{UL} & \text{Type 2 } \mathrm{N_{sb}}=1 \text{ PUSCH hopping} \\ N_{RB}^{UL}-\tilde{N}_{RB}^{HO} & \text{Type 2 } \mathrm{N_{sb}}>1 \text{ PUSCH hopping} \end{cases}$$

For type 1 and type 2 PUSCH hopping, $\tilde{N}_{\mathrm{RB}}^{\mathrm{HO}}=N_{\mathrm{RB}}^{\mathrm{HO}}+1$ if $N_{\mathrm{RB}}^{\mathrm{HO}}$ is an odd number where $N_{\mathrm{RB}}^{\mathrm{HO}}$ defined in [3]. $\tilde{N}_{\mathrm{RB}}^{\mathrm{HO}}=N_{\mathrm{RB}}^{\mathrm{HO}}$ in other cases. The size of the resource allocation field in DCI format 0 after excluding either 1 or 2 bits shall be $y=\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL}}(N_{\mathrm{RB}}^{\mathrm{UL}}+1)/2)\right\rceil - N_{UL\_hop}$, where N_{UL_hop} = 1 or 2 bits. The number of contiguous RBs that can be assigned to a type-1 hopping user is limited to $\left\lfloor 2^y / N_{\mathrm{RB}}^{\mathrm{UL}}\right\rfloor$. The number of contiguous RBs that can be assigned to a type-2 hopping user is limited to min($\left\lfloor 2^y / N_{\mathrm{RB}}^{\mathrm{UL}}\right\rfloor, \left\lfloor N_{\mathrm{RB}}^{\mathrm{PUSCH}} / N_{sb}\right\rfloor$), where the number of sub-bands N_{sb} is given by higher layers.

A UE performing PUSCH frequency hopping shall use one of two possible PUSCH frequency hopping types based on the hopping information. PUSCH hopping type 1 is described in clause 8.4.1 and type 2 is described in clause 8.4.2.

Table 8.4-1: Number of Hopping Bits N_{UL_hop} vs. System Bandwidth

System BW N_{RB}^{UL}	#Hopping bits for 2nd slot RA (N_{UL_hop})
6-49	1
50-110	2

The parameter *Hopping-mode* provided by higher layers determines if PUSCH frequency hopping is "inter-subframe" or "intra and inter-subframe".

8.4.1 Type 1 PUSCH hopping

For PUSCH hopping type 1 the hopping bit or bits indicated in Table 8.4-1 determine $\tilde{n}_{PRB}(i)$ as defined in Table 8.4-2. The lowest index PRB ($n_{PRB}^{S1}(i)$) of the 1st slot RA in subframe *i* is defined as $n_{PRB}^{S1}(i) = \tilde{n}_{PRB}^{S1}(i) + \tilde{N}_{\mathrm{RB}}^{\mathrm{HO}} / 2$, where $n_{PRB}^{S1}(i) = RB_{START}$, and RB_{START} is obtained from the uplink scheduling grant as in clause 8.4 and clause 8.1.

The lowest index PRB ($n_{PRB}(i)$) of the 2nd slot RA in subframe *i* is defined as $n_{PRB}(i) = \tilde{n}_{PRB}(i) + \tilde{N}_{\mathrm{RB}}^{\mathrm{HO}} / 2$.

The set of physical resource blocks to be used for PUSCH transmission are L_{CRBs} contiguously allocated resource blocks from PRB index $n_{PRB}^{S1}(i)$ for the 1st slot, and from PRB index $n_{PRB}(i)$ for the 2nd slot, respectively, where L_{CRBs} is obtained from the uplink scheduling grant as in clause 8.4 and clause 8.1.

If the *Hopping-mode* is "inter-subframe", the 1st slot RA is applied to even CURRENT_TX_NB, and the 2nd slot RA is applied to odd CURRENT_TX_NB, where CURRENT_TX_NB is defined in [8].

8.4.2 Type 2 PUSCH hopping

In PUSCH hopping type 2 the set of physical resource blocks to be used for transmission in slot n_{s} is given by the scheduling grant together with a predefined pattern according to [3] clause 5.3.4.
If the system frame number is not acquired by the UE yet, the UE shall not transmit PUSCH with type-2 hopping and $N_{sb} > 1$ for TDD, where N_{sb} is defined in [3].

Table 8.4-2: PDCCH/EPDCCH DCI format 0 hopping bit definition

System BW N_{RB}^{UL}	Number of Hopping bits	Information in hopping bits	$\tilde{n}_{PRB}(i)$
6 – 49	1	0	$\left(\left\lfloor N_{RB}^{PUSCH} / 2 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$,
		1	Type 2 PUSCH Hopping
50 – 110	2	00	$\left(\left\lfloor N_{RB}^{PUSCH} / 4 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		01	$\left(-\left\lfloor N_{RB}^{PUSCH} / 4 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		10	$\left(\left\lfloor N_{RB}^{PUSCH} / 2 \right\rfloor + \tilde{n}_{PRB}^{S1}(i)\right) \bmod N_{RB}^{PUSCH}$
		11	Type 2 PUSCH Hopping

8.5 UE Reference Symbol (RS) procedure

If UL sequence-group hopping or sequence hopping is configured in a serving cell, it applies to all Reference Symbols (SRS, PUSCH and PUCCH RS). If disabling of the sequence-group hopping and sequence hopping is configured for the UE in the serving cell through the higher-layer parameter *Disable-sequence-group-hopping*, the sequence-group hopping and sequence hopping for PUSCH RS are disabled.

8.6 Modulation order, redundancy version and transport block size determination

To determine the modulation order, redundancy version and transport block size for the physical uplink shared channel, the UE shall first

- read the "modulation and coding scheme and redundancy version" field (I_{MCS}), and
- check the "CSI request" bit field, and
- compute the total number of allocated PRBs (N_{PRB}) based on the procedure defined in clause 8.1, and
- compute the number of coded symbols for control information.

8.6.1 Modulation order and redundancy version determination

For $0 \le I_{\text{MCS}} \le 28$, the modulation order (Q_m) is determined as follows:

- If the UE is capable of supporting 64QAM in PUSCH and has not been configured by higher layers to transmit only QPSK and 16QAM, the modulation order is given by $Q_m^{'}$ in Table 8.6.1-1.
- If the UE is not capable of supporting 64QAM in PUSCH or has been configured by higher layers to transmit only QPSK and 16QAM, $Q_m^{'}$ is first read from Table 8.6.1-1. The modulation order is set to $Q_m = \min(4, Q_m^{'})$.
- If the parameter *ttiBundling* provided by higher layers is set to *TRUE*, then the resource allocation size is restricted to $N_{\text{PRB}} \le 3$ and the modulation order is set to $Q_m = 2$.

For $29 \le I_{\text{MCS}} \le 31$ the modulation order (Q_m) is determined as follows:

- if DCI format 0 is used and $I_{\text{MCS}} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{\text{MCS}} = 29$ for the enabled TB and the signalled number of transmission layers is 1, and if
  - o the "CSI request" bit field is 1 bit and the bit is set to trigger an aperiodic report and, $N_{\text{PRB}} \le 4$ or,
  - o the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and, $N_{\text{PRB}} \le 4$ or,
  - o the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{\text{PRB}} \le 20$, or,
  - o the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one CSI according to Table 7.2.1-1B and $N_{\text{PRB}} \le 20$,

then the modulation order is set to $Q_m = 2$.

- Otherwise, the modulation order shall be determined from the DCI transported in the latest PDCCH/EPDCCH with DCI format 0/4 for the same transport block using $0 \le I_{\text{MCS}} \le 28$. If there is no PDCCH/EPDCCH with DCI format 0/4 for the same transport block using $0 \le I_{\text{MCS}} \le 28$, the modulation order shall be determined from
  - o the most recent semi-persistent scheduling assignment PDCCH/EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
  - o the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

The UE shall use I_{MCS} and Table 8.6.1-1 to determine the redundancy version (rv_{idx}) to use in the physical uplink shared channel.

Table 8.6.1-1: Modulation, TBS index and redundancy version table for PUSCH

MCS Index I_{MCS}	Modulation Order Q'_m	TBS Index I_{TBS}	Redundancy Version rv_{idx}
0	2	0	0
1	2	1	0
2	2	2	0
3	2	3	0
4	2	4	0
5	2	5	0
6	2	6	0
7	2	7	0
8	2	8	0
9	2	9	0
10	2	10	0
11	4	10	0
12	4	11	0
13	4	12	0
14	4	13	0
15	4	14	0
16	4	15	0
17	4	16	0
18	4	17	0
19	4	18	0
20	4	19	0
21	6	19	0
22	6	20	0
23	6	21	0
24	6	22	0
25	6	23	0
26	6	24	0
27	6	25	0
28	6	26	0
29	reserved		1
30			2
31			3

8.6.2 Transport block size determination

For $0 \le I_{MCS} \le 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 8.6.1-1 except if the transport block is disabled in DCI format 4 as specified below. For a transport block that is not mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in clause 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in clause 7.17.2.2.

For $29 \le I_{MCS} \le 31$,

- if DCI format 0 is used and $I_{MCS} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{MCS} = 29$ for the enabled TB and the number of transmission layers is 1, and if
  - o the "CSI request" bit field is 1 bit and is set to trigger an aperiodic CSI report and $N_{PRB} \le 4$, or
  - o the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and , $N_{PRB} \le 4$ or,

- o the "CSI request" bit field is 2 bits and is triggering aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{\text{PRB}} \leq 20$,
- o the "CSI request" bit field is 2 bits and is triggering an aperiodic CSI report for more than one CSI according to Table 7.2.1-1B and, $N_{\text{PRB}} \leq 20$

then there is no transport block for the UL-SCH and only the control information feedback for the current PUSCH reporting mode is transmitted by the UE.

- Otherwise, the transport block size shall be determined from the initial PDCCH/EPDCCH for the same transport block using $0 \leq I_{\text{MCS}} \leq 28$. If there is no initial PDCCH/EPDCCH with an uplink DCI format for the same transport block using $0 \leq I_{\text{MCS}} \leq 28$, the transport block size shall be determined from
  - o the most recent semi-persistent scheduling assignment PDCCH/EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
  - o the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

In DCI format 4 a transport block is disabled if either the combination of $I_{\text{MCS}} = 0$ and $N_{\text{PRB}} > 1$ or the combination of $I_{\text{MCS}} = 28$ and $N_{\text{PRB}} = 1$ is signalled, otherwise the transport block is enabled.

8.6.3 Control information MCS offset determination

Offset values are defined for single codeword PUSCH transmission and multiple codeword PUSCH transmission. Single codeword PUSCH transmission offsets $\beta_{offset}^{HARQ-ACK}$, β_{offset}^{RI} and β_{offset}^{CQI} shall be configured to values according to Table 8.6.3-1,2,3 with the higher layer signalled indexes $I_{offset}^{HARQ-ACK}$, I_{offset}^{RI}, and I_{offset}^{CQI}, respectively. Multiple codeword PUSCH transmission offsets $\beta_{offset}^{HARQ-ACK}$, β_{offset}^{RI} and β_{offset}^{CQI} shall be configured to values according to Table 8.6.3-1,2,3 with the higher layer signalled indexes $I_{offset,MC}^{HARQ-ACK}$, $I_{offset,MC}^{RI}$ and $I_{offset,MC}^{CQI}$, respectively.

Table 8.6.3-1: Mapping of HARQ-ACK offset values and the index signalled by higher layers

$I_{offset}^{HARQ-ACK}$ **or** $I_{offset,MC}^{HARQ-ACK}$	$\beta_{offset}^{HARQ-ACK}$
0	2.000
1	2.500
2	3.125
3	4.000
4	5.000
5	6.250
6	8.000
7	10.000
8	12.625
9	15.875
10	20.000
11	31.000
12	50.000
13	80.000
14	126.000
15	1.0

Table 8.6.3-2: Mapping of RI offset values and the index signalled by higher layers

I_{offset}^{RI} or $I_{offset,MC}^{RI}$	β_{offset}^{RI}
0	1.250
1	1.625
2	2.000
3	2.500
4	3.125
5	4.000
6	5.000
7	6.250
8	8.000
9	10.000
10	12.625
11	15.875
12	20.000
13	reserved
14	reserved
15	reserved

Table 8.6.3-3: Mapping of CQI offset values and the index signalled by higher layers

I_{offset}^{CQI} or $I_{offset,MC}^{CQI}$	β_{offset}^{CQI}
0	reserved
1	reserved
2	1.125
3	1.250
4	1.375
5	1.625
6	1.750
7	2.000
8	2.250
9	2.500
10	2.875
11	3.125
12	3.500
13	4.000
14	5.000
15	6.250

8.7 UE transmit antenna selection

UE transmit antenna selection is configured by higher layers via parameter *ue-TransmitAntennaSelection*.

A UE configured with transmit antenna selection for a serving cell is not expected to

- be configured with more than one antenna port for any uplink physical channel or signal for any configured serving cell, or
- be configured with trigger type 1 SRS transmission on any configured serving cell, or
- be configured with simultaneous PUCCH and PUSCH transmission, or
- be configured with demodulation reference signal for PUSCH with OCC for any configured serving cell (see [3], clause 5.5.2.1.1), or
- receive DCI Format 0 indicating uplink resource allocation type 1 for any serving cell.

If UE transmit antenna selection is disabled or not supported by the UE, the UE shall transmit from UE port 0.

If closed-loop UE transmit antenna selection is enabled by higher layers the UE shall perform transmit antenna selection in response to the most recent command received via DCI Format 0 in clause 5.3.3.2 of [4].
If a UE is configured with more than one serving cell, the UE may assume the same transmit antenna port value is indicated in each PDCCH/EPDCCH with DCI format 0 in a given subframe.

If open-loop UE transmit antenna selection is enabled by higher layers, the transmit antenna to be selected by the UE is not specified.

9 Physical downlink control channel procedures

9.1 UE procedure for determining physical downlink control channel assignment

9.1.1 PDCCH assignment procedure

The control region of each serving cell consists of a set of CCEs, numbered from 0 to $N_{\mathrm{CCE},k}-1$ according to clause 6.8.1 in [3], where $N_{\mathrm{CCE},k}$ is the total number of CCEs in the control region of subframe k.
The UE shall monitor a set of PDCCH candidates on one or more activated serving cells as configured by higher layer signalling for control information, where monitoring implies attempting to decode each of the PDCCHs in the set according to all the monitored DCI formats.

The set of PDCCH candidates to monitor are defined in terms of search spaces, where a search space $S_k^{(L)}$ at aggregation level $L \in \{1,2,4,8\}$ is defined by a set of PDCCH candidates. For each serving cell on which PDCCH is monitored, the CCEs corresponding to PDCCH candidate *m* of the search space $S_k^{(L)}$ are given by

$$L \cdot \left\{(Y_k + m') \bmod \lfloor N_{\mathrm{CCE},k} / L \rfloor\right\} + i$$

where Y_k is defined below, $i = 0,\cdots,L-1$. For the common search space $m' = m$. For the PDCCH UE specific search space, for the serving cell on which PDCCH is monitored, if the monitoring UE is configured with carrier indicator field then $m' = m + M^{(L)} \cdot n_{CI}$ where n_{CI} is the carrier indicator field value, else if the monitoring UE is not configured with carrier indicator field then $m' = m$, where $m = 0,\cdots,M^{(L)}-1$. $M^{(L)}$ is the number of PDCCH candidates to monitor in the given search space.

Note that the carrier indicator field value is the same as *ServCellIndex* given in [11].

The UE shall monitor one common search space in every non-DRX subframe at each of the aggregation levels 4 and 8 on the primary cell.

If a UE is not configured for EPDCCH monitoring, and if the UE is not configured with a carrier indicator field, then the UE shall monitor one PDCCH UE-specific search space at each of the aggregation levels 1, 2, 4, 8 on each activated serving cell in every non-DRX subframe.

If a UE is not configured for EPDCCH monitoring, and if the UE is configured with a carrier indicator field, then the UE shall monitor one or more UE-specific search spaces at each of the aggregation levels 1, 2, 4, 8 on one or more activated serving cells as configured by higher layer signalling in every non-DRX subframe.

If a UE is configured for EPDCCH monitoring on a serving cell, and if that serving cell is activated, and if the UE is not configured with a carrier indicator field, then the UE shall monitor one PDCCH UE-specific search space at each of the aggregation levels 1, 2, 4, 8 on that serving cell in all non-DRX subframes where EPDCCH is not monitored on that serving cell.

If a UE is configured for EPDCCH monitoring on a serving cell, and if that serving cell is activated, and if the UE is configured with a carrier indicator field, then the UE shall monitor one or more PDCCH UE-specific search spaces at each of the aggregation levels 1, 2, 4, 8 on that serving cell as configured by higher layer signalling in all non-DRX subframes where EPDCCH is not monitored on that serving cell.

The common and PDCCH UE-specific search spaces on the primary cell may overlap.

A UE configured with the carrier indicator field associated with monitoring PDCCH on serving cell *c* shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by C-RNTI in the PDCCH UE specific search space of serving cell *c*.

A UE configured with the carrier indicator field associated with monitoring PDCCH on the primary cell shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by SPS C-RNTI in the PDCCH UE specific search space of the primary cell.

The UE shall monitor the common search space for PDCCH without carrier indicator field.

For the serving cell on which PDCCH is monitored, if the UE is not configured with a carrier indicator field, it shall monitor the PDCCH UE specific search space for PDCCH without carrier indicator field, if the UE is configured with a carrier indicator field it shall monitor the PDCCH UE specific search space for PDCCH with carrier indicator field.

A UE is not expected to monitor the PDCCH of a secondary cell if it is configured to monitor PDCCH with carrier indicator field corresponding to that secondary cell in another serving cell. For the serving cell on which PDCCH is monitored, the UE shall monitor PDCCH candidates at least for the same serving cell.

A UE configured to monitor PDCCH candidates with CRC scrambled by C-RNTI or SPS C-RNTI with a common payload size and with the same first CCE index n_{CCE} (as described in clause 10.1) but with different sets of DCI information fields as defined in [4] in the

- common search space
- PDCCH UE specific search space

on the primary cell shall assume that for the PDCCH candidates with CRC scrambled by C-RNTI or SPS C-RNTI,

- if the UE is configured with the carrier indicator field associated with monitoring the PDCCH on the primary cell, only the PDCCH in the common search space is transmitted by the primary cell;
- otherwise, only the PDCCH in the UE specific search space is transmitted by the primary cell.

A UE configured to monitor PDCCH candidates in a given serving cell with a given DCI format size with CIF, and CRC scrambled by C- RNTI, where the PDCCH candidates may have one or more possible values of CIF for the given DCI format size, shall assume that a PDCCH candidate with the given DCI format size may be transmitted in the given serving cell in any PDCCH UE specific search space corresponding to any of the possible values of CIF for the given DCI format size.

The aggregation levels defining the search spaces are listed in Table 9.1.1-1. The DCI formats that the UE shall monitor depend on the configured transmission mode per each serving cell as defined in clause 7.1.

Table 9.1.1-1: PDCCH candidates monitored by a UE

Search space $S_k^{(L)}$			Number of PDCCH candidates $M^{(L)}$
Type	**Aggregation level L**	**Size [in CCEs]**	
UE-specific	1	6	6
	2	12	6
	4	8	2
	8	16	2
Common	4	16	4
	8	16	2

For the common search spaces, Y_k is set to 0 for the two aggregation levels $L=4$ and $L=8$.

For the UE-specific search space $S_k^{(L)}$ at aggregation level L, the variable Y_k is defined by

$$Y_k = \left(A \cdot Y_{k-1}\right) \bmod D$$

where $Y_{-1} = n_{\mathrm{RNTI}} \neq 0$, $A = 39827$, $D = 65537$ and $k = \lfloor n_s/2 \rfloor$, n_s is the slot number within a radio frame. The RNTI value used for n_{RNTI} is defined in clause 7.1 in downlink and clause 8 in uplink.

9.1.2 PHICH assignment procedure

If a UE is not configured with multiple TAGs, or if a UE is configured with multiple TAGs and PUSCH transmissions scheduled from serving cell c in subframe *n* are not scheduled by a Random Access Response Grant corresponding to a random access preamble transmission for a secondary cell

- For PUSCH transmissions scheduled from serving cell c in subframe *n*, the UE shall determine the corresponding PHICH resource of serving cell c in subframe $n+k_{PHICH}$, where k_{PHICH} is always 4 for FDD.
- For TDD, if the UE is configured with one serving cell, or if the UE is configured with more than one serving cell and the TDD UL/DL configuration of all the configured serving cells is the same, for PUSCH transmissions scheduled from serving cell c in subframe *n*, the UE shall determine the corresponding PHICH resource of serving cell c in subframe $n+k_{PHICH}$, where k_{PHICH} is given in table 9.1.2-1.
- For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, for PUSCH transmissions scheduled from serving cell c in subframe *n*, the UE shall determine the corresponding PHICH resource of serving cell c in subframe $n+k_{PHICH}$, where k_{PHICH} is given in table 9.1.2-1, where the "TDD UL/DL Configuration" in the rest of this clause refers to the UL-reference UL/DL configuration (defined in clause 8.0) of the serving cell corresponding to the PUSCH transmission.

If a UE is configured with multiple TAGs, for PUSCH transmissions on subframe *n* for a secondary cell c scheduled by a Random Access Response grant corresponding to a random access preamble transmission for the secondary cell c,

- For TDD, if the UE is configured with more than one serving cell and the TDD UL/DL configuration of at least two configured serving cells is not the same, the "TDD UL/DL Configuration" in the rest of this clause refers to the UL-reference UL/DL configuration (defined in clause 8.0) of secondary cell c.
- If the UE is not configured to monitor PDCCH/EPDCCH with carrier indicator field corresponding to secondary cell c in another serving cell, the UE shall determine the corresponding PHICH resource on the secondary cell c in subframe $n+k_{PHICH}$, where k_{PHICH} is always 4 for FDD and where k_{PHICH} is given in table 9.1.2-1 for TDD.
- If the UE is configured to monitor PDCCH/EPDCCH with carrier indicator field corresponding to secondary cell c in another serving cell $c1$, the UE configured with multiple TAGs shall determine the corresponding PHICH resource on the serving cell $c1$ in subframe $n+k_{PHICH}$, where k_{PHICH} is always 4 for FDD and where k_{PHICH} is given in table 9.1.2-1 for TDD.

For subframe bundling operation, the corresponding PHICH resource is associated with the last subframe in the bundle.

Table 9.1.2-1: k_{PHICH} for TDD

TDD UL/DL Configuration	subframe index *n*									
	0	1	2	3	4	5	6	7	8	9
0			4	7	6			4	7	6
1			4	6				4	6	
2			6					6		
3			6	6	6					
4			6	6						
5			6							
6			4	6	6			4	7	

The PHICH resource is identified by the index pair $(n_{PHICH}^{group}, n_{PHICH}^{seq})$ where n_{PHICH}^{group} is the PHICH group number and n_{PHICH}^{seq} is the orthogonal sequence index within the group as defined by:

$$n_{PHICH}^{group} = (I_{PRB\_RA} + n_{DMRS}) \bmod N_{PHICH}^{group} + I_{PHICH} N_{PHICH}^{group}$$

$$n_{PHICH}^{seq} = (\lfloor I_{PRB\_RA} / N_{PHICH}^{group} \rfloor + n_{DMRS}) \bmod 2N_{SF}^{PHICH}$$

where

- n_{DMRS} is mapped from the cyclic shift for DMRS field (according to Table 9.1.2-2) in the most recent PDCCH with uplink DCI format [4] for the transport block(s) associated with the corresponding PUSCH transmission. n_{DMRS} shall be set to zero, if there is no PDCCH with uplink DCI format for the same transport block, and
  - if the initial PUSCH for the same transport block is semi-persistently scheduled, or
  - if the initial PUSCH for the same transport block is scheduled by the random access response grant .
- N_{SF}^{PHICH} is the spreading factor size used for PHICH modulation as described in clause 6.9.1 in [3].
- $$I_{PRB\_RA} = \begin{cases} I_{PRB\_RA}^{lowest\_index} & \text{for the first TB of a PUSCH with associated PDCCH or for the case of no associated PDCCH when the number of negatively acknowledged TBs is not equal to the number of TBs indicated in the most recent PDCCH associated with the corresponding PUSCH} \\ I_{PRB\_RA}^{lowest\_index} + 1 & \text{for a second TB of a PUSCH with associated PDCCH} \end{cases}$$

  where $I_{PRB\_RA}^{lowest\_index}$ is the lowest PRB index in the first slot of the corresponding PUSCH transmission
- N_{PHICH}^{group} is the number of PHICH groups configured by higher layers as described in clause 6.9 of [3],
- $$I_{PHICH} = \begin{cases} 1 & \text{for TDD UL/DL configuration 0 with PUSCH transmission in subframe } n = 4 \text{ or } 9 \\ 0 & \text{otherwise} \end{cases}$$

Table 9.1.2-2: Mapping between n_{DMRS} and the cyclic shift for DMRS field in PDCCH with uplink DCI format in [4]

Cyclic Shift for DMRS Field in PDCCH with uplink DCI format in [4]	n_{DMRS}
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

9.1.3 Control Format Indicator (CFI) assignment procedure

PHICH duration is signalled by higher layers according to Table 6.9.3-1 in [3]. The duration signalled puts a lower limit on the size of the control region determined from the control format indicator (CFI). When $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, if extended PHICH duration is indicated by higher layers then the UE shall assume that CFI is equal to PHICH duration.

9.1.4 EPDCCH assignment procedure

For each serving cell, higher layer signalling can configure a UE with one or two EPDCCH-PRB-sets for EPDCCH monitoring. The PRB-pairs corresponding to an EPDCCH-PRB-set are indicated by higher layers as described in clause

9.1.4.4. Each EPDCCH-PRB-set consists of set of ECCEs numbered from 0 to $N_{\text{ECCE},p,k}-1$ where $N_{\text{ECCE},p,k}$ is the number of ECCEs in EPDCCH-PRB-set p of subframe k. Each EPDCCH-PRB-set can be configured for either localized EPDCCH transmission or distributed EPDCCH transmission.

The UE shall monitor a set of EPDCCH candidates on one or more activated serving cells as configured by higher layer signalling for control information, where monitoring implies attempting to decode each of the EPDCCHs in the set according to the monitored DCI formats.

The set of EPDCCH candidates to monitor are defined in terms of EPDCCH UE-specific search spaces.

For each serving cell, the subframes in which the UE monitors EPDCCH UE-specific search spaces are configured by higher layers.

The UE shall not monitor EPDCCH

- For TDD and normal downlink CP, in special subframes for the special subframe configurations 0 and 5 shown in Table 4.2-1 of [3].
- For TDD and extended downlink CP, in special subframes for the special subframe configurations 0, 4 and 7 shown in Table 4.2-1 of [3].
- In subframes indicated by higher layers to decode PMCH.
- For TDD and if the UE is configured with different UL/DL configurations for the primary and a secondary cell, in a downlink subframe on the secondary cell when the same subframe on the primary cell is a special subframe and the UE is not capable of simultaneous reception and transmission on the primary and secondary cells.

An EPDCCH UE-specific search space $ES_k^{(L)}$ at aggregation level $L \in \{1,2,4,8,16,32\}$ is defined by a set of EPDCCH candidates.

For an EPDCCH-PRB-set p, the ECCEs corresponding to EPDCCH candidate *m* of the search space $ES_k^{(L)}$ are given by

$$L\left\{\left(Y_{p,k}+\left\lfloor\frac{m\cdot N_{ECCE,p,k}}{L\cdot M_p^{(L)}}\right\rfloor+b\right)\bmod\left\lfloor N_{\text{ECCE},p,k}/L\right\rfloor\right\}+i$$

where

$Y_{p,k}$ is defined below,

$i=0,\cdots,L-1$

$b=n_{CI}$ if the UE is configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, otherwise $b=0$

n_{CI} is the carrier indicator field value,

$m=0,1,\ldots M_p^{(L)}-1$,

If the UE is not configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, $M_p^{(L)}$ is the number of EPDCCH candidates to monitor at aggregation level L in EPDCCH-PRB-set p for the serving cell on which EPDCCH is monitored, as given in Tables 9.1.4-1a, 9.1.4-1b, 9.1.4-2a, 9.1.4-2b, 9.1.4-3a, 9.1.4-3b, 9.1.4-4a, 9.4.4-4b, 9.1.4-5a, 9.1.4-5b below; otherwise, $M_p^{(L)}$ is the number of EPDCCH candidates to monitor at aggregation level L in EPDCCH-PRB-set p for the serving cell indicated by n_{CI}.

Note that the carrier indicator field value is the same as *ServCellIndex* given in [11].

A UE is not expected to monitor an EPDCCH candidate, if an ECCE corresponding to that EPDCCH candidate is mapped to a PRB pair that overlaps in frequency with a transmission of either PBCH or primary or secondary synchronization signals in the same subframe.

If a UE is configured with two EPDCCH-PRB-sets with the same $n_{\mathrm{ID},i}^{\mathrm{EPDCCH}}$ value (where $n_{\mathrm{ID},i}^{\mathrm{EPDCCH}}$ is defined in clause 6.10.3A.1 in [3]), if the UE receives an EPDCCH candidate with a given DCI payload size corresponding to one of the EPDCCH-PRB-sets and mapped only to a given set of REs (as described in clause 6.8A.5 in [3]), and if the UE is also configured to monitor an EPDCCH candidate with the same DCI payload size and corresponding to the other EPDCCH-PRB-set and which is mapped only to the same set of REs, and if the number of the first ECCE of the received EPDCCH candidate is used for determining PUCCH resource for HARQ-ACK transmission (as described in clause 10.1.2 and clause 10.1.3), the number of the first ECCE shall be determined based on EPDCCH-PRB-set $p=0$.

The variable $Y_{p,k}$ is defined by

$$Y_{p,k} = \left(A_p \cdot Y_{p,k-1}\right) \bmod D$$

where $Y_{p,-1} = n_{\mathrm{RNTI}} \neq 0$, $A_0 = 39827$, $A_1 = 39829$, $D = 65537$ and $k = \lfloor n_s/2 \rfloor$, n_s is the slot number within a radio frame. The RNTI value used for n_{RNTI} is defined in clause 7.1 in downlink and clause 8 in uplink. The DCI formats that the UE shall monitor depend on the configured transmission mode per each serving cell as defined in clause 7.1.

The aggregation levels defining the search spaces and the number of monitored EPDCCH candidates is given as follows

- For a UE configured with only one EPDCCH-PRB-set for distributed transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-1a, Table 9.1.4-1b.
- For a UE configured with only one EPDCCH-PRB-set for localized transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-2a, Table 9.1.4-2b.
- For a UE configured with two EPDCCH-PRB-sets for distributed transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-3a, 9.1.4-3b.
- For a UE configured with two EPDCCH-PRB-sets for localized transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-4a, 9.4.4-4b.
- For a UE configured with one EPDCCH-PRB-set for distributed transmission, and one EPDCCH-PRB-set for localized transmission, the aggregation levels defining the search spaces and the number of monitored EPDCCH candidates are listed in Table 9.1.4-5a, 9.1.4-5b.

If the UE is not configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} = N_{\mathrm{RB}}^{\mathrm{DL}}$ of the serving cell on which EPDCCH is monitored. If the UE is configured with a carrier indicator field for the serving cell on which EPDCCH is monitored, $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} = N_{\mathrm{RB}}^{\mathrm{DL}}$ of the serving cell indicated by n_{CI}.

For Tables 9.1.4-1a, 9.1.4-1b, 9.1.4-2a, 9.1.4-2b, 9.1.4-3a, 9.1.4-3b, 9.1.4-4a, 9.4.4-4b, 9.1.4-5a, 9.1.4-5b

- Case 1 applies
  - for normal subframes and normal downlink CP when DCI formats 2/2A/2B/2C/2D are monitored and $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} \geq 25$, or
  - for special subframes with special subframe configuration 3,4,8 and normal downlink CP when DCI formats 2/2A/2B/2C/2D are monitored and $\hat{N}_{\mathrm{RB}}^{\mathrm{DL}} \geq 25$, or
  - for normal subframes and normal downlink CP when DCI formats 1A/1B/1D/1/2/2A/2B/2C/2D/0/4 are monitored, and when $n_{\mathrm{EPDCCH}} < 104$ (n_{EPDCCH} defined in clause 6.8A.1 in [3]), or

- o for special subframes with special subframe configuration 3, 4, 8 and normal downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4 are monitored, and when $n_{\text{EPDCCH}} < 104$ (n_{EPDCCH} defined in clause 6.8A.1 in [3]);

- Case 2 applies
  - o for normal subframes and extended downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4 are monitored or,
  - o for special subframes with special subframe configuration 1,2,6,7,9 and normal downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4 are monitored , or
  - o for special subframes with special subframe configuration 1,2,3,5,6 and extended downlink CP when DCI formats 1A/1B/1D/1/2A/2/2B/2C/2D/0/4 are monitored;
- otherwise
  - o Case 3 is applied.

$N_{\text{RB}}^{X_p}$ is the number of PRB-pairs constituting EPDCCH-PRB-set p.

Table 9.1.4-1a: EPDCCH candidates monitored by a UE (One Distributed EPDCCH-PRB-set - Case1, Case 2)

$N_{\text{RB}}^{X_p}$	Number of EPDCCH candidates $M_p^{(L)}$ for Case 1					Number of EPDCCH candidates $M_p^{(L)}$ for Case 2				
	L=2	L=4	L=8	L=16	L=32	L=1	L=2	L=4	L=8	L=16
2	4	2	1	0	0	4	2	1	0	0
4	8	4	2	1	0	8	4	2	1	0
8	6	4	3	2	1	6	4	3	2	1

Table 9.1.4-1b: EPDCCH candidates monitored by a UE (One Distributed EPDCCH-PRB-set – Case 3)

$N_{\text{RB}}^{X_p}$	Number of EPDCCH candidates $M_p^{(L)}$ for Case 3				
	L=1	L=2	L=4	L=8	L=16
2	8	4	2	1	0
4	4	5	4	2	1
8	4	4	4	2	2

Table 9.1.4-2a: EPDCCH candidates monitored by a UE (One Localized EPDCCH-PRB-set - Case1, Case 2)

$N_{\text{RB}}^{X_p}$	Number of EPDCCH candidates $M_p^{(L)}$ for Case 1				Number of EPDCCH candidates $M_p^{(L)}$ for Case 2			
	L=2	L=4	L=8	L=16	L=1	L=2	L=4	L=8
2	4	2	1	0	4	2	1	0
4	8	4	2	1	8	4	2	1
8	6	6	2	2	6	6	2	2

Table 9.1.4-2b: EPDCCH candidates monitored by a UE (One Localized EPDCCH-PRB-set – Case 3)

$N_{\text{RB}}^{X_p}$	Number of EPDCCH candidates $M_p^{(L)}$ for Case 3			
	L=1	L=2	L=4	L=8
2	8	4	2	1
4	6	6	2	2
8	6	6	2	2

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Table 9.1.4-3a: EPDCCH candidates monitored by a UE (Two Distributed EPDCCH-PRB-sets - Case1, Case 2)

$N_{\text{RB}}^{Xp_1}$	$N_{\text{RB}}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 1					Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 2				
		L=2	L=4	L=8	L=16	L=32	L=1	L=2	L=4	L=8	L=16
2	2	4,4	2,2	1,1	0,0	0,0	4,4	2,2	1,1	0,0	0,0
4	4	3,3	3,3	1,1	1,1	0,0	3,3	3,3	1,1	1,1	0,0
8	8	3,3	2,2	1,1	1,1	1,1	3,3	2,2	1,1	1,1	1,1
4	2	5,3	3,2	1,1	1,0	0,0	5,3	3,2	1,1	1,0	0,0
8	2	4,2	4,2	1,1	1,0	1,0	4,2	4,2	1,1	1,0	1,0
8	4	3,3	2,2	2,1	1,1	1,0	3,3	2,2	2,1	1,1	1,0

Table 9.1.4-3b: EPDCCH candidates monitored by a UE (Two Distributed EPDCCH-PRB-sets – Case 3)

$N_{\text{RB}}^{Xp_1}$	$N_{\text{RB}}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 3				
		L=1	L=2	L=4	L=8	L=16
2	2	2,2	3,3	2,2	1,1	0,0
4	4	2,2	2,2	2,2	1,1	1,1
8	8	2,2	2,2	2,2	1,1	1,1
4	2	3,1	3,2	3,1	1,1	1,0
8	2	3,1	4,1	3,1	1,1	1,0
8	4	2,2	2,2	2,2	1,1	1,1

Table 9.1.4-4a: EPDCCH candidates monitored by a UE (Two Localized EPDCCH-PRB-sets - Case1, Case 2)

$N_{\text{RB}}^{Xp_1}$	$N_{\text{RB}}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 1				Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 2			
		L=2	L=4	L=8	L=16	L=1	L=2	L=4	L=8
2	2	4,4	2,2	1,1	0,0	4,4	2,2	1,1	0,0
4	4	3,3	3,3	1,1	1,1	3,3	3,3	1,1	1,1
8	8	3,3	3,3	1,1	1,1	3,3	3,3	1,1	1,1
4	2	4,3	4,2	1,1	1,0	4,3	4,2	1,1	1,0
8	2	5,2	4,2	1,1	1,0	5,2	4,2	1,1	1,0
8	4	3,3	3,3	1,1	1,1	3,3	3,3	1,1	1,1

Table 9.1.4-4b: EPDCCH candidates monitored by a UE (Two Localized EPDCCH-PRB-sets – Case 3)

$N_{RB}^{Xp_1}$	$N_{RB}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 3			
		L=1	L=2	L=4	L=8
2	2	3,3	3,3	1,1	1,1
4	4	3,3	3,3	1,1	1,1
8	8	3,3	3,3	1,1	1,1
4	2	4,2	4,2	1,1	1,1
8	2	4,2	4,2	1,1	1,1
8	4	3,3	3,3	1,1	1,1

Table 9.1.4-5a: EPDCCH candidates monitored by a UE (NOTE)

$N_{RB}^{Xp_1}$	$N_{RB}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 1					Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 2				
		L=2	L=4	L=8	L=16	L=32	L=1	L=2	L=4	L=8	L=16
2	2	4,4	2,2	1,1	0,0	0,0	4,4	2,2	1,1	0,0	0,0
4	4	4,2	4,3	0,2	0,1	0,0	4,2	4,3	0,2	0,1	0,0
8	8	4,1	4,2	0,2	0,2	0,1	4,1	4,2	0,2	0,2	0,1
2	4	4,3	2,4	0,2	0,1	0,0	4,3	2,4	0,2	0,1	0,0
2	8	4,1	2,2	0,4	0,2	0,1	4,1	2,2	0,4	0,2	0,1
4	2	5,2	4,2	1,1	1,0	0,0	5,2	4,2	1,1	1,0	0,0
4	8	4,1	4,2	0,2	0,2	0,1	4,1	4,2	0,2	0,2	0,1
8	2	5,1	4,2	2,1	1,0	0,0	5,1	4,2	2,1	1,0	0,0
8	4	6,1	4,2	0,2	0,1	0,0	6,1	4,2	0,2	0,1	0,0
NOTE: One localized EPDCCH-PRB-set and one distributed EPDCCH-PRB-set, - Case1, Case 2; p_1 is the identity of the localized EPDCCH-PRB-set, p_2 is the identity of the distributed EPDCCH-PRB-set											

Table 9.1.4-5b: EPDCCH candidates monitored by a UE (NOTE) (

$N_{RB}^{Xp_1}$	$N_{RB}^{Xp_2}$	Number of EPDCCH candidates $\left[M_{p1}^{(L)}, M_{p2}^{(L)}\right]$ for Case 3				
		L=1	L=2	L=4	L=8	L=16
2	2	4,1	4,2	2,2	0,1	0,0
4	4	4,1	4,1	2,2	0,1	0,1
8	8	4,1	4,1	2,2	0,1	0,1
2	4	4,1	4,1	2,2	0,1	0,1
2	8	4,1	4,1	2,2	0,1	0,1
4	2	4,1	4,1	2,2	1,1	0,0
4	8	4,1	4,1	2,2	0,1	0,1
8	2	4,1	4,1	4,1	0,1	0,0
8	4	4,1	4,1	2,2	0,1	0,1
NOTE: One localized EPDCCH-PRB-set and one distributed EPDCCH-PRB-set - Case 3); p_1 is the identity of the localized EPDCCH-PRB-set, p_2 is the identity of the distributed EPDCCH-PRB-set)						

If the UE is not configured with a carrier indicator field, then the UE shall monitor one EPDCCH UE-specific search space at each of the aggregation levels given by Tables 9.1.4-1a to 9.1.4-5b on each activated serving cell for which it is configured to monitor EPDCCH.

If a UE is configured for EPDCCH monitoring, and if the UE is configured with a carrier indicator field, then the UE shall monitor one or more EPDCCH UE-specific search spaces at each of the aggregation levels given by Tables 9.1.4-1a to 9.1.4-5b on one or more activated serving cells as configured by higher layer signalling.

A UE configured with the carrier indicator field associated with monitoring EPDCCH on serving cell *c* shall monitor EPDCCH configured with carrier indicator field and with CRC scrambled by C-RNTI in the EPDCCH UE specific search space of serving cell *c*.

A UE configured with the carrier indicator field associated with monitoring EPDCCH on the primary cell shall monitor EPDCCH configured with carrier indicator field and with CRC scrambled by SPS C-RNTI in the EPDCCH UE specific search space of the primary cell.

For the serving cell on which EPDCCH is monitored, if the UE is not configured with a carrier indicator field, it shall monitor the EPDCCH UE specific search space for EPDCCH without carrier indicator field, if the UE is configured with a carrier indicator field it shall monitor the EPDCCH UE specific search space for EPDCCH with carrier indicator field.

A UE is not expected to monitor the EPDCCH of a secondary cell if it is configured to monitor EPDCCH with carrier indicator field corresponding to that secondary cell in another serving cell. For the serving cell on which EPDCCH is monitored, the UE shall monitor EPDCCH candidates at least for the same serving cell.

A UE configured to monitor EPDCCH candidates in a given serving cell with a given DCI format size with CIF, and CRC scrambled by C- RNTI, where the EPDCCH candidates may have one or more possible values of CIF for the given DCI format size, shall assume that an EPDCCH candidate with the given DCI format size may be transmitted in the given serving cell in any EPDCCH UE specific search space corresponding to any of the possible values of CIF for the given DCI format size.

For the serving cell on which EPDCCH is monitored, a UE is not required to monitor the EPDCCH in a subframe which is configured by higher layers to be part of a positioning reference signal occasion if the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix.

A UE may assume the same c_{init} value (described in clause 6.10.3A.1 of [3]) is used for antenna ports 107,108 while monitoring an EPDCCH candidate associated with either antenna port 107 or antenna port 108.
A UE may assume the same c_{init} value (described in clause 6.10.3A.1 of [3]) is used for antenna ports 109,110 while monitoring an EPDCCH candidate associated with either antenna port 109 or antenna port 110.

9.1.4.1 EPDCCH starting position

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission modes 1-9,

- if the UE is configured with a higher layer parameter *epdcch-StartSymbol-r11*,
    - the starting OFDM symbol for EPDCCH given by index $l_{\text{EPDCCHStart}}$ in the first slot in a subframe is determined from the higher layer parameter,
- otherwise
    - the starting OFDM symbol for EPDCCH given by index $l_{\text{EPDCCHStart}}$ in the first slot in a subframe is given by the CFI value in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} > 10$, and $l_{\text{EPDCCHStart}}$ is given by the CFI value+1 in the subframe of the given serving cell when $N_{\text{RB}}^{\text{DL}} \leq 10$

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission mode 10, for each EPDCCH-PRB-set, the starting OFDM symbol for monitoring EPDCCH in subframe k is determined from the higher layer parameter *pdsch-Start-r11* (defined in clause 9.1.4.3) as follows

- if the value of the parameter *pdsch-Start-r11* belongs to {1,2,3,4},
    - $l'_{EPDCCHStart}$ is given by the higher layer parameter *pdsch-Start-r11*
- otherwise

- $l'_{EPDCCHStart}$ is given by the CFI value in subframe k of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} > 10$, and $l'_{EPDCCHStart}$ is given by the CFI value+1 in subframe k of the given serving cell when $N_{\mathrm{RB}}^{\mathrm{DL}} \le 10$

- if subframe k is indicated by the higher layer parameter *mbsfn-SubframeConfigList-r11* (defined in clause 9.1.4.3), or if subframe k is subframe 1 or 6 for frame structure type 2,
  - $l_{EPDCCHStart} = \min(2, l'_{EPDCCHStart})$,
- otherwise
  - $l_{\mathrm{EPDCCHStart}} = l'_{\mathrm{EPDCCHStart}}$.

9.1.4.2 Antenna ports quasi co-location for EPDCCH

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission modes 1-9, and if the UE is configured to monitor EPDCCH,

- the UE may assume the antenna ports 0 – 3, 107 – 110 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission mode 10, and if the UE is configured to monitor EPDCCH, for each EPDCCH-PRB-set,

- if the UE is configured by higher layers to decode PDSCH according to quasi co-location Type-A as described in clause 7.1.10
  - the UE may assume the antenna ports 0 – 3, 107 – 110 of the serving cell are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread..
- if the UE is configured by higher layers to decode PDSCH according to quasi co-location Type-B as described in clause 7.1.10
  - the UE may assume antenna ports 15 – 22 corresponding to the higher layer parameter *qcl-CSI-RS-ConfigNZPId-r11* (defined in clause 9.1.4.3) and antenna ports 107-110 are quasi co-located (as defined in [3]) with respect to Doppler shift, Doppler spread, average delay, and delay spread.

9.1.4.3 Resource mapping parameters for EPDCCH

For a given serving cell, if the UE is configured via higher layer signalling to receive PDSCH data transmissions according to transmission mode 10, and if the UE is configured to monitor EPDCCH, for each EPDCCH-PRB-set, the UE shall use the parameter set indicated by the higher layer parameter *re-MappingQCL-ConfigId-r11* for determining the EPDCCH RE mapping (defined in clause 6.8A.5 of [3]) and EPDCCH antenna port quasi co-location. The following parameters for determining EPDCCH RE mapping (as described in clause 6.8A.5 of [3]) and EPDCCH antenna port quasi co-location are included in the parameter set:

- *crs-PortsCount-r11*.
- *crs-FreqShift-r11*.
- *mbsfn-SubframeConfigList-r11*.
- *csi-RS-ConfigZPId-r11*.
- *pdsch-Start-r11*.
- *qcl-CSI-RS-ConfigNZPId-r11*.

9.1.4.4 PRB-pair indication for EPDCCH

For a given serving cell, for each EPDCCH-PRB-pair set p, the UE is configured with a higher layer parameter *resourceBlockAssignment-r11* indicating a combinatorial index r corresponding to the PRB index $\{k_i\}_{i=0}^{N_{RB}^{X_p}-1}$, ($1 \le k_i \le N_{RB}^{DL}$, $k_i < k_{i+1}$) and given by equation $r = \sum_{i=0}^{N_{RB}^{X_p}-1} \left\langle \begin{matrix} N_{RB}^{DL} - k_i \\ N_{RB}^{X_p} - i \end{matrix} \right\rangle$, where N_{RB}^{DL} is the number of PRB pairs associated with the downlink bandwidth, $N_{\mathrm{RB}}^{X_p}$ is the number of PRB-pairs constituting EPDCCH-PRB-set p, and is configured by the higher layer parameter *numberPRBPairs-r11*, and $\left\langle \begin{matrix} x \\ y \end{matrix} \right\rangle = \begin{cases} \binom{x}{y} & x \geq y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label $r \in \left\{0,...,\binom{N_{RB}^{DL}}{N_{RB}^{X_p}} - 1\right\}$.

9.2 PDCCH/EPDCCH validation for semi-persistent scheduling

A UE shall validate a Semi-Persistent Scheduling assignment PDCCH only if all the following conditions are met:

- the CRC parity bits obtained for the PDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI
- the new data indicator field is set to '0'. In case of DCI formats 2, 2A, 2B, 2C and 2D, the new data indicator field refers to the one for the enabled transport block.

A UE shall validate a Semi-Persistent Scheduling assignment EPDCCH only if all the following conditions are met:

- the CRC parity bits obtained for the EPDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI
- the new data indicator field is set to '0'. In case of DCI formats 2, 2A, 2B, 2C and 2D, the new data indicator field refers to the one for the enabled transport block.

Validation is achieved if all the fields for the respective used DCI format are set according to Table 9.2-1 or Table 9.2-1A.

If validation is achieved, the UE shall consider the received DCI information accordingly as a valid semi-persistent activation or release.

If validation is not achieved, the received DCI format shall be considered by the UE as having been received with a non-matching CRC.

Table 9.2-1: Special fields for Semi-Persistent Scheduling Activation PDCCH/EPDCCH Validation

	DCI format 0	DCI format 1/1A	DCI format 2/2A/2B/2C/2D
TPC command for scheduled PUSCH	set to '00'	N/A	N/A
Cyclic shift DM RS	set to '000'	N/A	N/A
Modulation and coding scheme and redundancy version	MSB is set to '0'	N/A	N/A
HARQ process number	N/A	FDD: set to '000' TDD: set to '0000'	FDD: set to '000' TDD: set to '0000'
Modulation and coding scheme	N/A	MSB is set to '0'	For the enabled transport block: MSB is set to '0'
Redundancy version	N/A	set to '00'	For the enabled transport block: set to '00'

Table 9.2-1A: Special fields for Semi-Persistent Scheduling Release PDCCH/EPDCCH Validation

	DCI format 0	DCI format 1A
TPC command for scheduled PUSCH	set to '00'	N/A
Cyclic shift DM RS	set to '000'	N/A
Modulation and coding scheme and redundancy version	set to '11111'	N/A
Resource block assignment and hopping resource allocation	Set to all '1's	N/A
HARQ process number	N/A	FDD: set to '000' TDD: set to '0000'
Modulation and coding scheme	N/A	set to '11111'
Redundancy version	N/A	set to '00'
Resource block assignment	N/A	Set to all '1's

For the case that the DCI format indicates a semi-persistent downlink scheduling activation, the TPC command for PUCCH field shall be used as an index to one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 9.2-2

Table 9.2-2: PUCCH resource value for downlink semi-persistent scheduling

Value of 'TPC command for PUCCH'	$n_{\text{PUCCH}}^{(1,p)}$
'00'	The first PUCCH resource value configured by the higher layers
'01'	The second PUCCH resource value configured by the higher layers
'10'	The third PUCCH resource value configured by the higher layers
'11'	The fourth PUCCH resource value configured by the higher layers

9.3 PDCCH/EPDCCH control information procedure

A UE shall discard the PDCCH/EPDCCH if consistent control information is not detected.

10 Physical uplink control channel procedures

10.1 UE procedure for determining physical uplink control channel assignment

If the UE is configured for a single serving cell and is not configured for simultaneous PUSCH and PUCCH transmissions, then in subframe n uplink control information (UCI) shall be transmitted

- on PUCCH using format 1/1a/1b/3 or 2/2a/2b if the UE is not transmitting on PUSCH
- on PUSCH if the UE is transmitting on PUSCH in subframe n unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted

If the UE is configured for a single serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCI consists only of HARQ-ACK and/or SR
- on PUCCH using format 2 if the UCI consists only of periodic CSI
- on PUCCH using format 2/2a/2b/3 if the UCI consists of periodic CSI and HARQ-ACK and if the UE is not transmitting PUSCH
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK/HARQ-ACK+SR/positive SR and periodic/aperiodic CSI in which case the HARQ-ACK/HARQ-ACK+SR/positive SR is transmitted on PUCCH using format 1/1a/1b/3 and the periodic/aperiodic CSI transmitted on PUSCH unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case periodic/aperiodic CSI is not transmitted

If the UE is configured with more than one serving cell and is not configured for simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 or 2/2a/2b if the UE is not transmitting PUSCH
- on PUSCH of the serving cell given in clause 7.2.1 if the UCI consists of aperiodic CSI or aperiodic CSI and HARQ-ACK
- on primary cell PUSCH if the UCI consists of periodic CSI and/or HARQ-ACK and if the UE is transmitting on the primary cell PUSCH in subframe n unless the primary cell PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted
- on PUSCH of the secondary cell with smallest *SCellIndex* if the UCI consists of periodic CSI and/or HARQ-ACK and if the UE is not transmitting PUSCH on primary cell but is transmitting PUSCH on at least one secondary cell

If the UE is configured with more than one serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCI consists only of HARQ-ACK and/or SR
- on PUCCH using format 2 if the UCI consists only of periodic CSI
- as described in clause 10.1.1, if the UCI consists of periodic CSI and HARQ-ACK and if the UE is not transmitting on PUSCH
- on PUCCH and primary cell PUSCH if the UCI consists of HARQ-ACK and periodic CSI and the UE is transmitting PUSCH on the primary cell, in which case the HARQ-ACK is transmitted on PUCCH using format 1a/1b/3 and the periodic CSI is transmitted on PUSCH unless the primary cell PUSCH transmission

corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case periodic CSI is not transmitted

- on PUCCH and PUSCH of the secondary cell with the smallest *SCellIndex* if the UCI consists of HARQ-ACK and periodic CSI and if the UE is not transmitting PUSCH on primary cell but is transmitting PUSCH on at least one secondary cell, in which case, the HARQ-ACK is transmitted on PUCCH using format 1a/1b/3 and the periodic CSI is transmitted on PUSCH
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK/HARQ-ACK+SR/positive SR and aperiodic CSI in which case the HARQ-ACK/HARQ-ACK+SR/positive SR is transmitted on PUCCH using format 1/1a/1b/3 and the aperiodic CSI is transmitted on PUSCH of the serving cell given in clause 7.2.1

If the UE is configured with more than one serving cell, then reporting prioritization and collision handling of periodic CSI reports of a certain PUCCH reporting type is given in clause 7.2.2.

A UE transmits PUCCH only on the primary cell.

A UE is configured by higher layers to transmit PUCCH on one antenna port $(p = p_0)$ or two antenna ports $(p \in [p_0, p_1])$.

For FDD with two configured serving cells and PUCCH format 1b with channel selection or for FDD with two or more configured serving cells and PUCCH format 3, $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} N_c^{\text{received}}$ where N_{cells}^{DL} is the number of configured cells and N_c^{received} is the number of transport blocks or the SPS release PDCCH/EPDCCH, if any, received in subframe $n-4$ in serving cell c.

For TDD, if a UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configurations of all serving cells are the same, then

- For TDD with two configured serving cells and PUCCH format 1b with channel selection and a subframe *n* with *M = 1*, or for TDD UL/DL configuration 0 and PUCCH format 3, $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} \sum_{k \in K} N_{k,c}^{\text{received}}$, where $N_{k,c}^{\text{received}}$ is the number of transport blocks or the SPS release PDCCH/EPDCCH, if any, received in subframe $n-k$ in serving cell c, where $k \in K$, and *M* is the number of elements in *K*.
- For TDD UL/DL configurations 1-6 and PUCCH format 3, or for TDD with two configured serving cells and PUCCH format 1b with channel selection and *M* = 2, $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} \left(\left(\left(V_{\text{DAI},c}^{\text{DL}} - U_{\text{DAI},c} \right) \bmod 4 \right) \cdot n_c^{\text{ACK}} + \sum_{k \in K} N_{k,c}^{\text{received}} \right)$ where $V_{\text{DAI,c}}^{\text{DL}}$ is the $V_{\text{DAI}}^{\text{DL}}$ in serving cell c, $U_{\text{DAI,c}}$ is the U_{DAI} in serving cell c, and n_c^{ACK} is the number of HARQ-ACK bits corresponding to the configured DL transmission mode on serving cell c. In case spatial HARQ-ACK bundling is applied, $n_c^{ACK} = 1$ and $N_{k,c}^{\text{received}}$ is the number of PDCCH/EPDCCH or PDSCH without a corresponding PDCCH/EPDCCH received in subframe $n-k$ and serving cell c, where $k \in K$ and *M* is the number of elements in *K*. In case spatial HARQ-ACK bundling is not applied, $N_{k,c}^{\text{received}}$ is the number of transport blocks received or the SPS release PDCCH/EPDCCH received in subframe $n-k$ in serving cell c, where $k \in K$ and *M* is the number of elements in *K*. $V_{\text{DAI,c}}^{\text{DL}}$ =0 if no transport block or SPS release PDCCH/EPDCCH is detected in subframe(s) $n-k$ in serving cell c, where $k \in K$.
- For TDD with two configured serving cells and PUCCH format 1b with channel selection and *M* = 3 or 4, $n_{\text{HARQ}} = 2$ if UE receives PDSCH or PDCCH/EPDCCH indicating downlink SPS release only on one serving cell within subframes $n-k$,where $k \in K$;otherwise $n_{\text{HARQ}} = 4$.

For TDD if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then

- For PUCCH format 3, or for TDD with two configured serving cells and PUCCH format 1b with channel selection and $M \le 2$ (defined in clause 10.1.3.2.1), $n_{\text{HARQ}} = \sum_{c=0}^{N_{cells}^{DL}-1} \left(\left(\left(V_{\text{DAI},c}^{\text{DL}} - U_{\text{DAI},c} \right) \bmod 4 \right) \cdot n_c^{\text{ACK}} + \sum_{k \in K} N_{k,c}^{\text{received}} \right)$ where $V_{\text{DAI,c}}^{\text{DL}}$ is the $V_{\text{DAI}}^{\text{DL}}$ in serving cell c, $U_{\text{DAI,c}}$ is the U_{DAI} in serving cell c, and n_c^{ACK} is the number of HARQ-ACK bits corresponding to the configured DL transmission mode on serving cell c. In case spatial HARQ-ACK bundling is applied, $n_c^{\text{ACK}} = 1$ and $N_{k,c}^{\text{received}}$ is the number of PDCCH/EPDCCH or PDSCH without a corresponding PDCCH/EPDCCH received in subframe $n-k$ and serving cell c, where $k \in K$ and $K = K_c$ (defined in clause 7.3.2.2). In case spatial HARQ-ACK bundling is not applied, $N_{k,c}^{\text{received}}$ is the number of transport blocks received or the SPS release PDCCH/EPDCCH received in subframe $n-k$ in serving cell c, where $k \in K$ and $K = K_c$ (defined in clause 7.3.2.2). $V_{\text{DAI,c}}^{\text{DL}}$ =0 if no transport block or SPS release PDCCH/EPDCCH is detected in subframe(s) $n-k$ in serving cell c, where $k \in K$ and $K = K_c$ (defined in clause 7.3.2.2). For a serving cell c, set $V_{\text{DAI,c}}^{\text{DL}} = U_{\text{DAI,c}}$ if the DL-reference UL/DL configuration (defined in clause 10.2) for serving cell c is TDD UL/DL configuration 0,

- For TDD with two configured serving cells and PUCCH format 1b with channel selection and M = 3 or 4 (defined in clause 10.1.3.2.1) , $n_{\text{HARQ}} = 2$ if UE receives PDSCH or PDCCH/EPDCCH indicating downlink SPS release only on one serving cell within subframes $n-k$,where $k \in K$ and $K = K_c$ (defined in clause 7.3.2.2);otherwise $n_{\text{HARQ}} = 4$.

Throughout the following clauses, subframes are numbered in monotonically increasing order; if the last subframe of a radio frame is denoted as k , the first subframe of the next radio frame is denoted as $k+1$.

Throughout the following clauses, if the UE is configured with higher layer parameter *n1PUCCH-AN-r11* then $N_{\text{PUCCH}}^{(1)}$ is given by *n1PUCCH-AN-r11*, else $N_{\text{PUCCH}}^{(1)}$ is given by higher layer parameter *n1PUCCH-AN* .

10.1.1 PUCCH format information

Using the PUCCH formats defined in clause 5.4.1 and 5.4.2 in [3], the following combinations of UCI on PUCCH are supported:

- Format 1a for 1-bit HARQ-ACK or in case of FDD for 1-bit HARQ-ACK with positive SR
- Format 1b for 2-bit HARQ-ACK or for 2-bit HARQ-ACK with positive SR
- Format 1b for up to 4-bit HARQ-ACK with channel selection when the UE is configured with more than one serving cell or, in the case of TDD, when the UE is configured with a single serving cell
- Format 1 for positive SR
- Format 2 for a CSI report when not multiplexed with HARQ-ACK
- Format 2a for a CSI report multiplexed with 1-bit HARQ-ACK for normal cyclic prefix
- Format 2b for a CSI report multiplexed with 2-bit HARQ-ACK for normal cyclic prefix
- Format 2 for a CSI report multiplexed with HARQ-ACK for extended cyclic prefix
- Format 3 for up to 10-bit HARQ-ACK for FDD and for up to 20-bit HARQ-ACK for TDD
- Format 3 for up to 11-bit corresponding to 10-bit HARQ-ACK and 1-bit positive/negative SR for FDD and for up to 21-bit corresponding to 20-bit HARQ-ACK and 1-bit positive/negative SR for TDD.

- Format 3 for HARQ-ACK, 1-bit positive/negative SR (if any) and a CSI report for one serving cell.

For a UE configured with PUCCH format 3 and HARQ-ACK transmission on PUSCH or using PUCCH format 3, or for a UE configured with two serving cells and PUCCH format 1b with channel selection and HARQ-ACK transmission on PUSCH, or for UE configured with one serving cell and PUCCH format 1b with channel selection according to Tables 10.1.3-5, 10.1.3-6, 10.1.3-7 and HARQ-ACK transmission on PUSCH:

- if the configured downlink transmission mode for a serving cell supports up to 2 transport blocks and only one transport block is received in a subframe, the UE shall generate a NACK for the other transport block if spatial HARQ-ACK bundling is not applied.
- if neither PDSCH nor PDCCH/EPDCCH indicating downlink SPS release is detected in a subframe for a serving cell, the UE shall generate two NACKs when the configured downlink transmission mode supports up to 2 transport blocks and the UE shall generate a single NACK when the configured downlink transmission mode supports a single transport block.

The scrambling initialization of PUCCH format 2, 2a, 2b and 3 is by C-RNTI.

For a UE that is configured with a single serving cell and is not configured with PUCCH format 3, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, the periodic CSI report is multiplexed with HARQ-ACK on PUCCH if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, otherwise the CSI is dropped.

For TDD and for a UE that is configured with a single serving cell and with PUCCH format 3, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE* or if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*, the periodic CSI report is multiplexed with HARQ-ACK or dropped as described in clause 7.3, otherwise the CSI is dropped.

For FDD and for a UE that is configured with more than one serving cell, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH,

- if the parameter simultaneousAckNackAndCQI provided by higher layers is set TRUE and if the HARQ-ACK corresponds to a PDSCH transmission or PDCCH/EPDCCH indicating downlink SPS release only on the primary cell,

  then the periodic CSI report is multiplexed with HARQ-ACK on PUCCH using PUCCH format 2/2a/2b

- else if the UE is configured with PUCCH format 3 and if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*, and if PUCCH resource is determined according to clause 10.1.2.2.2, and
  - o if the total number of bits in the subframe corresponding to HARQ-ACKs, SR (if any), and the CSI is not larger than 22 or
  - o if the total number of bits in the subframe corresponding to spatially bundled HARQ-ACKs, SR (if any), and the CSI is not larger than 22

    then the periodic CSI report is multiplexed with HARQ-ACK on PUCCH using the determined PUCCH format 3 resource according to [4]

- otherwise,

  CSI is dropped.

For TDD and for a UE that is configured with more than one serving cell, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE* or if the parameter *simultaneousAckNackAndCQI-Format3-r11* provided by higher layers is set *TRUE*, the periodic CSI report is multiplexed with HARQ-ACK or dropped as described in clause 7.3, otherwise the CSI is dropped.

In case of collision between a periodic CSI report and an HARQ-ACK in a same subframe with PUSCH, the periodic CSI is multiplexed with the HARQ-ACK in the PUSCH transmission in that subframe if the UE is not configured by higher layers for simultaneous PUCCH and PUSCH transmissions. Otherwise, if the UE is configured by higher layers for simultaneous PUCCH and PUSCH transmissions, the HARQ-ACK is transmitted in the PUCCH and the periodic CSI is transmitted in the PUSCH.

10.1.2 FDD HARQ-ACK feedback procedures

For FDD and for a UE transmitting HARQ-ACK using PUCCH format 1b with channel selection or PUCCH format 3, the UE shall determine the number of HARQ-ACK bits, O, based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that support up to two transport blocks; and one HARQ-ACK bit otherwise.

A UE that supports aggregating at most 2 serving cells with frame structure type 1 shall use PUCCH format 1b with channel selection for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

A UE that supports aggregating more than 2 serving cells with frame structure type 1 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3 for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

The FDD HARQ-ACK feedback procedure for one configured serving cell is given in clause 10.1.2.1 and procedures for more than one configured serving cell are given in clause 10.1.2.2.

10.1.2.1 FDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1a/1b.

For FDD and one configured serving cell, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port *p* for PUCCH format 1a/1b [3], where

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-4$, the UE shall use $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0, where n_{CCE} is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding DCI assignment and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers. For two antenna port transmission the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.
- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.
- for a PDSCH transmission indicated by the detection of a corresponding EPDCCH in subframe $n-4$, or for an EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-4$, the UE shall use
    - o if EPDCCH-PRB-set q is configured for distributed transmission
      $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{ECCE,q}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$
    - o if EPDCCH-PRB-set q is configured for localized transmission
      $$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

for antenna port p_0, where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for localized EPDCCH transmission which is described in clause 6.8A.5 in [3]. For two antenna port transmission the PUCCH resource for antenna port p_1 is given by

- if EPDCCH-PRB-set q is configured for distributed transmission
  $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{ECCE,q}} + 1 + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$
- if EPDCCH-PRB-set q is configured for localized transmission
  $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$

Table 10.1.2.1-1: Mapping of ACK/NACK Resource offset Field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D to Δ_{ARO} values

ACK/NACK Resource offset field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D	Δ_{ARO}
0	0
1	-1
2	-2
3	2

10.1.2.2 FDD HARQ-ACK procedures for more than one configured serving cell

The FDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in clause 10.1.2.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in clause 10.1.2.2.2.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 3.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1b with channel selection and FDD with two configured serving cells.

10.1.2.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

For FDD with two configured serving cells and PUCCH format 1b with channel selection, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port p using PUCCH format 1b where

- $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{PUCCH}}^{(1)}$ for antenna port p_0 where $n_{\text{PUCCH}}^{(1)}$ is selected from A PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Table 10.1.2.2.1-3, Table 10.1.2.2.1-4, Table 10.1.2.2.1-5 in subframe n. HARQ-ACK(j) denotes the ACK/NACK/DTX response for a transport block or SPS release PDCCH/EPDCCH associated with serving cell c, where the transport block and serving cell for HARQ-ACK(j) and A PUCCH resources are given by Table 10.1.2.2.1-1.

- $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, where $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ is selected from A PUCCH resources, $n_{\text{PUCCH},j}^{(1,\tilde{p}_1)}$ configured by higher layers where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Table 10.1.2.2.1-3, Table 10.1.2.2.1-4, Table

10.1.2.2.1-5 by replacing $n_{\mathrm{PUCCH}}^{(1)}$ with $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ and replacing $n_{\mathrm{PUCCH},i}^{(1)}$ with $n_{\mathrm{PUCCH},i}^{(1,\tilde{p}_1)}$ in subframe n, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection.

A UE configured with a transmission mode that supports up to two transport blocks on serving cell, c, shall use the same HARQ-ACK response for both the transport blocks in response to a PDSCH transmission with a single transport block or a PDCCH/EPDCCH indicating downlink SPS release associated with the serving cell c.

Table 10.1.2.2.1-1: Mapping of Transport Block and Serving Cell to HARQ-ACK(*j*) for PUCCH format 1b HARQ-ACK channel selection

A	*HARQ-ACK(j)*			
	HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)
2	TB1 Primary cell	TB1 Secondary cell	NA	NA
3	TB1 Serving cell1	TB2 Serving cell1	TB1 Serving cell2	NA
4	TB1 Primary cell	TB2 Primary cell	TB1 Secondary cell	TB2 Secondary cell

The UE shall determine the A PUCCH resources, $n_{\mathrm{PUCCH},j}^{(1)}$ associated with HARQ-ACK(*j*) where $0 \le j \le A-1$ in Table 10.1.2.2.1-1, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-4$ on the primary cell, the PUCCH resource is $n_{\mathrm{PUCCH,j}}^{(1)} = n_{\mathrm{CCE}} + N_{\mathrm{PUCCH}}^{(1)}$, and for transmission mode that supports up to two transport blocks, the PUCCH resource $n_{\mathrm{PUCCH},j+1}^{(1)}$ is given by $n_{\mathrm{PUCCH},j+1}^{(1)} = n_{\mathrm{CCE}} + 1 + N_{\mathrm{PUCCH}}^{(1)}$ where n_{CCE} is the number of the first CCE used for transmission of the corresponding PDCCH and $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers.

- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the value of $n_{\mathrm{PUCCH},j}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2. For transmission mode that supports up to two transport blocks, the PUCCH resource $n_{\mathrm{PUCCH},j+1}^{(1)}$ is given by $n_{\mathrm{PUCCH},j+1}^{(1)} = n_{\mathrm{PUCCH},j}^{(1)} + 1$

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-4$ on the secondary cell, the value of $n_{\mathrm{PUCCH},j}^{(1)}$, and the value of $n_{\mathrm{PUCCH},j+1}^{(1)}$ for the transmission mode that supports up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode that supports up to two transport blocks a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources $(n_{\mathrm{PUCCH},j}^{(1)}, n_{\mathrm{PUCCH},j+1}^{(1)})$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\mathrm{PUCCH},j}^{(1)}$.

- for a PDSCH transmission indicated by the detection of a corresponding EPDCCH in subframe $n-4$ on the primary cell, or for an EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-4$ on the primary cell, the PUCCH resource is given by

    - o if EPDCCH-PRB-set q is configured for distributed transmission

      $n_{\mathrm{PUCCH,j}}^{(1)} = n_{\mathrm{ECCE,q}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(e1)}$

- if EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,j}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + n' + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for localized EPDCCH transmission which is described in clause 6.8A.5 in [3].

For transmission mode that supports up to two transport blocks, the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},j+1}$ is given by

- if EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH,j+1}} = n_{\mathrm{ECCE,q}} + 1 + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

- if EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,j+1}} = \left\lfloor \frac{n_{ECCE,q}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + 1 + n' + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

Table 10.1.2.2.1-2: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

Value of 'TPC command for PUCCH'	$n^{(1)}_{\mathrm{PUCCH},j}$ **or** $(n^{(1)}_{\mathrm{PUCCH},j}, n^{(1)}_{\mathrm{PUCCH},j+1})$
'00'	The 1st PUCCH resource value configured by the higher layers
'01'	The 2nd PUCCH resource value configured by the higher layers
'10'	The 3rd PUCCH resource value configured by the higher layers
'11'	The 4th PUCCH resource value configured by the higher layers
NOTE: $(n^{(1)}_{\mathrm{PUCCH},j}, n^{(1)}_{\mathrm{PUCCH},j+1})$ are determined from the first and second PUCCH resource lists configured by *n1PUCCH-AN-CS-List-r10* in [11], respectively.	

Table 10.1.2.2.1-3: Transmission of Format 1b HARQ-ACK channel selection for $A = 2$

HARQ-ACK(0)	HARQ-ACK(1)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$
ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1,1
ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1,1
NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0,0
NACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,0
DTX	NACK/DTX	No Transmission	

Table 10.1.2.2.1-4: Transmission of Format 1b HARQ-ACK channel selection for $A = 3$

HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK	ACK	ACK	$n^{(1)}_{\text{PUCCH},1}$	1,1
ACK	NACK/DTX	ACK	$n^{(1)}_{\text{PUCCH},1}$	1,0
NACK/DTX	ACK	ACK	$n^{(1)}_{\text{PUCCH},1}$	0,1
NACK/DTX	NACK/DTX	ACK	$n^{(1)}_{\text{PUCCH},2}$	1,1
ACK	ACK	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1,1
ACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1,0
NACK/DTX	ACK	NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0,1
NACK/DTX	NACK/DTX	NACK	$n^{(1)}_{\text{PUCCH},2}$	0,0
NACK	NACK/DTX	DTX	$n^{(1)}_{\text{PUCCH},0}$	0,0
NACK/DTX	NACK	DTX	$n^{(1)}_{\text{PUCCH},0}$	0,0
DTX	DTX	DTX	No Transmission	

Table 10.1.2.2.1-5: Transmission of Format 1b HARQ-ACK channel selection for $A = 4$

HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$
ACK	ACK	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1,1
ACK	NACK/DTX	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},2}$	0,1
NACK/DTX	ACK	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0,1
NACK/DTX	NACK/DTX	ACK	ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1,1
ACK	ACK	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1,0
ACK	NACK/DTX	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0,0
NACK/DTX	ACK	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0,0
NACK/DTX	NACK/DTX	ACK	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	1,0
ACK	ACK	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},2}$	1,1
ACK	NACK/DTX	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},2}$	1,0
NACK/DTX	ACK	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0,1
NACK/DTX	NACK/DTX	NACK/DTX	ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0,0
ACK	ACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1,1
ACK	NACK/DTX	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1,0
NACK/DTX	ACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,1
NACK/DTX	NACK	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,0
NACK	NACK/DTX	NACK/DTX	NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0,0
DTX	DTX	NACK/DTX	NACK/DTX	No Transmission	

10.1.2.2.2 PUCCH format 3 HARQ-ACK procedure

For FDD with PUCCH format 3, the UE shall use PUCCH resource $n^{(3,\tilde{p})}_{\mathrm{PUCCH}}$ or $n^{(1,\tilde{p})}_{\mathrm{PUCCH}}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port p where

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n^{(1,\tilde{p})}_{\mathrm{PUCCH}}$ with $n^{(1,\tilde{p}_0)}_{\mathrm{PUCCH}} = n_{\mathrm{CCE}} + N^{(1)}_{\mathrm{PUCCH}}$ for antenna port p_0, where n_{CCE} is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding PDCCH and $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH}} = n_{\mathrm{CCE}} + 1 + N^{(1)}_{\mathrm{PUCCH}}$.

- for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected in subframe $n-4$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n^{(1,\tilde{p})}_{\mathrm{PUCCH}}$ where the value of $n^{(1,\tilde{p})}_{\mathrm{PUCCH}}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n^{(1,\tilde{p}_0)}_{\mathrm{PUCCH}}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH in subframe $n-4$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For a UE configured for two antenna port transmission for PUCCH format 3, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in each DCI format of the corresponding secondary cell PDCCH assignments in a given subframe.

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-4$, or for a EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by

  - o if EPDCCH-PRB-set q is configured for distributed transmission

    $$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{ECCE,q}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - o if EPDCCH-PRB-set q is configured for localized transmission

    $$n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  for antenna port p_0, where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for localized EPDCCH transmission which is described in clause 6.8A.5 in [3]. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by.

  - o if EPDCCH-PRB-set q is configured for distributed transmission

    $$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{ECCE,q}} + 1 + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - o if EPDCCH-PRB-set q is configured for localized transmission

    $$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

Table 10.1.2.2.2-1: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

Value of 'TPC command for PUCCH' or 'HARQ-ACK resource offset'	$n_{\text{PUCCH}}^{(3,\tilde{p})}$
'00'	The 1st PUCCH resource value configured by the higher layers
'01'	The 2nd PUCCH resource value configured by the higher layers
'10'	The 3rd PUCCH resource value configured by the higher layers
'11'	The 4th PUCCH resource value configured by the higher layers

10.1.3 TDD HARQ-ACK feedback procedures

For TDD and a UE that does not support aggregating more than one serving cell with frame structure type 2, two HARQ-ACK feedback modes are supported by higher layer configuration.

- HARQ-ACK bundling and
- HARQ-ACK multiplexing

For TDD UL/DL configuration 5 and a UE that does not support aggregating more than one serving cell with frame structure type 2, only HARQ-ACK bundling is supported.

A UE that supports aggregating more than one serving cell with frame structure type 2 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3 for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 2.

A UE that supports aggregating more than one serving cell with frame structure type 2 is configured by higher layers to use HARQ-ACK bundling, PUCCH format 1b with channel selection according to the set of Tables 10.1.3-2/3/4 or according to the set of Tables 10.1.3-5/6/7, or PUCCH format 3 for transmission of HARQ-ACK when configured with one serving cell with frame structure type 2.

PUCCH format 1b with channel selection according to the set of Tables 10.1.3-2/3/4 or according to the set of Tables 10.1.3-5/6/7 is not supported for TDD UL/DL configuration 5.

TDD HARQ-ACK bundling is performed per codeword across M multiple DL subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in Table 10.1.3.1-1, by a logical AND operation of all the individual PDSCH transmission (with and without corresponding PDCCH/EPDCCH) HARQ-ACKs and ACK in response to PDCCH/EPDCCH indicating downlink SPS release. For one configured serving cell the bundled 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively.

For TDD HARQ-ACK multiplexing and a subframe *n* with $M > 1$, where M is the number of elements in the set K defined in Table 10.1.3.1-1, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. PUCCH format 1b with channel selection is used in case of one configured serving cell. For TDD HARQ-ACK multiplexing and a subframe *n* with $M = 1$, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is not performed, 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively for one configured serving cell.

In the case of TDD and more than one configured serving cell with PUCCH format 1b with channel selection and more than 4 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe *n*, where M is defined in clause 10.1.3.2.1, and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a DL subframe for all configured cells is performed and the bundled HARQ-ACK bits for each configured serving cell is transmitted using PUCCH format 1b with channel selection. For TDD and more than one configured serving cell with PUCCH format 1b with channel selection and up to 4 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe *n*, where M is defined in clause 10.1.3.2.1, and for the configured serving cells, spatial HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 1b with channel selection.

In the case of TDD and more than one configured serving cell with PUCCH format 3 and more than 20 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in clause 10.1.3.2.2 and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed for each serving cell by a logical AND operation of all of the corresponding individual HARQ-ACKs and PUCCH format 3 is used. For TDD and more than one configured serving cell with PUCCH format 3 and up to 20 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe *n*, where M is the number of elements in the set K defined in clause 10.1.3.2.2 and for the configured serving cells, spatial HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 3.

For TDD with PUCCH format 3, a UE shall determine the number of HARQ-ACK bits, O, associated with an UL subframe *n*

according to $O = \sum_{c=1}^{N_{cells}^{DL}} O_c^{ACK}$ where N_{cells}^{DL} is the number of configured cells, and O_c^{ACK} is the number of HARQ-bits for the *c*-th serving cell defined in clause 7.3.

TDD HARQ-ACK feedback procedures for one configured serving cell are given in clause 10.1.3.1 and procedures for more than one configured serving cell are given in clause 10.1.3.2.

10.1.3.1 TDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1a/1b with TDD HARQ-ACK bundling feedback mode and for PUCCH format 3.

A UE that supports aggregating more than one serving cell with frame structure type 2 can be configured by higher layers for HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ for PUCCH format 1b with channel selection.

The TDD HARQ-ACK procedure for a UE configured with PUCCH format 3 is as described in clause 10.1.3.2.2 when the UE receives PDSCH and/or SPS release PDCCH/EPDCCH only on the primary cell.

For TDD HARQ-ACK bundling or TDD HARQ-ACK multiplexing for one configured serving cell and a subframe *n* with $M = 1$ where M is the number of elements in the set K defined in Table 10.1.3.1-1, the UE shall use PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port *p* for PUCCH format 1a/1b, where

- If there is PDSCH transmission indicated by the detection of corresponding PDCCH/EPDCCH or there is PDCCH/EPDCCH indicating downlink SPS release within subframe(s) $n-k$, where $k \in K$ and K (defined in Table 10.1.3.1-1) is a set of *M* elements $\{k_0, k_1, \cdots k_{M-1}\}$ depending on the subframe *n* and the UL/DL configuration (defined in Table 4.2-2 in [3]), and if PDCCH indicating PDSCH transmission or downlink SPS release is detected in subframe $n-k_m$, where k_m is the smallest value in set K such that UE detects a PDCCH/EPDCCH indicating PDSCH transmission or downlink SPS release within subframe(s) $n-k$ and $k \in K$, the UE first selects a c value out of {0, 1, 2, 3} which makes $N_c \le n_{\mathrm{CCE}} < N_{c+1}$ and shall use $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)} = (M-m-1) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE}} + N_{\mathrm{PUCCH}}^{(1)}$ for antenna port p_0, where $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers, $N_c = \max\left\{0, \left\lfloor [N_{\mathrm{RB}}^{\mathrm{DL}} \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and n_{CCE} is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ and the corresponding *m*. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for HARQ-ACK bundling for antenna port p_1 is given by $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)} = (M-m-1) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE}} + 1 + N_{\mathrm{PUCCH}}^{(1)}$.

- If there is only a PDSCH transmission where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ with the value of $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b and HARQ-ACK bundling, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

- If there is PDSCH transmission indicated by the detection of corresponding PDCCH/EPDCCH or there is PDCCH/EPDCCH indicating downlink SPS release within subframe(s) $n-k$, where $k \in K$ and K (defined in Table 10.1.3.1-1) is a set of *M* elements $\{k_0, k_1, \cdots k_{M-1}\}$ depending on the subframe *n* and the UL/DL configuration (defined in Table 4.2-2 in [3]), and if EPDCCH indicating PDSCH transmission or downlink SPS release is detected in subframe $n-k_m$, where k_m is the smallest value in set K such that UE detects a PDCCH/EPDCCH indicating PDSCH transmission or downlink SPS release within subframe(s) $n-k$ and $k \in K$, the UE shall use

- if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

- if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\mathrm{PUCCH}}^{(1,\tilde{p}_0)} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

for antenna port p_0, where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$ and the corresponding *m*, $N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in clause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for HARQ-ACK bundling for antenna port p_1 is given by

- if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)} = n_{\mathrm{ECCE,q}} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

- if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

Table 10.1.3.1-1: Downlink association set index K : $\{k_0, k_1, \cdots k_{M-1}\}$ for TDD

UL/DL Configuration	Subframe *n*									
	0	1	2	3	4	5	6	7	8	9
0	-	-	6	-	4	-	-	6	-	4
1	-	-	7, 6	4	-	-	-	7, 6	4	-
2	-	-	8, 7, 4, 6	-	-	-	-	8, 7, 4, 6	-	-
3	-	-	7, 6, 11	6, 5	5, 4	-	-	-	-	-
4	-	-	12, 8, 7, 11	6, 5, 4, 7	-	-	-	-	-	-
5	-	-	13, 12, 9, 8, 7, 5, 4, 11, 6	-	-	-	-	-	-	-
6	-	-	7	7	5	-	-	7	7	-

Table 10.1.3.1-2: Mapping of ACK/NACK Resource offset Field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D to Δ_{ARO} values for TDD when $m > 0$

ACK/NACK Resource offset field in DCI format 1A/1B/1D/1/2A/2/2B/2C/2D	Δ_{ARO}
0	0
1	$-\sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} - 2$
2	$-\sum_{i1=m-\lceil m/3 \rceil}^{m-1} N_{ECCE,q,n-k_{i1}} - 1$
3	2

For TDD HARQ-ACK multiplexing and sub-frame n with $M > 1$ and one configured serving cell, where M is the number of elements in the set K defined in Table 10.1.3.1-1, denote $n_{\text{PUCCH},i}^{(1)}$ as the PUCCH resource derived from sub-frame $n - k_i$ and HARQ-ACK(i) as the ACK/NACK/DTX response from sub-frame $n - k_i$, where $k_i \in K$ (defined in Table 10.1.3.1-1) and $0 \le i \le M - 1$.

- For a PDSCH transmission indicated by the detection of corresponding PDCCH or a PDCCH indicating downlink SPS release in sub-frame $n - k_i$ where $k_i \in K$, the PUCCH resource $n_{\text{PUCCH},i}^{(1)} = (M - i - 1) \cdot N_c + i \cdot N_{c+1} + n_{\text{CCE},i} + N_{\text{PUCCH}}^{(1)}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, $n_{\text{CCE},i}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_i$, and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers.

- For a PDSCH transmission where there is not a corresponding PDCCH/EPDCCH detected in subframe $n - k_i$, the value of $n_{\text{PUCCH},i}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.

- For a PDSCH transmission indicated by the detection of corresponding EPDCCH or a EPDCCH indicating downlink SPS release in sub-frame $n - k_i$ where $k_i \in K$, the UE shall use

  - o if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH,i}}^{(1)} = n_{\text{ECCE,q}} + \sum_{i1=0}^{i-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - o if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH,i}}^{(1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{i-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_i$, $N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_i$ is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_i$ which is described in clause 6.8A.5 in [3]. If $i=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $i>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2, where the the variable m in the table is substituted with i. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0.

If a UE is not configured with two antenna port transmission for PUCCH format 1b with channel selection, based on higher layer signalling the UE configured with a single serving cell will perform channel selection either according to the set of Tables 10.1.3-2, 10.1.3-3, and 10.1.3-4 or according to the set of Tables 10.1.3-5, 10.1.3-6, and 10.1.3-7.

If a UE is configured with two antenna port transmission for PUCCH format 1b with channel selection, then the UE will perform channel selection according to the set of Tables 10.1.3-5, 10.1.3-6, and 10.1.3-7.

For the selected table set, the UE shall transmit $b(0),b(1)$ on PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ in sub-frame n for $\tilde{p}$ mapped to antenna port p using PUCCH format 1b according to clause 5.4.1 in [3] where

- $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}=n_{\mathrm{PUCCH}}^{(1)}$ for antenna port p_0 and the value of $b(0),b(1)$ and the PUCCH resource $n_{\mathrm{PUCCH}}^{(1)}$ are generated by channel selection according to the selected set of Tables for M = 2, 3, and 4 respectively
- $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, where $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ is selected from PUCCH resources $n_{\mathrm{PUCCH},i}^{(1,\tilde{p}_1)}$ configured by higher layers where $0 \le i \le M-1$, according to selected set of Tables for M = 2, 3, and 4 respectively by replacing $n_{\mathrm{PUCCH}}^{(1)}$ with $n_{\mathrm{PUCCH}}^{(1,\tilde{p}_1)}$ and replacing $n_{\mathrm{PUCCH},i}^{(1)}$ with $n_{\mathrm{PUCCH},i}^{(1,\tilde{p}_1)}$, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection.

Table 10.1.3-2: Transmission of HARQ-ACK multiplexing for *M* = 2

HARQ-ACK(0), HARQ-ACK(1)	$n_{\mathrm{PUCCH}}^{(1)}$	$b(0),b(1)$
ACK, ACK	$n_{\mathrm{PUCCH},1}^{(1)}$	1, 1
ACK, NACK/DTX	$n_{\mathrm{PUCCH},0}^{(1)}$	0, 1
NACK/DTX, ACK	$n_{\mathrm{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, NACK	$n_{\mathrm{PUCCH},1}^{(1)}$	1, 0
NACK, DTX	$n_{\mathrm{PUCCH},0}^{(1)}$	1, 0
DTX, DTX	No transmission	

Table 10.1.3-3: Transmission of HARQ-ACK multiplexing for *M* = 3

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n^{(1)}_{\text{PUCCH}}$	$b(0), b(1)$
ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 1
ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	1, 1
ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 1
NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0
NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 0
NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0
DTX, DTX, NACK	$n^{(1)}_{\text{PUCCH},2}$	0, 1
DTX, NACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
NACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 0
DTX, DTX, DTX	No transmission	

Table 10.1.3-4: Transmission of HARQ-ACK multiplexing for *M* = 4

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0),b(1)$
ACK, ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
NACK/DTX,NACK/DTX,NACK,DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
NACK, DTX, DTX, DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, NACK/DTX, NACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 1
ACK, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
NACK/DTX, NACK, DTX, DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 0
NACK/DTX, ACK, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 0
DTX, DTX, DTX, DTX	No transmission	

Table 10.1.3-5: Transmission of HARQ-ACK multiplexing for *M* = 2

HARQ-ACK(0), HARQ-ACK(1)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0)b(1)$
ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0
ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1
NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1
NACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 0
DTX, NACK/DTX	No Transmission	

Table 10.1.3-6: Transmission of HARQ-ACK multiplexing for *M* = 3

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3-7: Transmission of HARQ-ACK multiplexing for *M* = 4

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 0
NACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX, NACK/DTX	No Transmission	

10.1.3.2 TDD HARQ-ACK procedure for more than one configured serving cell

The TDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in clause 10.1.3.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in clause 10.1.3.2.2.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 3 and TDD with more than one configured serving cell.

If a UE is configured with more than one serving cell and the TDD UL/DL configurations of all serving cells are the same, TDD UL/DL configuration 5 with PUCCH format 3 is only supported for up to two configured serving cells. If a UE is configured with two serving cells and the TDD UL/DL configuration of the two serving cells is the same, TDD UL/DL configuration 5 with PUCCH format 1b with channel selection for two configured serving cells is not supported. If a UE is configured with two serving cells and if the TDD UL/DL configuration of the two serving cells are not the same and if the DL-reference UL/DL configuration (as defined in clause 10.2) of at least one serving cell is TDD UL/DL Configuration 5, PUCCH format 1b with channel selection is not supported.

HARQ-ACK transmission on two antenna ports $(p \in [p_0, p_1])$ is supported for PUCCH format 1b with channel selection and TDD with two configured serving cells.

10.1.3.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

If a UE is configured with two serving cells with the same UL/DL configurations, then K is as defined in Sec 10.2 and M is the number of elements for subframe *n* in the set K, and $M_{primary} = M$.

If a UE is configured with two serving cells with different UL/DL configurations,

– then the UE shall determine M for a subframe *n* in this clause as $M = \max\left(M_{primary}, M_{secondary}\right)$, where

- $M_{primary}$ is the number of elements for subframe *n* in the set K defined in Table 10.1.3.1-1 for the primary cell TDD UL/DL configuration , and
- $M_{secondary}$ denotes the number of elements for subframe *n* in the set K_c for the secondary serving cell (as defined in clause 10.2)

– if $M_{secondary} < M$, then the UE shall, for the secondary serving cell, set HARQ-ACK(j) to DTX for *j* = $M_{secondary}$ to $M-1$.

– if $M_{primary} < M$, then the UE shall, for the primary cell, set HARQ-ACK(j) to DTX for *j* = $M_{primary}$ to $M-1$

If the UE is configured with two serving cells with different UL/DL configurations, then in the rest of this clause, $K = K_c$ where K_c is defined in clause 10.2.

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and two configured serving cells and a subframe *n* with $M = 1$, a UE shall determine the number of HARQ-ACK bits, O, based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that supports up to two transport blocks; and one HARQ-ACK bit otherwise.

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and two configured serving cells and a subframe *n* with $M \le 2$, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port *p* using PUCCH format 1b where

- $n_{\mathrm{PUCCH}}^{(1,\tilde{p})} = n_{\mathrm{PUCCH}}^{(1)}$ for antenna port p_0, where $n_{\mathrm{PUCCH}}^{(1)}$ selected from A PUCCH resources, $n_{\mathrm{PUCCH},j}^{(1)}$ where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Tables 10.1.3.2-1, 10.1.3.2-2, and 10.1.3.2-3 in subframe n using PUCCH format 1b.

- $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1, where $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ selected from A PUCCH resources, $n_{\text{PUCCH},j}^{(1,\tilde{p}_1)}$ configured by higher layers where $0 \le j \le A-1$ and $A \in \{2,3,4\}$, according to Tables 10.1.3.2-1, 10.1.3.2-2, and 10.1.3.2-3 by replacing $n_{\text{PUCCH}}^{(1)}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ and replacing $n_{\text{PUCCH},i}^{(1)}$ with $n_{\text{PUCCH},i}^{(1,\tilde{p}_1)}$ in subframe n, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection,

and for a subframe *n* with $M = 1$, HARQ-ACK(*j*) denotes the ACK/NACK/DTX response for a transport block or SPS release PDCCH/EPDCCH associated with serving cell, where the transport block and serving cell for HARQ-ACK(*j*) and A PUCCH resources are given by Table 10.1.2.2.1-1. For a subframe *n* with $M = 2$, HARQ-ACK(*j*) denotes the ACK/NACK/DTX response for a PDSCH transmission or SPS release PDCCH/EPDCCH within subframe(s) given by set K on each serving cell, where the subframes on each serving cell for HARQ-ACK(*j*) and A PUCCH resources are given by Table 10.1.3.2-4. The UE shall determine the A PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ associated with HARQ-ACK(*j*) where $0 \le j \le A-1$ in Table 10.1.2.2.1-1 for $M = 1$ and Table 10.1.3.2-4 for $M = 2$, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n - k_m$, where $k_m \in K$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n - k_m$, where $k_m \in K$ on the primary cell, the PUCCH resource is $n_{\text{PUCCH},j}^{(1)} = (M_{primary} - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\{0, \lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \rfloor\}$ where $N_{\text{RB}}^{\text{DL}}$ is determined from the primary cell, and for a subframe *n* with $M = 1$ and a transmission mode that supports up to two transport blocks on the serving cell where the corresponding PDSCH transmission occurs, the PUCCH resource $n_{\text{PUCCH},j+1}^{(1)}$ is given by $n_{\text{PUCCH},j+1}^{(1)} = (M_{primary} - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + 1 + N_{\text{PUCCH}}^{(1)}$ where $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding DCI assignment and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers.

- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n - k$, where $k \in K$, the value of $n_{\text{PUCCH},j}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.

- For a PDSCH transmission indicated by the detection of corresponding EPDCCH or a EPDCCH indicating downlink SPS release in sub-frame $n - k_m$ where $k_m \in K$ on the primary cell, the PUCCH resource $n_{\text{PUCCH},j}^{(1)}$ is given by

  - o if EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH,j}}^{(1)} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(e1)}$$

  - o if EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH,j}}^{(1)} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(e1)}$$

  where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n - k_m$, $N_{\text{PUCCH,q}}^{(e1)}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n - k_m$ is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n - k_m$ which is described in clause 6.8A.5 in [3]. If $m = 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m > 0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For a subframe n with $M=1$ and a transmission mode that supports up to two transport blocks on the serving cell where the corresponding PDSCH transmission occurs, the PUCCH resource $n^{(1)}_{\text{PUCCH},j+1}$ is given by

- o if EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1,\tilde{p}_1)}_{\text{PUCCH}} = n_{\text{ECCE,q}} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

- o if EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1,\tilde{p}_1)}_{\text{PUCCH}} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + 1 + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\text{e1})}_{\text{PUCCH,q}}$$

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$ on the secondary cell, the value of $n^{(1)}_{\text{PUCCH},j}$, and the value of $n^{(1)}_{\text{PUCCH},j+1}$ for a subframe n with $M=2$ or for a subframe n with $M=1$ and a transmission mode on the secondary cell that supports up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode on the secondary cell that supports up to two transport blocks and a subframe n with $M=1$, or for a subframe n with $M=2$, a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources $(n^{(1)}_{\text{PUCCH},j}, n^{(1)}_{\text{PUCCH},j+1})$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n^{(1)}_{\text{PUCCH},j}$. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in the TPC field on all PDCCH/EPDCCH assignments on the secondary cell within subframe(s) $n-k$, where $k \in K$.

Table 10.1.3.2-1: Transmission of HARQ-ACK multiplexing for *A* = 2

HARQ-ACK(0), HARQ-ACK(1)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-2: Transmission of HARQ-ACK multiplexing for *A* = 3

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-3: Transmission of HARQ-ACK multiplexing for *A* = 4

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n^{(1)}_{\text{PUCCH}}$	$b(0)b(1)$
ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},0}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},1}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 1
NACK/DTX, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 0
NACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},0}$	0, 0
DTX, NACK/DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-4: Mapping of subframes on each serving cell to HARQ-ACK(*j*) for PUCCH format 1b HARQ-ACK channel selection for TDD with $M = 2$

A	HARQ-ACK(j)			
	HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)
4	The first subframe of Primary cell	The second subframe of Primary cell	The first subframe of Secondary cell	The second subframe of Secondary cell

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and sub-frame n with $M > 2$ and two configured serving cells, denotes $n^{(1)}_{\mathrm{PUCCH},i}$ $0 \le i \le 3$ as the PUCCH resource derived from the transmissions in M DL sub-frames associated with the UL subframe n . $n^{(1)}_{\mathrm{PUCCH},0}$ and $n^{(1)}_{\mathrm{PUCCH},1}$ are associated with the PDSCH transmission(s) or a PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) on the primary cell and $n^{(1)}_{\mathrm{PUCCH},2}$ and $n^{(1)}_{\mathrm{PUCCH},3}$ are associated with the PDSCH transmission(s) on the secondary cell.

For Primary cell:

- If there is a PDSCH transmission on the primary cell without a corresponding PDCCH/EPDCCH detected within the subframe(s) $n-k$, where $k \in K$,
  - o the value of $n^{(1)}_{\mathrm{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2.
  - o for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', the PUCCH resource $n^{(1)}_{\mathrm{PUCCH},1} = (M_{primary} - m - 1)\cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE},m} + N^{(1)}_{\mathrm{PUCCH}}$ where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\mathrm{DL}}_{\mathrm{RB}} \cdot (N^{\mathrm{RB}}_{\mathrm{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, where $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ and $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers.
  - o for a PDSCH transmission on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X) or an EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1', the PUCCH resource is given by
    - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\mathrm{e}1)}_{\mathrm{PUCCH,q}}$$

    - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH},1} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\mathrm{e}1)}_{\mathrm{PUCCH,q}}$$

  where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(\mathrm{e}1)}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in clause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0.

- o HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH transmission without a corresponding PDCCH/EPDCCH. For $1 \le j \le M-1$, if a PDSCH transmission with a corresponding PDCCH/EPDCCH and DAI value in the PDCCH/EPDCCH equal to ' j ' or a PDCCH/EPDCCH indicating downlink SPS release and with DAI value in the PDCCH/EPDCCH equal to ' j ' is received, HARQ-ACK(j) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX.

- Otherwise,

  - o for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the PDCCH equal to either '1' or '2' or a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resource $n_{\mathrm{PUCCH},i}^{(1)} = \left(M_{primary} - m - 1\right)\cdot N_c + m\cdot N_{c+1} + n_{\mathrm{CCE},m} + N_{\mathrm{PUCCH}}^{(1)}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\mathrm{RB}}^{\mathrm{DL}}\cdot(N_{\mathrm{sc}}^{\mathrm{RB}}\cdot c-4)]/36 \right\rfloor\right\}$, where $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}, $i=0$ for the corresponding PDCCH with the DAI value equal to '1' and $i=1$ for the corresponding PDCCH with the DAI value equal to '2', and for the primary cell with TDD UL/DL configuration 0 $i=0$ for the corresponding PDCCH.

  - o for a PDSCH transmission on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} the DAI value in the EPDCCH equal to either '1' or '2' or an EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$ and for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}the DAI value in the EPDCCH equal to either '1' or '2', the PUCCH resource is given by

    - If EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\mathrm{PUCCH,i}}^{(1)} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

- If EPDCCH-PRB-set q is configured for localized transmission

$$n_{\mathrm{PUCCH,i}}^{(1)} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$$

where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N_{\mathrm{PUCCH,q}}^{(\mathrm{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11*, $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in clause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. Here, for TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6} $i=0$ for the corresponding EPDCCH with the DAI value equal to '1' and $i=1$ for the corresponding EPDCCH with the DAI value equal to '2', and for the primary cell with TDD UL/DL configuration 0 $i=0$ for the corresponding EPDCCH.

o For $0 \le j \le M-1$ and TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,6}, if a PDSCH transmission with a corresponding PDCCH/EPDCCH and DAI value in the PDCCH/EPDCCH equal to '$j+1$' or a PDCCH/EPDCCH indicating downlink SPS release and with DAI value in the PDCCH/EPDCCH equal to '$j+1$' is received, HARQ-ACK(j) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX. For $0 \le j \le M-1$ and the primary cell with TDD UL/DL configuration 0, if a PDSCH transmission with a corresponding PDCCH/EPDCCH or a PDCCH/EPDCCH indicating downlink SPS release is received, HARQ-ACK(0) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX.

For Secondary cell:

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH on the primary cell in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resources $n_{\mathrm{PUCCH},i}^{(1)} = (M_{primary} - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\mathrm{CCE},m} + N_{\mathrm{PUCCH}}^{(1)}$, where c is selected from {0, 1, 2, 3} such that $N_c \le n_{\mathrm{CCE,m}} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\mathrm{RB}}^{\mathrm{DL}} \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, where $N_{\mathrm{RB}}^{\mathrm{DL}}$ is determined from the primary cell, $n_{\mathrm{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$, $N_{\mathrm{PUCCH}}^{(1)}$ is configured by higher layers, $i=2$ for the corresponding PDCCH with the DAI value equal to '1' and $i=3$ for the corresponding PDCCH with the DAI value equal to '2'.

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding EPDCCH on the primary cell in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resources are given by

- o If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\mathrm{PUCCH,i}} = n_{\mathrm{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

- o If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\mathrm{PUCCH,i}} = \left\lfloor \frac{n_{\mathrm{ECCE,q}}}{N^{ECCE,q}_{RB}} \right\rfloor \cdot N^{ECCE,q}_{RB} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$$

- where $n_{\mathrm{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(\mathrm{e1})}_{\mathrm{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter *pucch-ResourceStartOffset-r11* , $N^{ECCE,q}_{RB}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in clause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. Here, $i=2$ for the corresponding EPDCCH with the DAI value equal to '1' and $i=3$ for the corresponding EPDCCH with the DAI value equal to '2'.
- for a PDSCH transmission indicated by the detection of a corresponding PDCCH/EPDCCH within the subframe(s) $n-k$, where $k \in K$ on the secondary cell, the value of $n^{(1)}_{\mathrm{PUCCH,2}}$ and $n^{(1)}_{\mathrm{PUCCH,3}}$ is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in the TPC field on all PDCCH/EPDCCH assignments on the secondary cell within subframe(s) $n-k$, where $k \in K$.
- For $0 \le j \le M-1$, if a PDSCH transmission with a corresponding PDCCH/EPDCCH and DAI value in the PDCCH/EPDCCH equal to '$j+1$' is received, HARQ-ACK(j) is the corresponding ACK/NACK/DTX response; otherwise HARQ-ACK(j) shall be set to DTX.

A UE shall perform channel selection according to the Tables 10.1.3.2-5, and 10.1.3.2-6 and transmit $b(0), b(1)$ on PUCCH resource $n^{(1,\tilde{p})}_{\mathrm{PUCCH}}$ for $\tilde{p}$ mapped to antenna port *p* using PUCCH format 1b according to clause 5.4.1 in [3] where

- $n^{(1,\tilde{p}_0)}_{\mathrm{PUCCH}} = n^{(1)}_{\mathrm{PUCCH}}$ in sub-frame n for $\tilde{p}$ mapped to antenna port p_0 where "any" in Tables 10.1.3.2-5, and 10.1.3.2-6 represents any response of ACK, NACK, or DTX. The value of $b(0), b(1)$ and the PUCCH resource $n^{(1)}_{\mathrm{PUCCH}}$ are generated by channel selection according to Tables 10.1.3.2-5, and 10.1.3.2-6 for *M* = 3, and 4 respectively.
- $n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH}}$ for antenna port p_1, where $n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH}}$ selected from PUCCH resources, $n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH},i}$ configured by higher layers where $0 \le i \le 3$ according Tables 10.1.3.2-5, and 10.1.3.2-6 for *M* = 3, and 4 respectively by

replacing $n^{(1)}_{\mathrm{PUCCH}}$ with $n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH}}$ and replacing $n^{(1)}_{\mathrm{PUCCH},i}$ with $n^{(1,\tilde{p}_1)}_{\mathrm{PUCCH},i}$, where "any" in Tables 10.1.3.2-5, and 10.1.3.2-6 represents any response of ACK, NACK, or DTX, when the UE is configured with two antenna port transmission for PUCCH format 1b with channel selection.

Table 10.1.3.2-5: Transmission of HARQ-ACK multiplexing for *M* = 3

Primary Cell	Secondary Cell	Resource	Constellation	RM Code Input Bits
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	**HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)**	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0),b(1)$	$o(0),o(1),o(2),o(3)$
ACK, ACK, ACK	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 1	1,1,1,1
ACK, ACK, NACK/DTX	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 0	1,0,1,1
ACK, NACK/DTX, any	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 1	0,1,1,1
NACK/DTX, any, any	ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 1	0,0,1,1
ACK, ACK, ACK	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 0	1,1,1,0
ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 0	1,0,1,0
ACK, NACK/DTX, any	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 1	0,1,1,0
NACK/DTX, any, any	ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 0	0,0,1,0
ACK, ACK, ACK	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 1	1, 1, 0, 1
ACK, ACK, NACK/DTX	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 1	1, 0, 0, 1
ACK, NACK/DTX, any	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	1, 0	0, 1, 0, 1
NACK/DTX, any, any	ACK, NACK/DTX, any	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 0	0, 0, 0, 1
ACK, ACK, ACK	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},1}$	1, 0	1, 1, 0, 0
ACK, ACK, NACK/DTX	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},1}$	0, 1	1, 0, 0, 0
ACK, NACK/DTX, any	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},0}$	1, 1	0, 1, 0, 0
NACK, any, any	NACK/DTX, any, any	$n^{(1)}_{\mathrm{PUCCH},0}$	0, 0	0, 0, 0, 0
DTX, any, any	NACK/DTX, any, any	No Transmission		0, 0, 0, 0

Table 10.1.3.2-6: Transmission of HARQ-ACK multiplexing for *M* = 4

Primary Cell	Secondary Cell	Resource	Constellation	RM Code Input Bits
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	**HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)**	$n^{(1)}_{\text{PUCCH}}$	$b(0), b(1)$	$o(0), o(1), o(2), o(3)$
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 1	1, 1, 1, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 0	1, 0, 1, 1
ACK, DTX, DTX, DTX	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	1, 1	0, 1, 1, 1
ACK, ACK, ACK, ACK	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	1, 1	0, 1, 1, 1
NACK/DTX, any, any, any	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	0, 1	0, 0, 1, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	0, 1	0, 0, 1, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},0}$	1, 0	1, 1, 1, 0
ACK, ACK, NACK/DTX, any	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},3}$	1, 0	1, 0, 1, 0
ACK, DTX, DTX, DTX	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},0}$	0, 1	0, 1, 1, 0
ACK, ACK, ACK, ACK	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},0}$	0, 1	0, 1, 1, 0
NACK/DTX, any, any, any	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},3}$	0, 0	0, 0, 1, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, NACK/DTX, any	$n^{(1)}_{\text{PUCCH},3}$	0, 0	0, 0, 1, 0
ACK, ACK, ACK, NACK/DTX	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 1	1, 1, 0, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 1	1, 1, 0, 1
ACK, ACK, NACK/DTX, any	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 1	1, 0, 0, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 1	1, 0, 0, 1
ACK, DTX, DTX, DTX	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0	0, 1, 0, 1
ACK, DTX, DTX, DTX	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0	0, 1, 0, 1
ACK, ACK, ACK, ACK	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0	0, 1, 0, 1
ACK, ACK, ACK, ACK	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0	0, 1, 0, 1
NACK/DTX, any, any, any	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0	0, 0, 0, 1
NACK/DTX, any, any, any	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0	0, 0, 0, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0	0, 0, 0, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	0, 0	0, 0, 0, 1
ACK, ACK, ACK, NACK/DTX	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},1}$	1, 0	1, 1, 0, 0
ACK, ACK, ACK, NACK/DTX	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},1}$	1, 0	1, 1, 0, 0
ACK, ACK, NACK/DTX, any	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},1}$	0, 1	1, 0, 0, 0

ACK, ACK, NACK/DTX, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},1}$	0, 1	1, 0, 0, 0
ACK, DTX, DTX, DTX	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	1, 1	0, 1, 0, 0
ACK, DTX, DTX, DTX	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	1, 1	0, 1, 0, 0
ACK, ACK, ACK, ACK	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	1, 1	0, 1, 0, 0
ACK, ACK, ACK, ACK	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	1, 1	0, 1, 0, 0
NACK, any, any, any	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
NACK, any, any, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	NACK/DTX, any, any, any	$n^{(1)}_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n^{(1)}_{\text{PUCCH},0}$	0, 0	0, 0, 0, 0
DTX, any, any, any	NACK/DTX, any, any, any	No Transmission		0, 0, 0, 0
DTX, any, any, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	No Transmission		0, 0, 0, 0

10.1.3.2.2 PUCCH format 3 HARQ-ACK procedure

If a UE is configured with one serving cell, or if a UE is configured with more than one serving cells and the UL/DL configuration of all serving cells is same, then K is defined in Sec 10.2, and M is the number of elements in the set K.

If a UE is configured with more than one serving cell and if at least two cells have different UL/DL configurations, then K in this clause refers to K_c (as defined in clause 10.2) , and M is the number of elements in the set K.

For TDD HARQ-ACK transmission with PUCCH format 3 and sub-frame n with $M \geq 1$ and more than one configured serving cell, where M is the number of elements in the set K, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ or $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port p where

- for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1' (defined in Table 7.3-X), or for a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the PDCCH is equal to '1', the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = (M-m-1)\cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0, where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, c is selected from {0, 1, 2, 3} such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ where $k_m \in K$. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$

- for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1' (defined in Table 7.3-X), or for a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$, and for a TDD UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} the DAI value in the EPDCCH is equal to '1', the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ given by

  - o If EPDCCH-PRB-set q is configured for distributed transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  - o If EPDCCH-PRB-set q is configured for localized transmission

$$n_{\text{PUCCH}}^{(1,\tilde{p})} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N_{\text{PUCCH,q}}^{(\text{e1})}$$

  where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N_{\text{PUCCH,q}}^{(\text{e1})}$ for EPDCCH-PRB-set q is configured by the higher layer parameter pucch-ResourceStartOffset-r11 , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in clause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n^{(1,\tilde{p}_1)}_{\text{PUCCH}} = n^{(1,\tilde{p}_0)}_{\text{PUCCH}} + 1$.

- for a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH/EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH/EPDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n^{(1,\tilde{p})}_{\text{PUCCH}}$ with the value of $n^{(1,\tilde{p})}_{\text{PUCCH}}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n^{(1,\tilde{p}_0)}_{\text{PUCCH}}$ for antenna port p_0 and the second PUCCH resource $n^{(1,\tilde{p}_1)}_{\text{PUCCH}}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n^{(1,\tilde{p}_0)}_{\text{PUCCH}}$ for antenna port p_0.

- for $M > 1$ and a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', the UE shall transmit $b(0), b(1)$ in subframe n using PUCCH format 1b on PUCCH resource $n^{(1)}_{\text{PUCCH}}$ selected from A PUCCH resources $n^{(1)}_{\text{PUCCH},i}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A = 2$ and $A = 3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A = 3$; otherwise, $A = 2$.

    - o The PUCCH resource $n^{(1)}_{\text{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\text{PUCCH},1}$ is determined as $n^{(1)}_{\text{PUCCH},1} = (M-m-1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N^{(1)}_{\text{PUCCH}}$, where $N^{(1)}_{\text{PUCCH}}$ is configured by higher layers, c is selected from {0, 1, 2, 3} such that $N_c \le n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor [N^{\text{DL}}_{\text{RB}} \cdot (N^{\text{RB}}_{\text{sc}} \cdot c - 4)]/36 \right\rfloor\right\}$, and $n_{\text{CCE,m}}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ where $k_m \in K$. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},2}$ is determined as $n^{(1)}_{\text{PUCCH},2} = n^{(1)}_{\text{PUCCH},1} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding PDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1' or for the PDCCH indicating downlink SPS release for which the value of the DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1'.

- for $M > 1$ and a PDSCH transmission only on the primary cell where there is not a corresponding EPDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1' (defined in Table 7.3-X) or a EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH equal to '1', the UE shall transmit $b(0), b(1)$ in subframe n using PUCCH format 1b on PUCCH resource $n^{(1)}_{\text{PUCCH}}$ selected from A PUCCH resources $n^{(1)}_{\text{PUCCH},i}$ where $0 \le i \le A-1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A=2$ and $A=3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A=3$; otherwise, $A=2$.

- The PUCCH resource $n^{(1)}_{\text{PUCCH},0}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n^{(1)}_{\text{PUCCH},1}$ is determined as

  - If EPDCCH-PRB-set q is configured for distributed transmission

$$n^{(1)}_{\text{PUCCH},1} = n_{\text{ECCE,q}} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + \Delta_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

  - If EPDCCH-PRB-set q is configured for localized transmission

$$n^{(1)}_{\text{PUCCH},1} = \left\lfloor \frac{n_{\text{ECCE,q}}}{N_{RB}^{ECCE,q}} \right\rfloor \cdot N_{RB}^{ECCE,q} + \sum_{i1=0}^{m-1} N_{ECCE,q,n-k_{i1}} + n' + \Delta_{ARO} + N^{(e1)}_{\text{PUCCH,q}}$$

  where $n_{\text{ECCE,q}}$ is the number of the first ECCE (i.e. lowest ECCE index used to construct the EPDCCH) used for transmission of the corresponding DCI assignment in EPDCCH-PRB-set q in subframe $n-k_m$, $N^{(e1)}_{\text{PUCCH,q}}$ for EPDCCH-PRB-set q is configured by the higher layer parameter pucch-ResourceStartOffset-r11 , $N_{RB}^{ECCE,q}$ for EPDCCH-PRB-set q in subframe $n-k_m$ is given in clause 6.8A.1 in [3], n' is determined from the antenna port used for EPDCCH transmission in subframe $n-k_m$ which is described in clause 6.8A.5 in [3]. If $m=0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.2.1-1. If $m>0$, Δ_{ARO} is determined from the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH as given in Table 10.1.3.1-2. If the UE is configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs in EPDCCH-PRB-set q configured for that UE in subframe $n-k_{i1}$. If the UE is not configured to monitor EPDCCH in subframe $n-k_{i1}$, $N_{ECCE,q,n-k_{i1}}$ is equal to the number of ECCEs computed assuming EPDCCH-PRB-set q is configured for that UE in subframe $n-k_{i1}$. For normal downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 5, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For extended downlink CP, if subframe $n-k_{i1}$ is a special subframe with special subframe configuration 0 or 4 or 7, $N_{ECCE,q,n-k_{i1}}$ is equal to 0. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n^{(1)}_{\text{PUCCH},2}$ is determined as $n^{(1)}_{\text{PUCCH},2} = n^{(1)}_{\text{PUCCH},1} + 1$.HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding EPDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1' or for the EPDCCH indicating downlink SPS release for which the value of the DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding EPDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1'.

- for $M>1$ and a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH greater than '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where

$k_m \in K$ with the DAI value in the PDCCH greater than '1', the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in a PDCCH assignment with DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments used to determine the PUCCH resource values within the subframe(s) $n-k$, where $k \in K$.

- for $M > 1$ and a PDSCH transmission only on the primary cell indicated by the detection of a corresponding EPDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH greater than '1' (defined in Table 7.3-X) or an EPDCCH indicating downlink SPS release (defined in clause 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the EPDCCH greater than '1', the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments used to determine the PUCCH resource values within the subframe(s) $n-k$, where $k \in K$.

- If the UL/DL configurations of all serving cells are the same, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For TDD UL/DL configurations 1-6, if a PDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or a PDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the TPC field in the PDCCH with the DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$. For TDD UL/DL configurations 1-6, if an EPDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or an EPDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with the DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$.

- If the UL/DL configurations of at least two serving cells are different, for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH/EPDCCH within subframe(s) $n-k$, where $k \in K$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in the corresponding PDCCH/EPDCCH shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For a UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} as defined in clause 10.2, if a PDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or a PDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the TPC field in the PDCCH with the DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$. For a UL/DL configuration of the primary cell belonging to {1,2,3,4,5,6} as defined in clause 10.2, if an EPDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n-k$, where $k \in K$, or an EPDCCH indicating downlink SPS release (defined in clause 9.2) within subframe(s) $n-k$, where $k \in K$, is detected, the HARQ-ACK resource offset field in the DCI format of the corresponding EPDCCH assignment with the DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all EPDCCH assignments in the primary cell and in each secondary cell that are used to determined the PUCCH resource value within the subframe(s) $n-k$, where $k \in K$.

- For PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ and a UE configured for two antenna port transmission, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0.

10.1.4 HARQ-ACK Repetition procedure

HARQ-ACK repetition is enabled or disabled by a UE specific parameter *ackNackRepetition* configured by higher layers. Once enabled, the UE shall repeat any HARQ-ACK transmission with a repetition factor N_{ANRep}, where N_{ANRep} is provided by higher layers and includes the initial HARQ-ACK transmission, until HARQ-ACK repetition is disabled by higher layers. For a PDSCH transmission without a corresponding PDCCH/EPDCCH detected, the UE shall transmit the corresponding HARQ-ACK response N_{ANRep} times using PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ configured by higher layers. For a PDSCH transmission with a corresponding PDCCH/EPDCCH detected, or for a PDCCH/EPDCCH indicating downlink SPS release, the UE shall first transmit the corresponding HARQ-ACK response once using PUCCH resource derived from the corresponding PDCCH CCE index or EPDCCH ECCE index (as described in clauses 10.1.2 and 10.1.3), and repeat the transmission of the corresponding HARQ-ACK response $N_{\text{ANRep}}-1$ times always using PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p})}$, where $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p})}$ is configured by higher layers.

HARQ-ACK repetition is only applicable for UEs configured with one serving cell for FDD and TDD. For TDD, HARQ-ACK repetition is only applicable for HARQ-ACK bundling.

HARQ-ACK repetition can be enabled with PUCCH format 1a/1b on two antenna ports. For a UE configured for two antenna port transmission for HARQ-ACK repetition with PUCCH format 1a/1b, a PUCCH resource value $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p})}$ maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p}_1)}$ for antenna port p_1, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p}_0)}$ for antenna port p_0.

10.1.5 Scheduling Request (SR) procedure

A UE is configured by higher layers to transmit the SR on one antenna port or two antenna ports.
The scheduling request shall be transmitted on the PUCCH resource(s) $n_{\text{PUCCH}}^{(1,\tilde{p})} = n_{\text{PUCCH,SRI}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port p as defined in [3], where $n_{\text{PUCCH,SRI}}^{(1,\tilde{p})}$ is configured by higher layers unless the SR coincides in time with the transmission of HARQ-ACK using PUCCH Format 3 in which case the SR is multiplexed with HARQ-ACK according to clause 5.2.3.1 of [4]. The SR configuration for SR transmission periodicity $SR_{\text{PERIODICITY}}$ and SR subframe offset $N_{\text{OFFSET,SR}}$ is defined in Table 10.1.5-1 by the parameter *sr-ConfigIndex* I_{SR} given by higher layers.

SR transmission instances are the uplink subframes satisfying
$\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{\text{OFFSET,SR}}\right) \bmod SR_{\text{PERIODICITY}} = 0$.

Table 10.1.5-1: UE-specific SR periodicity and subframe offset configuration

SR configuration Index I_{SR}	SR periodicity (ms) $SR_{\text{PERIODICITY}}$	SR subframe offset $N_{\text{OFFSET,SR}}$
0 – 4	5	I_{SR}
5 – 14	10	$I_{SR} - 5$
15 – 34	20	$I_{SR} - 15$
35 – 74	40	$I_{SR} - 35$
75 – 154	80	$I_{SR} - 75$
155 – 156	2	$I_{SR} - 155$
157	1	$I_{SR} - 157$

10.2 Uplink HARQ-ACK timing

For FDD, the UE shall upon detection of a PDSCH transmission in subframe *n-4* intended for the UE and for which an HARQ-ACK shall be provided, transmit the HARQ-ACK response in subframe *n*. If HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission in subframe *n-4* intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in subframes $n-N_{\text{ANRep}}-3, \ldots, n-5$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-4$) on PUCCH in subframes n, $n+1, \ldots, n+N_{\text{ANRep}}-1$;
- shall not transmit any other signal in subframes n, $n+1, \ldots, n+N_{\text{ANRep}}-1$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n-3, \ldots, n+N_{\text{ANRep}}-5$.

For TDD, if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations and if a serving cell is a primary cell, then the primary cell UL/DL configuration is the DL-reference UL/DL configuration for the serving cell.

For TDD if the UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations and if a serving cell is a secondary cell

- o if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration) belongs to Set 1 in Table 10.2-1 or
- o if the UE is not configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, and if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration) belongs to Set 2 or Set 3 in Table 10.2-1 or
- o if the UE is configured to monitor PDCCH/EPDCCH in another serving cell for scheduling the serving cell, and if the pair formed by (primary cell UL/DL configuration, serving cell UL/DL configuration) belongs to Set 4 or Set 5 in Table 10.2-1

then the DL-reference UL/DL configuration for the serving cell is defined in the corresponding Set in Table 10.2-1.

For TDD if a UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations and if the DL-reference UL/DL configuration for at least one serving cell is TDD UL/DL Configuration 5, then the UE is not expected to be configured with more than two serving cells.

For TDD, if a UE is configured with one serving cell, or the UE is configured with more than one serving cell and the UL/DL configurations of all serving cells is same, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*.

For TDD, if a UE is configured with more than one serving cell and if at least two serving cells have different UL/DL configurations, then the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$ for serving cell *c*, where $k \in K_c$ intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe *n*, wherein set K_c contains values of $k \in K$ such that subframe *n-k* corresponds to a DL subframe or a special subframe for serving cell *c*, K defined in Table 10.1.3.1-1 (where "UL/DL configuration" in Table 10.1.3.1-1 refers to the "DL-reference UL/DL configuration") is associated with subframe *n.*

For TDD, if HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in a DL subframe earlier than subframe $n-k$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-k$) on PUCCH in UL subframe n and the next $N_{\text{ANRep}}-1$ UL subframes denoted as n_1, …, $n_{N_{\text{ANRep}}-1}$;
- shall not transmit any other signal in UL subframe n, n_1, …, $n_{N_{\text{ANRep}}-1}$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes n_i-k, where $k \in K_i$, K_i is the set defined in Table 10.1.3.1-1 corresponding to UL subframe n_i, and $1 \le i \le N_{\text{ANRep}}-1$.

For TDD, HARQ-ACK bundling, if the UE detects that at least one downlink assignment has been missed as described in clause 7.3, the UE shall not transmit HARQ-ACK on PUCCH if HARQ-ACK is the only UCI present in a given subframe.

The uplink timing for the ACK corresponding to a detected PDCCH/EPDCCH indicating downlink SPS release shall be the same as the uplink timing for the HARQ-ACK corresponding to a detected PDSCH, as defined above.

Table 10.2-1: DL-reference UL/DL configuration for serving cell based on pair formed by (primary cell UL/DL configuration, secondary cell UL/DL configuration)

Set #	(Primary cell UL/DL configuration, Secondary cell UL/DL configuration)	DL-reference UL/DL configuration
Set 1	(0,0)	0
	(1,0),(1,1),(1,6)	1
	(2,0),(2,2),(2,1),(2,6)	2
	(3,0),(3,3),(3,6)	3
	(4,0),(4,1),(4,3),(4,4),(4,6)	4
	(5,0),(5,1),(5,2),(5,3),(5,4),(5,5),(5,6)	5
	(6,0),(6,6)	6
Set 2	(0,1),(6,1)	1
	(0,2),(1,2),(6,2)	2
	(0,3),(6,3)	3
	(0,4),(1,4),(3,4),(6,4)	4
	(0,5),(1,5),(2,5),(3,5),(4,5),(6,5)	5
	(0,6)	6
Set 3	(3,1),(1,3)	4
	(3,2),(4,2),(2,3),(2,4)	5
Set 4	(0,1),(0,2),(0,3),(0,4),(0,5),(0,6)	0
	(1,2),(1,4),(1,5)	1
	(2,5)	2
	(3,4),(3,5)	3
	(4,5)	4
	(6,1),(6,2),(6,3),(6,4),(6,5)	6
Set 5	(1,3)	1
	(2,3),(2,4)	2
	(3,1),(3,2)	3
	(4,2)	4

11 Physical Multicast Channel (PMCH) related procedures

11.1 UE procedure for receiving the PMCH l

The UE shall decode the PMCH when configured by higher layers. The UE may assume that an eNB transmission on the PMCH is performed according to clause 6.5 of [3].

The I_{MCS} for the PMCH is configured by higher layers. The UE shall use I_{MCS} for the PMCH and Table 7.1.7.1-1 to determine the modulation order (Q_m) and TBS index (I_{TBS}) used in the PMCH.
The UE shall then follow the procedure in clause 7.1.7.2.1 to determine the transport block size, assuming N_{PRB} is equal to $N_{\text{RB}}^{\text{DL}}$. The UE shall set the redundancy version to 0 for the PMCH.

11.2 UE procedure for receiving MCCH change notification

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the M-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 11.2-1.

Table 11.2-1: PDCCH configured by M-RNTI

DCI format	Search Space
DCI format 1C	Common

The 8-bit information for MCCH change notification [11], as signalled on the PDCCH, shall be delivered to higher layers.

12 Assumptions independent of physical channel

A UE shall not assume that two antenna ports are quasi co-located unless specified otherwise.

A UE may assume the antenna ports 0 – 3 of a serving cell are quasi co-located (as defined in [3]) with respect to delay spread, Doppler spread, Doppler shift, average gain, and average delay.

Annex A (informative): Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2006-09					Draft version created		0.0.0
2006-10					Endorsed by RAN1	0.0.0	0.1.0
2007-01					Inclusion of decisions from RAN1#46bis and RAN1#47	0.1.0	0.1.1
2007-01					Endorsed by RAN1	0.1.1	0.2.0
2007-02					Inclusion of decisions from RAN1#47bis	0.2.0	0.2.1
2007-02					Endorsed by RAN1	0.2.1	0.3.0
2007-02					Editor's version including decisions from RAN1#48 & RAN1#47bis	0.3.0	0.3.1
2007-03					Updated Editor's version	0.3.1	0.3.2
2007-03	RAN-35	RP-070171			For information at RAN#35	0.3.2	1.0.0
2007-03					Random access text modified to better reflect RAN1 scope	1.0.0	1.0.1
2007-03					Updated Editor's version	1.0.1	1.0.2
2007-03					Endorsed by RAN1	1.0.2	1.1.0
2007-05					Updated Editor's version	1.1.0	1.1.1
2007-05					Updated Editor's version	1.1.1	1.1.2
2007-05					Endorsed by RAN1	1.1.2	1.2.0
2007-08					Updated Editor's version	1.2.0	1.2.1
2007-08					Updated Editor's version – uplink power control from RAN1#49bis	1.2.1	1.2.2
2007-08					Endorsed by RAN1	1.2.2	1.3.0
2007-09					Updated Editor's version reflecting RAN#50 decisions	1.3.0	1.3.1
2007-09					Updated Editor's version reflecting comments	1.3.1	1.3.2
2007-09					Updated Editor's version reflecting further comments	1.3.2	1.3.3
2007-09					Updated Editor's version reflecting further comments	1.3.3	1.3.4
2007-09					Updated Edtior's version reflecting further comments	1.3.4	1.3.5
2007-09	RAN-37	RP-070731			Endorsed by RAN1	1.3.5	2.0.0
2007-09	RAN-37	RP-070737			For approval at RAN#37	2.0.0	2.1.0
12/09/07	RP-37	RP-070737	-	-	Approved version	2.1.0	8.0.0
28/11/07	RP-38	RP-070949	0001	2	Update of 36.213	8.0.0	8.1.0
05/03/08	RP-39	RP-080145	0002	-	Update of TS 36.213 according to changes listed in cover sheet	8.1.0	8.2.0
28/05/08	RP-40	RP-080434	0003	1	PUCCH timing and other formatting and typo corrections	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0006	1	PUCCH power control for non-unicast information	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0008	-	UE ACK/NACK Procedure	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0009	-	UL ACK/NACK timing for TDD	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0010	-	Specification of UL control channel assignment	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0011	-	Precoding Matrix for 2Tx Open-loop SM	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0012	-	Clarifications on UE selected CQI reports	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0013	1	UL HARQ Operation and Timing	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0014	-	SRS power control	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0015	1	Correction of UE PUSCH frequency hopping procedure	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0017	4	Blind PDCCH decoding	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0019	1	Tx Mode vs DCI format is clarified	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0020	-	Resource allocation for distributed VRB	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0021	2	Power Headroom	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0022	-	Clarification for RI reporting in PUCCH and PUSCH reporting modes	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0025	-	Correction of the description of PUSCH power control for TDD	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0026	-	UL ACK/NACK procedure for TDD	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0027	-	Indication of radio problem detection	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0028	-	Definition of Relative Narrowband TX Power Indicator	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0029	-	Calculation of $\Delta_{TF}(i)$ for UL-PC	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0030	-	CQI reference and set S definition, CQI mode removal, and Miscellanious	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0031	-	Modulation order and TBS determination for PDSCH and PUSCH	8.2.0	8.3.0
28/05/08	RP-40	RP-080434	0032	-	On Sounding RS	8.2.0	8.3.0
28/05/08	RP-40	RP-080426	0033	-	Multiplexing of rank and CQI/PMI reports on PUCCH	8.2.0	8.3.0
28/05/08	RP-40	RP-080466	0034	-	Timing advance command responding time	8.2.0	8.3.0
09/09/08	RP-41	RP-080670	37	2	SRS hopping pattern for closed loop antenna selection	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	39	2	Clarification on uplink power control	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	41	-	Clarification on DCI formats using resource allocation type 2	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	43	2	Clarification on tree structure of CCE aggregations	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	46	2	Correction of the description of PUCCH power control for TDD	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	47	1	Removal of CR0009	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	48	1	Correction of mapping of cyclic shift value to PHICH modifier	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	49	-	TBS disabling for DCI formats 2 and 2A	8.3.0	8.4.0

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
09/09/08	RP-41	RP-080670	50	-	Correction of maximum TBS sizes	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	51	-	Completion of the table specifying the number of bits for the periodic feedback	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	54	-	Clarification of RNTI for PUSCH/PUCCH power control with DCI formats 3/3A	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	55	1	Clarification on mapping of Differential CQI fields	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	59	1	PUSCH Power Control	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	60	-	RB restriction and modulation order for CQI-only transmission on PUSCH	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	61	-	Modulation order determination for uplink retransmissions	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	62	2	Introducing missing L1 parameters into 36.213	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	63	2	Correcting the range and representation of delta_TF_PUCCH	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	64	1	Adjusting TBS sizes to for VoIP	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	67	-	Correction to the downlink resource allocation	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	68	-	Removal of special handling for PUSCH mapping in PUCCH region	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	69	-	Correction to the formulas for uplink power control	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	70	1	Definition of Bit Mapping for DCI Signalling	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	71	-	Clarification on PUSCH TPC commands	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	72	1	Reference for CQI/PMI Reporting Offset	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	74	-	Correction to the downlink/uplink timing	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	75	-	Correction to the time alignment command	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	77	1	Correction of offset signalling of UL Control information MCS	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	78	2	DCI format1C	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	80	-	Correction to Precoder Cycling for Open-loop Spatial Multiplexing	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	81	1	Clarifying Periodic CQI Reporting using PUCCH	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	84	1	CQI reference measurement period	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	86	-	Correction on downlink multi-user MIMO	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	87	-	PUCCH Reporting	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	88	1	Handling of Uplink Grant in Random Access Response	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	89	-	Correction to UL Hopping operation	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	90	-	DRS EPRE	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	92	-	Uplink ACK/NACK mapping for TDD	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	93	-	UL SRI Parameters Configuration	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	94	-	Miscellaneous updates for 36.213	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	95	-	Clarifying Requirement for Max PDSCH Coding Rate	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	96	-	UE Specific SRS Configuration	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	97	-	DCI Format 1A changes needed for scheduling Broadcast Control	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	98	-	Processing of TPC bits in the random access response	8.3.0	8.4.0
09/09/08	RP-41	RP-080670	100	1	Support of multi-bit ACK/NAK transmission in TDD	8.3.0	8.4.0
03/12/08	RP-42	RP-081075	82	3	Corrections to RI for CQI reporting	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	83	2	Moving description of large delay CDD to 36.211	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	102	3	Reception of DCI formats	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	105	8	Alignment of RAN1/RAN2 specification	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	107	1	General correction of reset of power control and random access response message	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	108	2	Final details on codebook subset restrictions	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	109	-	Correction on the definition of Pmax	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	112	2	CQI/PMI reference measurement periods	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	113	-	Correction of introduction of shortened SR	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	114	-	RAN1/2 specification alignment on HARQ operation	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	115	-	Introducing other missing L1 parameters in 36.213	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	116	-	PDCCH blind decoding	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	117	-	PDCCH search space	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	119	-	Delta_TF for PUSCH	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	120	-	Delta_preamble_msg3 parameter values and TPC command in RA response	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	122	1	Correction of offset signaling of uplink control information MCS	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	124	-	Miscellaneous Corrections	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	125	-	Clarification of the uplink index in TDD mode	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	126	-	Clarification of the uplink transmission configurations	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	127	2	Correction to the PHICH index assignment	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	128	-	Clarification of type-2 PDSCH resource allocation for format 1C	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	129	-	Clarification of uplink grant in random access response	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	130	-	UE sounding procedure	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	134	-	Change for determining DCI format 1A TBS table column indicator for broadcast control	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	135	-	Clarifying UL VRB Allocation	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	136	1	Correction for Aperiodic CQI	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	137	1	Correction for Aperiodic CQI Reporting	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	138	1	Correction to PUCCH CQI reporting mode for N^DL_RB <= 7	8.4.0	8.5.0

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03/12/08	RP-42	RP-081075	140	1	On sounding procedure in TDD	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	141	1	Alignment of RAN1/RAN3 specification	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	143	1	TTI bundling	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	144	1	ACK/NACK transmission on PUSCH for LTE TDD	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	145	1	Timing relationship between PHICH and its associated PUSCH	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	147	1	Definition of parameter for downlink reference signal transmit power	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	148	1	Radio link monitoring	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	149	1	Correction in 36.213 related to TDD downlink HARQ processes	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	151	-	Nominal PDSCH-to-RS EPRE Offset for CQI Reporting	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	152	1	Support of UL ACK/NAK repetition in Rel-8	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	155	-	Clarification of misconfiguration of aperiodic CQI and SR	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	156	1	Correction of control information multiplexing in subframe bundling mode	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	157	-	Correction to the PHICH index assignment	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	158	1	UE transmit antenna selection	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	159	-	Clarification of spatial different CQI for CQI reporting Mode 2-1	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	160	1	Corrections for TDD ACK/NACK bundling and multiplexing	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	161	-	Correction to RI for Open-Loop Spatial Multiplexing	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	162	-	Correction of differential CQI	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	163	-	Inconsistency between PMI definition and codebook index	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	164	-	PDCCH validation for semi-persistent scheduling	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	165	1	Correction to the UE behavior of PUCCH CQI piggybacked on PUSCH	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	166	-	Correction on SRS procedure when shortened PUCCH format is used	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	167	1	Transmission overlapping of physical channels/signals with PDSCH for transmission mode 7	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	169	-	Clarification of SRS and SR transmission	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	171	-	Clarification on UE behavior when skipping decoding	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	172	1	PUSCH Hopping operation corrections	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	173	-	Clarification on message 3 transmission timing	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	174	-	MCS handling for DwPTS	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	175	-	Clarification of UE-specific time domain position for SR transmission	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	176	1	Physical layer parameters for CQI reporting	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	177	-	A-periodic CQI clarification for TDD UL/DL configuration 0	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	179	1	Correction to the definitions of rho_A and rho_B (downlink power allocation)	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	180	-	Clarification of uplink A/N resource indication	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	181	-	PDCCH format 0 for message 3 adaptive retransmission and transmission of control information in message 3 during contention based random access procedure	8.4.0	8.5.0
03/12/08	RP-42	RP-081075	182	-	To Fix the Discrepancy of Uplink Power Control and Channel Coding of Control Information in PUSCH	8.4.0	8.5.0
03/12/08	RP-42	RP-081122	183	1	CQI reporting for antenna port 5	8.4.0	8.5.0
03/12/08	RP-42	RP-081110	168	1	Clarification on path loss definition	8.4.0	8.5.0
04/03/09	RP-43	RP-090236	184	1	Corrections to Transmitted Rank Indication	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	185	4	Corrections to transmission modes	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	186	2	Delta_TF configuration for control only PUSCH	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	187	1	Correction to concurrent SRS and ACK/NACK transmission	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	191	1	PDCCH release for semi-persistent scheduling	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	192	1	Correction on ACKNACK transmission on PUSCH for LTE TDD	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	193	-	Correction to subband differential CQI value to offset level mapping for aperiodic CQI reporting	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	194	-	Correction for DRS Collision handling	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	196	2	Alignment of RAN1/RAN4 specification on UE maximum output power	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	197	-	Transmission scheme for transmission mode 7 with SPS C-RNTI	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	198	-	Clarifying bandwidth parts for periodic CQI reporting and CQI refererence period	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	199	2	Correction to the ACK/NACK bundling in case of transmission mode 3 and 4	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	200	-	ACK/NAK repetition for TDD ACK/NAK multiplexing	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	201	-	Clarifying UL ACK/NAK transmission in TDD	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	202	-	Corrections to UE Transmit Antenna Selection	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	203	-	Correction to UE PUSCH hopping procedure	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	204	-	Correction to PHICH resource association in TTI bundling	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	205	-	Clarification of the length of resource assignment	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	206	-	Correction on ACK/NACK transmission for downlink SPS resource	8.5.0	8.6.0

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04/03/09	RP-43	RP-090236	207	-	Introduction of additional values of wideband CQI/PMI periodicities	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	208	2	Correction to CQI/PMI/RI reporting field	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	209	2	Correction to rho_A definition for CQI calculation	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	210	-	Correction to erroneous cases in PUSCH linear block codes	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	211	1	Removing RL monitoring start and stop	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	214	1	Correction to type-1 and type-2 PUSCH hopping	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	215	-	Contradicting statements on determination of CQI subband size	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	216	-	Corrections to SRS	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	219	2	Miscellaneous corrections on TDD ACKNACK	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	221	1	CR for Redundancy Version mapping function for DCI 1C	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	223	-	Scrambling of PUSCH corresponding to Random Access Response Grant	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	225	-	Removal of SRS with message 3	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	226	3	PRACH retransmission timing	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	227	-	Clarifying error handling of PDSCH and PUSCH assignments	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	228	-	Clarify PHICH index mapping	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	229	-	Correction of CQI timing	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	230	-	Alignment of CQI parameter names with RRC	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	231	1	Removal of 'Off' values for periodic reporting in L1	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	232	-	Default value of RI	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	233	1	Clarification of uplink timing adjustments	8.5.0	8.6.0
04/03/09	RP-43	RP-090236	234	-	Clarification on ACK/NAK repetition	8.5.0	8.6.0
27/05/09	RP-44	RP-090529	235	1	Correction to the condition of resetting accumulated uplink power correction	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	236	-	Correction to the random access channel parameters received from higher layer	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	237	-	Correction on TDD ACKNACK	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	238	1	Correction on CQI reporting	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	239	-	Correction on the HARQ process number	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	241	1	CR correction of the description on TTI-bundling	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	242	1	Clarify latest and initial PDCCH for PDSCH and PUSCH transmisisons, and NDI for SPS activation	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	243	-	Clarify DRS EPRE	8.6.0	8.7.0
27/05/09	RP-44	RP-090529	244	1	Clarification on TPC commands for SPS	8.6.0	8.7.0
15/09/09	RP-45	RP-090888	245	1	Correction to PUSCH hopping and PHICH mapping procedures	8.7.0	8.8.0
15/09/09	RP-45	RP-090888	246	-	Clarification on subband indexing in periodic CQI reporting	8.7.0	8.8.0
15/09/09	RP-45	RP-090888	247	2	Correction to DVRB operation in TDD transmission mode 7	8.7.0	8.8.0
15/09/09	RP-45	RP-090888	249	-	Clarification of concurrent ACKNACK and periodic PMI/RI transmission on PUCCH for TDD	8.7.0	8.8.0
15/09/09	RP-45	RP-090888	250	-	Clarify Inter-cell synchronization text	8.7.0	8.8.0
01/12/09	RP-46	RP-091172	248	1	Introduction of LTE positioning	8.8.0	9.0.0
01/12/09	RP-46	RP-091172	254	-	Clarification of PDSCH and PRS in combination for LTE positioning	8.8.0	9.0.0
01/12/09	RP-46	RP-091177	255	5	Editorial corrections to 36.213	8.8.0	9.0.0
01/12/09	RP-46	RP-091257	256	1	Introduction of enhanced dual layer transmission	8.8.0	9.0.0
01/12/09	RP-46	RP-091177	257	1	Add shorter SR periodicity	8.8.0	9.0.0
01/12/09	RP-46	RP-091256	258	-	Introduction of LTE MBMS	8.8.0	9.0.0
17/12/09	RP-46	RP-091257	256	1	Correction by MCC due to wrong implementation of CR0256r1 – Sentence is added to Single-antenna port scheme clause 7.1.1	9.0.0	9.0.1
16/03/10	RP-47	RP-100211	259	3	UE behavior when collision of antenna port 7/8 with PBCH or SCH happened and when distributed VRB is used with antenna port 7	9.0.1	9.1.0
16/03/10	RP-47	RP-100210	260	1	MCCH change notification using DCI format 1C	9.0.1	9.1.0
16/03/10	RP-47	RP-100211	263	-	Correction on PDSCH EPRE and UE-specific RS EPRE for Rel-9 enhanced DL transmissions	9.0.1	9.1.0
01/06/10	RP-48	RP-100589	265	-	Clarification for TDD when multiplexing ACK/NACK with SR of ACK/NACK with CQI/PMI or RI	9.1.0	9.2.0
01/06/10	RP-48	RP-100590	268	1	Clarification of PRS EPRE	9.1.0	9.2.0
14/09/10	RP-49	RP-100900	269	-	Clarification on Extended CP support with Transmission Mode 8	9.2.0	9.3.0
07/12/10	RP-50	RP-101320	270	-	Introduction of Rel-10 LTE-Advanced features in 36.213	9.3.0	10.0.0
27/12/10	-	-	-	-	Editorial change to correct a copy/past error in clause 7.2.2	10.0.0	10.0.1
15/03/11	RP-51	RP-110255	271	1	A clarification for redundancy version of PMCH	10.0.1	10.1.0
15/03/11	RP-51	RP-110258	272	-	RLM Procedure with restricted measurements	10.0.1	10.1.0
15/03/11	RP-51	RP-110256	273	-	Corrections to Rel-10 LTE-Advanced features in 36.213	10.0.1	10.1.0
01/06/11	RP-52	RP-110819	274	3	Correction to HARQ-ACK procedure for TDD mode b with M=2	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	275	3	Determination of PUSCH A/N codebook size for TDD	10.1.0	10.2.0
01/06/11	RP-52	RP-110823	276	-	The triggering of aperiodic SRS in DCI formats 2B and 2C	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	278	3	Corrections to power headroom	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	279	1	Removal of square brackets for PUCCH format 3 ACK/NACK	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	281	1	Correction of AN repetition and PUCCH format 3	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	282	2	Correction to timing for secondary cell activation and deactivation	10.1.0	10.2.0

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01/06/11	RP-52	RP-110823	283	1	Correction to MCS offset for multiple TBs	10.1.0	10.2.0
01/06/11	RP-52	RP-110820	286	1	Miscellaneous Corrections	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	288	1	Corrections on UE procedure for determining PUCCH Assignment	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	289	2	Correction to Multi-cluster flag in DCI format 0	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	290	2	Joint transmission of ACK/NACK and SR with PUCCH format 3	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	291	3	Correction of uplink resource allocation type 1	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	292	1	Correction on CSI-RS configuration	10.1.0	10.2.0
01/06/11	RP-52	RP-110818	294	-	ACK/NACK and CQI simultaneous transmission in ACK/NACK bundling in TDD	10.1.0	10.2.0
01/06/11	RP-52	RP-110823	295	-	UE specific disabling of UL DMRS sequence hopping	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	296	-	PDSCH transmission in MBSFN subframes	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	297	-	Introduction of PCMAX for PUSCH power scaling	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	298	-	Power control for SR and ACK/NACK with PUCCH format 3	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	299	2	CR on power control for HARQ-ACK transmission on PUCCH	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	300	2	Correction to handling of search space overlap	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	301	1	Correction to simultaneous transmission of SRS and PUCCH format 2/2a/2b	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	302	1	Correction for Simultaneous PUCCH and SRS Transmissions on CA	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	303	-	Correction on 8Tx Codebook Sub-sampling for PUCCH Mode 1-1	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	304	1	Corrections on CQI type in PUCCH mode 2-1 and clarification on simultaneous PUCCH and PUSCH transmission for UL-SCH subframe bundling	10.1.0	10.2.0
01/06/11	RP-52	RP-110818	305	1	Correction on UE behaviour upon reporting periodic CSI using PUCCH Mode1-1	10.1.0	10.2.0
01/06/11	RP-52	RP-110818	306	-	Clarification for the definition of CQI	10.1.0	10.2.0
01/06/11	RP-52	RP-110818	307	-	Clarification for the definition of Precoding Matrix Indicator	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	308	-	Simultaneous SRS transmissions in more than one cell	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	310	1	Miscellaneous Corrections for TS 36.213	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	311	1	Configuration of pmi-RI-Report	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	312	1	Correction on the support of PUCCH format 3 and channel selection	10.1.0	10.2.0
01/06/11	RP-52	RP-110821	313	-	Correction on UE behaviour during DM-RS transmission on subframes carrying synchronization signals	10.1.0	10.2.0
01/06/11	RP-52	RP-110820	314	1	36.213 CR on antenna selection	10.1.0	10.2.0
01/06/11	RP-52	RP-110823	316	1	Number of HARQ process for UL spatial multiplexing	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	317	-	PUCCH format 3 Fallback procedure in TDD	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	318	-	Clarification on CSI reporting under an invalid downlink subframe	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	320	-	Multiple Aperiodic SRS Triggers for Same Configuration	10.1.0	10.2.0
01/06/11	RP-52	RP-110823	321	-	UE antenna switch in UL MIMO	10.1.0	10.2.0
01/06/11	RP-52	RP-110819	322	-	UE behaviour for PDSCH reception with limited soft buffer in CA	10.1.0	10.2.0
01/06/11	RP-52	RP-110859	323	-	Joint transmission of ACK/NACK and SR or CSI with PUCCH format 3 and channel selection	10.1.0	10.2.0
15/09/11	RP-53	RP-111229	277	1	Correction to reception of PRS in MBSFN subframes	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	325	3	Corrections on UE procedure for reporting HARQ-ACK	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	326	2	Corrections on Physical Uplink Control Channel Procedure	10.2.0	10.3.0
15/09/11	RP-53	RP-111231	331	1	Correction to uplink transmission scheme usage for random access response and PHICH-triggered retransmissions	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	336	-	Corrections on transmission mode 9	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	339	-	Corrections on HARQ-ACK codebook size determination	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	340	-	Corrections on TDD PUCCH format 1b with channel selection and HARQ-ACK transmission on PUSCH	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	341	-	Corrections on NACK generation	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	342	-	Corrections on power headroom reporting	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	346	-	Correction on TBS translation table	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	347	2	Correction to the condition of enabling PMI feedback	10.2.0	10.3.0
15/09/11	RP-53	RP-111232	348	-	Miscellaneous corrections to 36.213	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	349	-	Corrections on PUSCH and PUCCH modes	10.2.0	10.3.0
15/09/11	RP-53	RP-111231	350	1	CR on UL HARQ ACK determination	10.2.0	10.3.0
15/09/11	RP-53	RP-111231	351	1	Correction on UL DMRS resources for PHICH-triggered retransmission	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	352	-	Clarification on the common search space description	10.2.0	10.3.0
15/09/11	RP-53	RP-111232	353	1	Clarification on ambiguous DCI information between UE-specific search space and common search space for DCI formats 0 and 1A	10.2.0	10.3.0
15/09/11	RP-53	RP-111229	354	-	Clarification of Reference PDSCH Power for CSI-RS based CSI Feedback	10.2.0	10.3.0
15/09/11	RP-53	RP-111230	355	2	Corrections on reporting Channel State Information	10.2.0	10.3.0
05/12/11	RP-54	RP-111669	324	3	Accumulation of power control commands from DCI format 3/3A	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	357	1	Miscellaneous corrections on uplink power control	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	358	-	Corrections on N_c^{received}	10.3.0	10.4.0

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
05/12/11	RP-54	RP-111666	359	-	Corrections on TDD PUCCH format 1b with channel selection and two configured serving cells	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	360	-	Corrections on the notation of k and k_m	10.3.0	10.4.0
05/12/11	RP-54	RP-111668	361	1	Corrections on PUCCH mode 2-1	10.3.0	10.4.0
05/12/11	RP-54	RP-111668	362	3	A correction to PDSCH transmission assumption for CQI calculation	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	363	1	Corrections on PUCCH Resource Notation	10.3.0	10.4.0
05/12/11	RP-54	RP-111667	364	-	Correction on the notation of SRS transmission comb	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	365	-	Clarification on the HARQ-ACK procedure of TDD UL-DL configuration 5	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	366	2	Clarification on the determination of resource for PUCCH Format 1b with channel selection in TDD mode	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	367	1	Correction on HARQ-ACK procedure	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	368	-	Correction for A/N on PUSCH with W=1,2 in case of TDD channel selection	10.3.0	10.4.0
05/12/11	RP-54	RP-111668	369	-	Clarification of PUCCH 2-1 Operation	10.3.0	10.4.0
05/12/11	RP-54	RP-111668	370	1	Correction on PMI index	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	371	2	Correction to periodic CSI reports for carrier aggregation	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	373	1	Removal of square bracket in HARQ-ACK procedure	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	374	1	Clarification on UE's capability of supporting PUCCH format 3	10.3.0	10.4.0
05/12/11	RP-54	RP-111666	375	1	Clarifications of UE behavior on PUSCH power control	10.3.0	10.4.0
28/02/12	RP-55	RP-120286	376	1	RNTI Configuration associated with DL Resource Allocation Type 2	10.4.0	10.5.0
28/02/12	RP-55	RP-120283	377	2	Correction for ACK/NACK related procedure in case of TDD UL-DL configuration 0	10.4.0	10.5.0
13/06/12	RP-56	RP-120737	378	3	Correction of FDD channel selection HARQ-ACK and SR transmission	10.5.0	10.6.0
13/06/12	RP-56	RP-120738	379	-	Removal of description with square brackets	10.5.0	10.6.0
13/06/12	RP-56	RP-120738	381	-	Correction on transmission mode 9 with a single antenna port transmission	10.5.0	10.6.0
04/09/12	RP-57	RP-121265	382	-	Clarification of codebook subsampling for PUCCH 2-1	10.6.0	10.7.0
04/09/12	RP-57	RP-121266	383	-	Correction to UE transmit antenna selection	10.6.0	10.7.0
04/09/12	RP-57	RP-121264	384	-	TDD HARQ-ACK procedure for PUCCH format 1b with channel selection in carrier aggregation	10.6.0	10.7.0
04/09/12	RP-57	RP-121265	385	-	Corrections for Handling CSI-RS patterns	10.6.0	10.7.0
04/09/12	RP-57	RP-121264	386	1	Reference serving cell for pathloss estimation	10.6.0	10.7.0
04/09/12	RP-57	RP-121264	387	-	Power control for PUCCH format 3 with single configured cell	10.6.0	10.7.0
04/09/12	RP-57	RP-121264	388	-	ACK/NACK resource in case of channel selection	10.6.0	10.7.0
04/09/12	RP-57	RP-121274	380	4	Introduction of an additional special subframe configuration	10.7.0	11.0.0
04/09/12	RP-57	RP-121272	389	-	Introduction of Rel-11 features	10.7.0	11.0.0
04/12/12	RP-58	RP-121839	393	-	Correction to the parameter ue-Category-v10xy	11.0.0	11.1.0
04/12/12	RP-58	RP-121837	395	-	Correction of reference signal scrambling sequence initialization for SPS in transmission mode 7	11.0.0	11.1.0
04/12/12	RP-58	RP-121846	396	-	Finalisation for introducing Rel-11 features	11.0.0	11.1.0
26/02/13	RP-59	RP-130254	398	-	Correction on UE procedure for reporting HARQ-ACK	11.1.0	11.2.0
26/02/13	RP-59	RP-130252	400	-	Corrections for SRS power scaling in UpPTS	11.1.0	11.2.0
26/02/13	RP-59	RP-130252	403	-	CR on UE specific search and Common search space overlap on PDCCH	11.1.0	11.2.0
26/02/13	RP-59	RP-130358	404	-	Additional clarifications/corrections for introducing Rel-11 features	11.1.0	11.2.0
11/06/13	RP-60	RP-130752	405	-	Correction to EPDCCH monitoring in case of cross-carrier scheduling	11.2.0	11.3.0
11/06/13	RP-60	RP-130751	407	1	Correction on the RI bit width	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	408	-	Correction on parallel reception of PDSCH and Msg 2	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	409	-	Correction on zero power CSI-RS resource configuration	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	410	1	Corrections on different TDD UL-DL configurations on different bands	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	411	-	Correction on EPDCCH PRB pair indication	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	412	-	Correction on EPDCCH hashing function	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	413	-	Correction on PUCCH resource determination for FDD EPDCCH	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	414	2	CR on ambiguity in EPDCCH decoding candidates under two overlapped EPDCCH resource sets	11.2.0	11.3.0
11/06/13	RP-60	RP-130749	415	-	Removal of the case for spatial domain bundling in TDD UL/DL configuration 0	11.2.0	11.3.0
11/06/13	RP-60	RP-130752	416	-	Corrections to EPDCCH PRB pair indication	11.2.0	11.3.0
11/06/13	RP-60	RP-130753	417	1	Correction to PUSCH/PUCCH transmit power after PRACH power ramping	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	418	-	CR on RI-Reference CSI Process with Subframe Sets	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	420	-	Correction on UE-specific RS scrambling for SPS PDSCH in TM10	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	421	-	CR on resolving ambiguous UE capability signaling for CoMP	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	422	-	Correction of valid downlink subframe	11.2.0	11.3.0
11/06/13	RP-60	RP-130749	424	-	Correction on HARQ-ACK transmission for a UE configured with	11.2.0	11.3.0

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					PUCCH format 3		
11/06/13	RP-60	RP-130750	425	-	Correction of PHICH resource for half duplex TDD UE	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	426	-	Correction on n_{HARQ} for TDD CA with different UL-DL configurations	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	427	-	Correction on implicit HARQ-ACK resource determination for PUCCH format 1b with channel selection for TDD CA with different UL-DL configurations	11.2.0	11.3.0
11/06/13	RP-60	RP-130750	428	-	Correction on SRS power scaling with multiple TAGs	11.2.0	11.3.0
11/06/13	RP-60	RP-130747	429	-	Correction on MBSFN subframe configuration	11.2.0	11.3.0
11/06/13	RP-60	RP-130749	430	-	CR on SCell activation timing	11.2.0	11.3.0
03/09/13					MCC clean-up	11.3.0	11.4.0
03/09/13	RP-61	RP-131249	432	-	Correction for EPDCCH Search Space	11.3.0	11.4.0
03/09/13	RP-61	RP-131250	433	-	Correction to QCL behaviour on CRS	11.3.0	11.4.0
03/09/13	RP-61	RP-131250	434	-	Correction on PUCCH power control	11.3.0	11.4.0
03/09/13	RP-61	RP-131248	435	-	Correction on the ratio of PDSCH EPRE to CRS EPRE for TM10	11.3.0	11.4.0
03/09/13	RP-61	RP-131249	436	-	CR on EPDCCH Search Space for Cross-Carrier Scheduling	11.3.0	11.4.0
03/09/13	RP-61	RP-131249	437	-	Correction to the UE behaviour in case of collision between PRS and EPDCCH in different CP case	11.3.0	11.4.0
03/09/13	RP-61	RP-131249	438	-	On correction to higher layer parameter name for EPDCCH resource mapping	11.3.0	11.4.0
03/09/13	RP-61	RP-131248	439	-	Correction to PDSCH mapping for CoMP	11.3.0	11.4.0

History

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