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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 TS36.321, 'Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification'

3 Definitions, symbols, and abbreviations

3.1 Symbols

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

$N_{\mathrm{RB}}^{\mathrm{DL}}$ 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 following abbreviations apply.

ACK	Acknowledgement
BCH	Broadcast Channel
CCE	Control Channel Element
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
DAI	Downlink Assignment Index
DL	Downlink
DTX	Discontinuous Transmission
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
PRACH	Physical Random Access Channel
PRB	Physical Resource Block
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QoS	Quality of Service
RBG	Resource Block Group
RE	Resource Element
RPF	Repetition Factor
RS	Reference Signal
SIR	Signal-to-Interference Ratio
SINR	Signal to Interference plus Noise Ratio
SRS	Sounding Reference Symbol
TA	Time alignment
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel
VRB	Virtual Resource Block

4 Synchronisation 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.

4.2 Timing synchronisation

4.2.1 Radio link monitoring

The downlink radio link quality of the serving cell shall be monitored by the UE for the purpose of indicating radio problem detection status to higher layers. The radio problem detection may be based on cell-specific reference signals.

In non-DRX mode operations, the physical layer in the UE shall every radio frame check the quality, measured over the previous [200ms] period, against thresholds (Qout and Qin) defined implicitly by relevant tests in [6].

The UE shall indicate radio problem detection to higher layers when the quality is worse than the threshold Qout and continue until the quality is better than the threshold Qin.

The start and stop of the radio problem detection monitoring are triggered by higher layers.

4.2.2 Inter-cell synchronisation

[For example, for cell sites with a multicast physical channel]

4.2.3 Transmission timing adjustments

Upon reception of a timing advance command, the UE shall adjust its uplink transmission timing. The timing advance command is expressed in multiples of $16\,T_s$ and is relative to the current uplink timing.

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

In other cases, 6-bit timing advance command [8], T_A, 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 by a given amount respectively.

For a timing advance command received on subframe *n*, the corresponding adjustment of the timing shall apply from the beginning of subframe *n+6.* When the UE"s uplink transmissions in subframe *n* and subframe *n*+1 are overlapped due to the timing adjustment, the UE shall transmit complete subframe *n* and not transmit the overlapped part of subframe *n*+1.

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 DFT-SOFDM 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.

A cell wide overload indicator (OI) is exchanged over X2 for inter-cell power control. An indication X also exchanged over X2 indicates PRBs that an eNodeB scheduler allocates to cell edge UEs and that will be most sensitive to inter-cell interference.

[Note: Above lines regarding OI, X and X2 to be moved to an appropriate RAN3 spec when it becomes available]

5.1.1 Physical uplink shared channel

5.1.1.1 UE behaviour

The setting of the UE Transmit power P_{PUSCH} for the physical uplink shared channel (PUSCH) transmission in subframe *i* is defined by

$$P_{\text{PUSCH}}(i) = \min\{P_{\text{MAX}}, 10\log_{10}(M_{\text{PUSCH}}(i)) + P_{\text{O\_PUSCH}}(j) + \alpha(j)\cdot PL + \Delta_{\text{TF}}(i) + f(i)\} \text{ [dBm]}$$

where,

- P_{MAX} is the maximum allowed power that depends on the UE power class
- $M_{\text{PUSCH}}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for subframe *i*.
- $P_{\text{O\_PUSCH}}(j)$ is a parameter composed of the sum of a 8-bit cell specific nominal component $P_{\text{O\_NOMINAL\_PUSCH}}(j)$ signalled from higher layers for *j=0* and *1* in the range of [-126,24] dBm with 1dB resolution and a 4-bit UE specific component $P_{\text{O\_UE\_PUSCH}}(j)$ configured by RRC for *j=0* and *1* in the range of [-8, 7] dB with 1dB resolution. For PUSCH (re)transmissions corresponding to a configured scheduling grant then *j=0* and for PUSCH (re)transmissions corresponding to a received PDCCH with DCI format 0 associated with a new packet transmission then *j=1*. For PUSCH (re)transmissions corresponding to the random access response grant then *j=2*. $P_{\text{O\_UE\_PUSCH}}(2) = 0$ and

  $P_{\text{O\_NOMINAL\_PUSCH}}(2) = P_{\text{O\_PRE}} + \Delta_{PREAMBLE\_Msg3}$, where $P_{\text{O\_PRE}}$ and $\Delta_{PREAMBLE\_Msg3}$ are signalled from higher layers.
- For *j* =0 or *1*, $\alpha \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$ is a 3-bit cell specific parameter provided by higher layers. For j=2, $\alpha(j) = 1.$
- *PL* is the downlink pathloss estimate calculated in the UE
- $\Delta_{\text{TF}}(i) = 10\log_{10}(2^{MPR(i)\cdot K_S} - 1)$ for $K_S = 1.25$ and 0 for $K_S = 0$ where K_S is a cell specific parameter given by RRC
  - $MPR(i) = TBS(i)/N_{RE}(i)$ where $TBS(i)$ is the Transport Block Size for subframe *i* and $N_{\text{RE}}(i)$ is the number of resource elements determined as $N_{RE}(i) = M_{\text{PUSCH}}(i)\cdot N_{\text{sc}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUSCH}}$ for subframe *i*, where $N_{\text{symb}}^{\text{PUSCH}}$ is defined in [4].
- δ_{PUSCH} is a UE specific correction value, also referred to as a TPC command and is included in PDCCH with DCI format 0 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 is given by $f(i)$ which is defined by:
  - $f(i) = f(i-1) + \delta_{PUSCH}(i - K_{PUSCH})$ if accumulation is enabled based on the UE-specific parameter *Accumulation-enabled* provided by higher layers
    - where $f(0) = 0$ and $\delta_{\text{PUSCH}}(i - K_{PUSCH})$ was signalled on PDCCH with DCI format 0 or 3/3A on subframe $i - K_{PUSCH}$
    - The value of K_{PUSCH} is
      - For FDD, $K_{PUSCH} = 4$
      - 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 of DCI format 0 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.
    - The UE attempts to decode a PDCCH of DCI format 0 with the UE"s C-RNTI and a PDCCH of DCI format 3/3A with ths UE"s TPC-PUSCH-RNTI in every subframe except when in DRX
  - If DCI format 0 and DCI format 3/3A are both detected in the same subframe, then the UE shall use the δ_{PUSCH} provided in DCI format 0.
  - $\delta_{\mathrm{PUSCH}} = 0$ dB for a subframe where no TPC command is decoded or where DRX occurs or *i* is not an uplink subframe in TDD.
  - The δ_{PUSCH} dB accumulated values signalled on PDCCH with DCI format 0 are given in Table 5.1.1.1-2.
  - 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-step-size* provided by higher layers.
  - If UE has reached maximum power, positive TPC commands shall not be accumulated
  - If UE has reached minimum power, negative TPC commands shall not be accumulated
  - UE shall reset accumulation
    - at cell-change
    - when entering/leaving RRC active state
    - when an absolute TPC command is received
    - when $P_{\mathrm{O\_UE\_PUSCH}}(j)$ is received
    - when the UE (re)synchronizes
- $f(i) = \delta_{\mathrm{PUSCH}}(i - K_{\mathrm{PUSCH}})$ if accumulation is not enabled based on the UE-specific parameter *Accumulation-enabled* provided by higher layers
  - where $\delta_{\mathrm{PUSCH}}(i - K_{PUSCH})$ was signalled on PDCCH with DCI format 0 on subframe $i - K_{PUSCH}$
  - The value of K_{PUSCH} is
    - For FDD, $K_{PUSCH} = 4$
    - 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 PDCCHof DCI format 0 in which the second bit 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.
  - The δ_{PUSCH} dB absolute values signalled on PDCCH with DCI format 0 are given in Table 5.1.1.1-2.
  - $f(i) = f(i-1)$ for a subframe where no PDCCH with DCI format 0 is decoded or where DRX occurs or *i* is not an uplink subframe in TDD.
- For both types of $f(*)$ (accumulation or current absolute) the first value is set as follows:

- $f(0) = \Delta P_{rampup} + \delta_{msg2}$
    - where δ_{msg2} is the TPC command indicated in the random access response, and where ΔP_{rampup} is provided by higher layers and corresponds to the total power ramp-up from the first to the last preamble

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 to absolute and accumulated δ_{PUSCH} values.

TPC Command Field in DCI format 0/3	Accumulated δ_{PUSCH} [dB]	Absolute δ_{PUSCH} [dB] only DCI format 0
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 δ_{PUSCH} values.

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

5.1.1.2 Power headroom

The UE power headroom PH valid for subframe *i* is defined by

$$PH(i) = P_{\mathrm{MAX}} - \{10\log_{10}(M_{\mathrm{PUSCH}}(i)) + P_{\mathrm{O\_PUSCH}}(j) + \alpha \cdot PL + \Delta_{\mathrm{TF}}(i) + f(i)\} \text{ [dB]}$$

where, P_{MAX}, $M_{\mathrm{PUSCH}}(i)$, $P_{\mathrm{O\_PUSCH}}(j)$, α, PL, $\Delta_{\mathrm{TF}}(i)$ and $f(i)$ are defined in section 5.1.1.1.

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

The setting of the UE Transmit power P_{PUCCH} for the physical uplink control channel (PUCCH) transmission in subframe i is defined by

$$P_{\mathrm{PUCCH}}(i) = \min\left\{P_{\mathrm{MAX}}, P_{\mathrm{0\_PUCCH}} + PL + h(n_{CQI}, n_{HARQ}) + \Delta_{\mathrm{F\_PUCCH}}(F) + g(i)\right\} \quad \text{[dBm]}$$

where

- $\Delta_{\mathrm{F\_PUCCH}}(F)$ table entries for each PUCCH format (F) defined in Table 5.4-1 in [3] are given by RRC
  - Each signalled $\Delta_{\mathrm{F\_PUCCH}}(F)$ 2-bit value corresponds to a PUCCH format (F) relative to PUCCH format 1a.
  - The $\Delta_{\mathrm{F\_PUCCH}}(F)$ value for each PUCCH format (F) is defined in Table 5.1-2.

Table 5.1-2 Definition of $\Delta_{\mathrm{F\_PUCCH}}(F)$ for each PUCCH format (F)

PUCCH format (F)	$\Delta_{\mathrm{F\_PUCCH}}(F)$ **(dB)**
1	[-2, 0, 2]
1b	[1, 3, 5]
2	[-2, 0,1, 2]
2a	[-2, 0, 2]
2b	[-2, 0, 2]

- $h(n)$ is a PUCCH format dependent value, where n_{CQI} corresponds to the number information bits for the channel quality information defined in section 5.2.3.3 in [4] and n_{HARQ} is the number of HARQ bits.
  - For PUCCH format 1,1a and 1b $h(n_{CQI}, n_{HARQ}) = 0$
  - For PUCCH format 2, 2a, 2b and normal cyclic prefix

$$h(n_{CQI}, n_{HARQ}) = \begin{cases} 10\log_{10}\left(\frac{n_{CQI}}{4}\right) & \text{if } n_{CQI} \geq 4 \\ 0 & \text{otherwise} \end{cases}$$

  - For PUCCH format 2 and extended cyclic prefix

$$h(n_{CQI}, n_{HARQ}) = \begin{cases} 10\log_{10}\left(\frac{n_{CQI} + n_{HARQ}}{4}\right) & \text{if } n_{CQI} + n_{HARQ} \geq 4 \\ 0 & \text{otherwise} \end{cases}$$

- $P_{\text{O\_PUCCH}}$ is a parameter composed of the sum of a 5-bit cell specific parameter $P_{\text{O\_NOMINAL\_PUCCH}}$ provided by higher layers with 1 dB resolution in the range of [-127, -96] dBm and a UE specific component $P_{\text{O\_UE\_PUCCH}}$ configured by RRC in the range of [-8, 7] dB with 1 dB resolution.
- 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 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.
  - o 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 with the UE"s C-RNTI on every subframe except when in DRX.
  - o If the UE decodes a PDCCH with DCI format 1A/1B/1D/1/2A/2 and the corresponding detected RNTI equals the C-RNTI of the UE, the UE shall use the δ_{PUCCH} provided in that PDCCH.

    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.

  - o $g(i) = g(i-1) + \sum_{m=0}^{M-1} \delta_{PUCCH}(i-k_m)$ where $g(i)$ is the current PUCCH power control adjustment state.
    - ▪ For FDD, $M = 1$ and $k_0 = 4$.
    - ▪ For TDD, values of M and k_m are given in Table 10.1-1.
    - ▪ The δ_{PUCCH} dB values signalled on PDCCH with DCI format 1A/1B/1D/1/2A/2 are given in Table 5.1.2.1-1.
    - ▪ 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.
    - ▪ The initial value of $g(i)$ is defined as
      - $g(0) = \Delta P_{rampup} + \delta_{Msg2}$
        - o where δ_{msg2} is the TPC command indicated in the random access response, and
        - o ΔP_{rampup} is the total power ramp-up from the first to the last preamble provided by higher layers
    - ▪ If UE has reached maximum power, positive TPC commands shall not be accumulated
    - ▪ If UE has reached minimum power, negative TPC commands shall not be accumulated
    - ▪ UE shall reset accumulation
      - at cell-change
      - when entering/leaving RRC active state
      - when $P_{\text{O\_UE\_PUCCH}}(j)$ is received
      - when the UE (re)synchronizes
    - ▪ $g(i) = g(i-1)$ 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/2/3 to δ_{PUCCH} values.

TPC Command Field in DCI format 1A/1B/1D/1/2A/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

5.1.3.1 UE behaviour

The setting of the UE Transmit power P_{SRS} for the Sounding Reference Symbol transmitted on subframe *i* is defined by

$$P_{\text{SRS}}(i) = \min\{P_{\text{MAX}},\ P_{\text{SRS\_OFFSET}} + 10\log_{10}(M_{\text{SRS}}) + P_{\text{O\_PUSCH}}(j) + \alpha \cdot PL + f(i)\}\ \text{[dBm]}$$

where

- For $K_S = 1.25$, $P_{\text{SRS\_OFFSET}}$ is a 4-bit UE specific parameter semi-statically configured by higher layers with 1dB step size in the range [-3, 12] dB.
- For $K_S = 0$, $P_{\text{SRS\_OFFSET}}$ is a 4-bit UE specific parameter semi-statically configured by higher layers with 1.5 dB step size in the range [-10.5,12] dB
- M_{SRS} is the bandwidth of the SRS transmission in subframe *i* expressed in number of resource blocks.
- $f(i)$ is the current power control adjustment state for the PUSCH, see Section 5.1.1.1.
- $P_{\text{O\_PUSCH}}(j)$ is a parameter as defined in Section 5.1.1.1, where $j = 1$.

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 reference-signal EPRE is given by the parameter *Reference-signal-power* provided by higher layers.

For each UE, the ratio of PDSCH EPRE to cell-specific RS EPRE among PDSCH REs in all the OFDM symbols not containing cell-specific RS is equal and is denoted by ρ_A.

The UE may assume that for 16 QAM, 64 QAM, RI>1 spatial multiplexing or for PDSCH transmissions associated with the multi-user MIMO transmission mode, ρ_A is equal to $\delta_{\text{power-offset}} + P_A$ where $\delta_{\text{power-offset}}$ is 0 dB for all transmission modes except multi-user MIMO and where P_A is a UE specific parameter configured by RRC and which can take the values of [3, 2, 1, 0, -1, -2, -3, -6] in dB.

If UE-specific RSs are present in a PRB, the ratio of PDSCH EPRE to UE-specific RS EPRE for each OFDM symbol is equal. In addition, the UE may assume that for 16QAM or 64QAM, this ratio is 0 dB.

For each UE, the ratio of PDSCH EPRE to cell-specific RS EPRE among PDSCH REs in all the OFDM symbols containing cell-specific RS is equal and is denoted by ρ_B.

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: Ratio of PDSCH EPRE to cell-specific RS EPRE in symbols with and without cell-specific RS 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.

5.2.1 eNodeB Relative Narrowband TX Power restrictions

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

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

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, frequency position and preamble format)
2. Parameters for determining the root sequences and their cyclic shifts in the preamble sequence set for the cell (index to 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_{max}, PREAMBLE_RECEIVED_TARGET_POWER + PL}, where P_{max} is the maximum allowed power that depends on the UE power class and PL is the downlink pathloss estimate calculated in the UE.
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 PDSCH transport block is passed to higher layers. The higher layers parse the transport block and indicate the 20-bit UL-SCH grant to the physical layer, which is processed according to section 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 $n+k_1$, $k_1 \geq 6$, where an UL-SCH transmission is available.

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, transmit a new preamble sequence in the first subframe $n+k_2$, $k_2 \geq 5$, where a PRACH resource is available.

c. If no random access response is received in subframe *n*, the UE shall, if requested by higher layers, transmit a new preamble sequence in the first subframe $n+k_3$, $k_3 \geq 4$, where a PRACH resource is available.

In case random access procedure is triggered by the PDCCH indicating downlink data arrival in subframe *n*, UE shall, if requested by higher layers, transmit random access preamble in the first subframe $n+k_4$, $k_4 \geq 6$, where a PRACH resource is available.

6.2 Random Access Response Grant

The higher layers indicate the 20-bit Random Access Response to 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

- CQI request – 1 bit

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, 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 defined in Table 8.4-1, 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 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 for Scheduled PUSCH

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

The UL delay applies for both TDD and FDD. If this field is set to 0 the UE shall upon detection of a Random Access Response grant in subframe n transmit the corresponding PUSCH transmission in subframe $n+k$, where k is the first available UL subframe for PUSCH transmission, such that k>5. If the UL delay field is set to 1, UE shall postpone the

PUSCH transmission to the first available subframe after subframe n+k. A UE shall perform aperiodic CQI, PMI and RI reporting using the PUSCH upon receiving the CQI request indication sent in the scheduling grant.

7 Physical downlink shared channel related procedures

7.1 UE procedure for receiving the physical downlink shared channel

A UE shall upon detection of a PDCCH with DCI format 1, 1A, 1B, 1C, 2 or 2A intended for the UE in a subframe, decode the corresponding PDSCH in the same subframe. A UE shall receive PDSCH broadcast control transmissions, [namely Paging, RACH Response, and BCCH] associated with DCI formats 1A or 1C signalled by a PDCCH in the common search spaces. Additionally, the UE is semi-statically configured via higher layer signalling to receive PDSCH data transmissions signalled via PDCCH UE specific search spaces, based on one of the following transmission modes:

1. Single-antenna port; port 0
2. Transmit diversity
3. Open-loop spatial multiplexing
4. Closed-loop spatial multiplexing
5. Multi-user MIMO
6. Closed-loop Rank=1 precoding
7. Single-antenna port; port 5

A UE not configured to receive PDSCH data transmissions based on one of the transmission modes may receive PDSCH data transmissions with DCI format 1A signalled by a PDCCH in its UE specific search spaces or the common search spaces.

A UE semi-statically configured with a transmission mode shall receive PDSCH data transmissions associated with a reference DCI format signalled by a PDCCH in its UE specific search spaces based on Table 7.1-1. In the case of transmission modes 1, 2, and 7 a UE shall receive PDSCH data transmissions associated with reference DCI formats 1 or 1A in its UE specific search spaces or DCI format 1A in the common search spaces. A UE with reference DCI format 1B or 2 may also receive PDSCH data transmissions associated with DCI format 1A signalled by a PDCCH in its UE specific search spaces or the common search spaces. A UE shall be configured to use the PUCCH or PUSCH feedback mode corresponding to its reference DCI format.

Table 7.1-1: Reference DCI Format(s) supported by each Transmission Mode

Transmission Mode	Reference DCI Format
1	1, 1A
2	1, 1A
3	2A
4	2
5	1D
6	1B
7	1, 1A

7.1.1 Single-antenna port

For the single-antenna port mode, the UE may assume that an eNB transmission on the PDSCH would be performed according to Section 6.3.4.1 of [3]7.1.2 Transmit diversity

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

7.1.3 Open-loop spatial multiplexing

For the open-loop spatial multiplexing transmission mode, the UE may assume, based on the rank indication (RI) obtained from an associated DCI as determined from the number of assigned transmission layers, that an eNB transmission on the physical PDSCH would be performed according to the following:

- RI = 1 : transmit diversity as defined in Section 6.3.4.3 of [3]
- RI > 1 : large delay CDD as defined in Section 6.3.4.2.2 of [3]

For RI>1, the operation of large delay CDD is further defined as follows:

- For 2 antenna ports, the precoder for data resource element index *i*, denoted by W(i) is selected according to $W(i) = C_1$ where C_1 denotes the precoding matrix corresponding to precoder index 0 in Table 6.3.4.2.3-1 of [3].
- For 4 antenna ports, the UE may assume that the eNB cyclically assigns different precoders to different data resource elements on the physical downlink shared channel as follows. A different precoder is used every υ data resource elements, where υ denotes the number of transmission layers in the case of spatial multiplexing. In particular, the precoder for data resource element index *i*, denoted by *W(i)* in Section 6.3.4.2.2 of [3] is selected according to $W(i) = C_k$, where k is the precoder index given by $k = \left(\left\lfloor \frac{i}{\upsilon} \right\rfloor \bmod 4\right) + 1$, where *k=1,2,3,4*, and C_1, C_2, C_3, C_4 denote precoder matrices corresponding to precoder indices 12,13,14 and 15, respectively, in Table 6.3.4.2.3-2 of [3].

7.1.4 Closed-loop spatial multiplexing

For the closed-loop spatial multiplexing transmission mode, 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 Section 6.3.4.2.1 of [3].

7.1.5 Multi-user MIMO

For the multi-user MIMO transmission mode, the UE may assume that an eNB transmission on the PDSCH would be performed on one layer and according to Section 6.3.4.2.1 of [3]. The $\delta_{\text{power-offset}}$ dB value signalled on PDCCH 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**

7.1.6 Resource allocation

The UE shall interpret the resource allocation field depending on the PDCCH DCI format detected. A resource allocation field in each PDCCH includes two parts, a resource allocation header field and information consisting of the actual resource block assignment. PDCCH DCI formats 1, 2 and 2A with type 0 and PDCCH DCI formats 1, 2 and 2A 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 (section 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 and 1C have a type 2 resource allocation while PDCCH with DCI format 1, 2 and 2A 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.

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 physical resource blocks (PRBs). 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 $N_{\mathrm{RB}}^{\mathrm{DL}}$ PRBs 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 PRBs from the set of PRBs from one of P RBG subsets. 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 PRB in the selected RBG subset in such a way that MSB to LSB of the bitmap are mapped to the PRBs in the increasing frequency order. The PRB is allocated to the UE if the corresponding bit value in the bit field is 1, the PRB is not allocated to the UE otherwise. The portion of the bitmap used to address PRBs 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 PRB numbers of a selected RBG subset start from an offset, $\Delta_{\mathrm{shift}}(p)$ to the smallest PRB number within the selected RBG subset, which is mapped to the MSB of the bitmap. The offset is in terms of the number of PRBs 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

PRB number within the selected RBG subset. $N_{\mathrm{RB}}^{\mathrm{RBG\ subset}}(p)$ is the number of PRBs in RBG subset p and can be calculated by the following equation,

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

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 PRB number,

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

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 or 1B, 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. With PDCCH DCI format 1A or 1B, 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, where $N_{\mathrm{VRB}}^{\mathrm{DL}}$ is defined in [3]. 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 1A or 1B	DCI format 1C
6-49	1	2
50-110	1	4

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

if $(L'_{CRBs}-1)\le \left\lfloor N'^{DL}_{VRB}/2\right\rfloor$ 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 $L'_{CRBs} = L_{CRBs} / N^{step}_{RB}$, $RB'_{start} = RB_{start} / N^{step}_{RB}$ and $N'^{DL}_{VRB} = \lfloor N^{DL}_{VRB} / N^{step}_{RB} \rfloor$.

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 1A:
  - set the Table 7.1.7.2.1-1 column indicator N_{PRB} to N^{1A}_{PRB} from Section 5.3.3.1.3 in [4]
- for DCI 1C:
  - set the Table 7.1.7.2.1-1 column indicator N_{PRB} to [2]

else

- set the Table 7.1.7.2.1-1 column indicator N_{PRB} to the total number of allocated PRBs based on the procedure defined in Section 7.1.6.

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 UE shall send a NAK.

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

- the UE shall set the TBS index (I_{TBS}) equal to I_{MCS}

else

- for $0 \le I_{\mathrm{MCS}} \le 28$, 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 and 2A as specified below. For a transport block that is not mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in Section 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 Section 7.1.7.2.2. For $29 \le I_{\mathrm{MCS}} \le 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH for the same transport block using $0 \le I_{\mathrm{MCS}} \le 28$.
- In DCI formats 2 and 2A a transport block is disabled if $I_{\mathrm{MCS}} = 0$ and if rv_{idx} = 1 otherwise the transport block is enabled.

7.1.7.2.1 Transport blocks not mapped to two-layer spatial multiplexing

For $1 \le N_{\mathrm{PRB}} \le 110$, 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

7.2 UE procedure for reporting channel quality indication (CQI), precoding matrix indicator (PMI) and rank indication (RI)

The time and frequency resources that can be used by the UE to report CQI, PMI, and 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.

CQI, PMI, and RI reporting is periodic or aperiodic. A UE transmits CQI, PMI, and RI reporting on a PUCCH for subframes with no PUSCH allocation. A UE transmits CQI, PMI, and RI reporting on a PUSCH for those subframes with PUSCH allocation for a) scheduled PUSCH transmissions with or without an associated scheduling grant or b) PUSCH transmissions with no UL-SCH. The CQI 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 CQI reporting

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

In case both periodic and aperiodic reporting would occur in the same subframe, the UE shall only transmit the aperiodic 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 during closed-loop spatial multiplexing, a UE shall determine a RI from the supported set of RI values for the corresponding eNodeB and UE antenna configuration and report the number in each RI report. For each RI reporting interval during open-loop spatial multiplexing, a UE shall determine RI for the corresponding eNodeB and UE antenna configuration in each reporting interval and report the detected number in each RI report to support selection between RI=1 transmit diversity and RI>1 large delay CDD open-loop spatial multiplexing.

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 $N_{\mathrm{RB}}^{\mathrm{DL}}$ 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 and RI within a precoder codebook subset specified by a bitmap parameter *codebookSubsetRestriction* configured by higher layer signalling. 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 open-loop spatial multiplexing, closed-loop spatial multiplexing, multi-user MIMO and closed-loop Rank=1 precoding. 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. Open-loop spatial multiplexing
    a.
2. Closed-loop spatial multiplexing
    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. Multi-user MIMO and Closed-loop Rank=1 precoding

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].

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**
Transmission mode	**Open-loop spatial multiplexing**		
	Closed-loop spatial multiplexing	6	64
	Multi-user MIMO	4	16
	Closed-loop rank=1 precoding	4	16

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 also semi-statically configured by higher layers. 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 term 'Wideband CQI' denotes a CQI value obtained over the set S.

- For single-antenna port and transmit diversity, as well as open-loop spatial multiplexing, and closed-loop spatial multiplexing with RI=1 a single 4-bit wideband CQI is reported according to Table 7.2.3-1.

- For open-loop and closed-loop spatial multiplexing, CQI is calculated assuming transmission of one codeword for RI=1 and two codewords for RI > 1.
- For RI > 1, closed-loop spatial multiplexing PUSCH based triggered reporting includes reporting a wideband CQI which comprises:
  - A 4-bit wideband CQI for codeword 1 according to Table 7.2.3-1
  - A 4-bit wideband CQI for codeword 2 according to Table 7.2.3-1
- For RI > 1, closed-loop spatial multiplexing PUCCH based reporting includes separately reporting a 4-bit wideband CQI for codeword 1 according to Table 7.2.3-1 and a wideband spatial differential CQI each with a distinct reporting period and relative subframe offset. The wideband spatial differential CQI value comprises:
  - A 3-bit wideband spatial differential CQI value for codeword 2 offset level
    - Codeword 2 offset level = wideband CQI index for codeword 1 – wideband CQI index for codeword 2.
  - 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 wideband spatial differential CQI value to offset level

Wideband 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 CQI/PMI/RI Reporting using PUSCH

A UE shall perform aperiodic CQI, PMI and RI reporting using the PUSCH upon receiving DCI format 0 with the CQI request field set to 1.

The aperiodic CQI report size and message format is given by RRC.

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.

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 reporting modes given in Table 7.2.1-1 and described below:

Table 7.2.1-1: CQI and PMI Feedback Types for PUSCH 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 Section 7.1, the following reporting modes are supported on PUSCH:

1. Single-antenna port; port 0 : Modes 2-0, 3-0
2. Transmit diversity : Modes 2-0, 3-0
3. Open-loop spatial multiplexing : Modes 2-0, 3-0
4. Closed-loop spatial multiplexing : Modes 1-2, 2-2, 3-1
5. Multi-user MIMO : Mode 3-1
6. Closed-loop Rank=1 precoding : Modes 1-2, 2-2, 3-1
7. Single-antenna port ; port 5 :

For $N_{\mathrm{RB}}^{\mathrm{DL}} \leq 7$, PUSCH reporting modes are not supported.
The selection of PMI and the calculation of CQI are both dependent on the RI value that the UE selects for the corresponding reporting instance.

RI report on a PUSCH reporting mode is valid only for CQI/PMI report on that PUSCH 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.
        - Subband size is given by Table 7.2.1-3.

- 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.
    - 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
        - 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 single selected precoding matrix indicator

- 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	-2

- 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 across all layers irrespective of computed or reported RI.

    - Additionally, the UE shall also report one wideband CQI value.

  - 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 best subbands and using the same selected single precoding matrix in each of the *M* subbands.

    - The UE shall also report the selected single precoding matrix preferred 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
- A UE shall also report the selected single precoding matrix indicator for all set S subbands.

- 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
  - $r = \sum_{k=0}^{M-1} \left\langle \begin{matrix} N - s_k \\ M - k \end{matrix} \right\rangle$
  - where the set $\{s_k\}_{k=0}^{M-1}$, $(1 \le s_k \le N, \quad s_k < s_{k+1})$ 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 = best-M average 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 $N_{\mathrm{RB}}^{\mathrm{DL}}$	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 CQI/PMI/RI Reporting using PUCCH

A UE is semi-statically configured by higher layers to periodically feed back different CQI, PMI, and RI on the PUCCH using the reporting modes given in Table 7.2.2-1 and described below.

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

- There are a total of *N* subbands for a 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* is scanned in sequential order according to increasing frequency as defined by the equation $j = \mathrm{mod}(N_{SF}, J)$, where N_{SF} is a counter that a UE increments after each subband report transmission for the bandwidth part.
- 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 where $L = \lceil \log_2 \lceil N_{\mathrm{RB}}^{\mathrm{DL}} / k / J \rceil \rceil$.

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

Four CQI/PMI and RI reporting types with distinct periods and offsets are supported for each PUCCH reporting mode as given in Table 7.2.2-3:

- Type 1 report supports CQI feedback for the UE selected sub-bands
- Type 2 report supports wideband CQI and PMI feedback.
- Type 3 report supports RI feedback
- Type 4 report supports wideband CQI

In the case where RI and wideband CQI/PMI reporting are configured, RI and wideband CQI/PMI are not reported in the same subframe (reporting instance):

- The reporting instances for wideband CQI/PMI are subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}\right) \mathrm{mod}\, N_P = 0$, where n_f is the system frame number, and n_s = {0,1,…, 19} is the slot index within the frame, and $N_{OFFSET,CQI}$ is the corresponding wideband CQI/PMI reporting offset (in subframes) and N_{P} is the wideband CQI/PMI period (in subframes).
- The reporting interval of the RI reporting is an integer multiple M_{RI} of wideband CQI/PMI period N_{P} (in subframes).
    - The parameter M_{RI} is selected from the set {1, 2, 4, 8, 16, 32, OFF}.
    - In case M_{RI} is not OFF, the reporting instances for RI are subframes satisfying $\left(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}\right) \mathrm{mod}\left(N_P \cdot M_{RI}\right) = 0$, where n_f is the system frame number, and n_s = {0,1,…, 19} is the slot index within the frame, $N_{OFFSET,CQI}$ is the corresponding wideband CQI/PMI reporting offset (in subframes) and $N_{OFFSET,RI}$ is the corresponding relative RI offset to the wideband CQI/PMI reporting offset (in subframes).

- The reporting offset for RI $N_{OFFSET,RI}$ takes values from the set {0, −1, …, −(N_P−1)}.
- In case of collision of RI and wideband CQI/PMI the wideband CQI/PMI is dropped.

- The parameters M_{RI}, N_P, $N_{OFFSET,CQI}$ and $N_{OFFSET,RI}$ are configured by higher-layer. The periodicity N_P and offset $N_{OFFSET,CQI}$ for wideband CQI/PMI reporting are determined based on a 9-bit configuration index given in Table 7.2.2-1A.

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

- The reporting instances for wideband CQI/PMI and subband CQI are subframes satisfying $\left(10 \times n_f + \lfloor n_s/2 \rfloor - N_{OFFSET,CQI}\right) \bmod N_P = 0$, where n_f is the system frame number, and n_s = {0,1,…, 19} is the slot index within the frame, and $N_{OFFSET,CQI}$ is the corresponding wideband CQI/PMI reporting offset (in subframes).
  - The wideband CQI/PMI report has period H*N_P, and is reported on the subframes satisfying $\left(10 \times n_f + \lfloor n_s/2 \rfloor - N_{OFFSET,CQI}\right) \bmod \left(H \cdot N_P\right) = 0$, where n_f is the system frame number, and n_s = {0,1,…, 19} is the slot index within the frame. .The integer H is defined as H=J*K+1, where J is the number of bandwidth parts.
  - Between every two consecutive wideband CQI/PMI reports, the remaining J*K reporting instances are used in sequence for subband CQI reports on K full cycles of bandwidth parts.

- The reporting interval of RI is M_{RI} times the wideband CQI/PMI period, and RI is reported on the same PUCCH cyclic shift resource as both the wideband CQI/PMI and subband CQI reports.
  - The parameter M_{RI} is selected from the set {1, 2, 4, 8, 16, 32, OFF}.
  - In case M_{RI} is not OFF, the reporting instances for RI are subframes satisfying $\left(10 \times n_f + \lfloor n_s/2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}\right) \bmod \left(H \cdot N_P \cdot M_{RI}\right) = 0$, where n_f is the system frame number, and n_s = {0,1,…, 19} is the slot index within the frame, $N_{OFFSET,CQI}$ is the corresponding wideband CQI/PMI reporting offset (in subframes) and $N_{OFFSET,RI}$ is the corresponding relative RI offset to the wideband CQI/PMI reporting offset (in subframes).
  - In case of collision between RI and wideband CQI/PMI or subband CQI, the wideband CQI/PMI or subband CQI is dropped.

- The parameters N_P, K, M_{RI}, $N_{OFFSET,RI}$ are configured by higher layer. The parameter K is selected from the set {1, 2, 3, 4}, and the parameter $N_{OFFSET,RI}$ is selected from the set {0, -1, …,-(N_P -1), - N_P }. The periodicity N_P and offset $N_{OFFSET,CQI}$ for CQI reporting are configured based on a 9-bit configuration index given in Table 7.2.2-1A.

The following PUCCH formats are used:

- Format 2 as defined in section 5.4.2 in [3] when CQI/PMI or RI report is not multiplexed with ACK/NAK
- Format 2a/2b as defined in section 5.4.2 in [3] when CQI/PMI or RI report is multiplexed with ACK/NAK for normal CP
- Format 2 as defined in section 5.4.2 in [3] when CQI/PMI or RI report is multiplexed with ACK/NAK for extended CP

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

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

	(subband CQI)		

Table 7.2.2-1A: Mapping of CQI/PMI Configuration Index to N_P and $N_{OFFSET,CQI}$.

CQI/PMI Periodicity and Offset Configuration Index $I_{CQI/PMI}$	Value of N_P	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	$I_{CQI/PMI} - 157$
$I_{CQI/PMI} = 317$	OFF	*n/a*
$318 \le I_{CQI/PMI} \le 511$	Reserved	

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

1. Single-antenna port, port 0 : Modes 1-0, 2-0
2. Transmit diversity : Modes 1-0, 2-0
3. Open-loop spatial multiplexing : Modes 1-0, 2-0
4. Closed-loop spatial multiplexing : Modes 1-1, 2-1
5. Multi-user MIMO : Modes 1-1, 2-1
6. Closed-loop Rank=1, precoding : Modes 1-1, 2-1
7. Single-antenna port, port 5 :

RI report in a PUCCH reporting mode is valid only for CQI/PMI report on that PUCCH reporting mode.

- Wideband feedback
    - Mode 1-0 description:
        - In the subframe where RI is reported (only for open-loop spatial multiplexing):
            - 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. For open-loop spatial multiplexing the CQI is calculated conditioned on the last reported RI.
    - Mode 1-1 description:
        - In the subframe where RI is reported (only for closed-loop spatial multiplexing):
            - 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/PMI is reported:

- A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands and conditioned on the last reported RI
- A UE shall report a type 2 report on each respective successive reporting opportunity 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 and conditioned on the last reported RI.
  - The selected single precoding matrix indicator (wideband PMI)
  - When RI>1, a 3-bit wideband spatial differential CQI.

- UE Selected subband feedback
  - Mode 2-0 description:
    - In the subframe where RI is reported (only for open-loop spatial multiplexing):
      - 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 conditioned on the last reported RI.
    - 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. For open-loop spatial multiplexing, the selection is conditioned on the last reported RI.
      - 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 best 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 across all layers irrespective of the computed or reported RI. For open-loop spatial multiplexing, the selection is conditioned on the last reported RI
  - Mode 2-1 description:
    - In the subframe where RI is reported:
      - 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/PMI is reported:
      - A single precoding matrix is selected from the codebook subset assuming transmission on set *S* subbands and conditioned on the last reported RI.
      - 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 and conditioned on the last reported RI.
        - The selected single precoding matrix indicator (wideband PMI).
        - When RI>1, and additional 3-bit wideband spatial differential CQI.

- 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 conditioned on the last reported wideband PMI and RI.
  - The UE shall report a type 1 report per bandwidth part on each respective successive reporting opportunity consisting of:
    - A single CQI value 1 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding best subband L-bit label conditioned on the last reported wideband PMI and RI.
    - If RI>1, an additional 3-bit spatial differential CQI represents the difference between CQI value 1 for codeword 1 and CQI value 2 for codeword 2 assuming the use of the most recently reported single precoding matrix in all subbands and transmission on set S subbands.

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

System Bandwidth N_{RB}^{DL}	Subband Size k (RBs)	Bandwidth Parts (J)
6 – 7	(wideband CQI only)	1
8 – 10	4	1
11 – 26	4	2
27 – 63	6	3
64 – 110	8	4

The corresponding periodicity parameters for the different CQI/PMI modes are defined as:

- N_P is the periodicity of the sub-frame pattern allocated for the CQI reports in terms of subframes were the minimum reporting interval is N_{PMIN} .
- N_{OFFSET} is the subframe offset

A UE with a scheduled PUSCH allocation in the same subframe as its CQI report shall use the same PUCCH-based reporting format when reporting CQI on the PUSCH unless an associated PDCCH with scheduling grant format indicates an aperiodic report is required.

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

PUCCH Report 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
2	Wideband CQI/PMI	2 TX Antennas RI = 1	6	6	NA	NA
		4 TX Antennas RI = 1	8	8	NA	NA
		2 TX Antennas RI > 1	8	8	NA	NA
		4 TX Antennas RI > 1	11	11	NA	NA

3	RI	2-layer spatial multiplexing	1	1	1	1
		4-layer spatial multiplexing	2	2	2	2
4	Wideband CQI	RI = 1	NA	NA	4	4

7.2.3 Channel quality indicator (CQI) definition

The number of entries in the CQI table for a single layer = 16 as given by Table 7.2.3-1.

A single CQI index corresponds to an index pointing to a value in the CQI table. The CQI index is defined in terms of a channel coding rate value and modulation scheme (QPSK, 16QAM, 64QAM),

Based on an unrestricted observation interval in time and frequency, the UE shall report in uplink subframe *n* the highest CQI index in Table 7.2.3-1 which satisfies the following 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 CQI reference resource, could be received with a transport block error probability not exceeding 0.1.

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

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

The CQI reference resource is defined as follows:

- In the frequency domain, the CQI reference resource is defined by the group of downlink physical resource blocks corresponding to the CQI reporting band to which the CQI report relates.
- In the time domain, the CQI reference resource is defined by a single downlink subframe $n-n_{CQI\_ref}$ where n_{CQI_ref} is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink subframe. A downlink subframe shall be considered to be valid if it is configured as a downlink subframe for that UE and is not an MBSFN subframe.
- In the layer domain, the CQI reference resource is defined by any RI and PMI on which the CQI is conditioned.

In the CQI reference resource, the UE shall assume the following for the purpose of deriving the CQI index to report:

- The first 3 OFDM symbols are occupied by control signalling
- No resource elements used by primary or secondary synchronisation signals or PBCH
- CP length of the non-MBSFN subframes
- Redundancy Version 0
- the PDSCH transmission mode currently configured for the UE (which may be the default mode)
- the PDSCH EPRE is offset from the RS EPRE by an amount given by the Nominal PDSCH-to-RS-EPRE-offset, which is given by higher layers.

Table 7.2.3-1: 4-bit CQI Table

CQI index	modulation	coding 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 closed-loop spatial multiplexing transmission, precoding feedback is used for channel dependent codebook based precoding and relies on UEs reporting precoding matrix indicator (PMI). A UE shall report PMI based on the feedback modes described in 7.2.1 and 7.2.2. 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].

For open-loop spatial multiplexing transmission, PMI reporting is not supported.

7.3 UE procedure for reporting ACK/NACK

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

For TDD and a UE in ACK/NACK bundling mode, when both bundled ACK/NACK and SR are transmitted in the same sub-frame, the UE shall transmit the bundled ACK/NACK on its assigned ACK/NACK PUCCH resource for a negative SR transmission and transmit the bundled ACK/NACK on its assigned SR PUCCH resource for a positive SR transmission.

For TDD and a UE in ACK/NACK multiplexing mode, when both ACK/NACK and SR are transmitted in the same sub-frame, the UE shall transmit the multiple ACK/NACK response according to section 10.1 for a negative SR transmission, and transmit $b(0), b(1)$ on its assigned SR PUCCH resource for a positive SR transmission using PUCCH format 1b according to section 5.4.1 in [3]. The value of $b(0), b(1)$ are generated according to Table 7.3-1 from the multiple ACK/NACK responses, where the number of multiple ACK/NACK responses is equal to M according to section 10.1 depending on the UL-DL configurations.

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

Number of ACK among multiple (M) ACK/NACK 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 ACK/NACK bundling, when both bundled ACK/NACK and CQI are configured to be transmitted in the same sub-frame on PUCCH, a UE shall transmit bundled ACK/NACK and CQI using PUCCH format 2a or 2b in normal CP, or PUCCH format 2 in extended CP.

For TDD ACK/NACK multiplexing, when both ACK/NACK and CQI are configured to be transmitted in the same sub-frame on PUCCH, a UE shall transmit CQI and $b(0), b(1)$ using PUCCH format 2b for normal CP or PUCCH format 2 for extended CP, according to section 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 multiple ACK/NACK responses, where the number of multiple ACK/NACK responses is equal to M according to section 10.1 depending on the UL-DL configurations.

When only an ACK/NACK or only a SR is transmitted a UE shall use PUCCH Format 1a or 1b for the ACK/NACK resource and PUCCH Format 1 for the SR resource as defined in section 5.4.1 in [3].

8 Physical uplink shared channel related procedures

For FDD, there shall be 8 HARQ processes in the uplink. For FDD, the UE shall upon detection of a PDCCH with DCI format 0 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 and PHICH information.

For TDD, the number of HARQ processes shall be determined by the DL/UL configuration (Table 4.2-2 of [3]), as indicated in table 8-1.

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

TDD UL/DL configuration	Number of HARQ processes
0	7
1	4
2	2
3	3
4	2
5	1
6	6

For TDD UL/DL configurations 1-6, the UE shall upon detection of a PDCCH with DCI format 0 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 and PHICH information

For TDD UL/DL configuration 0 the UE shall upon detection of a PDCCH with DCI format 0 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 DCI format 0 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 Section 9.1.2, with *k* given in Table 8-2. If, for TDD UL/DL configuration 0, the LSB of the UL index in the DCI format 0 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 Section 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*.

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

TDD UL/DL Configuration	DL 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

8.1 Resource Allocation for PDCCH DCI Format 0

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_{CRBs}). The resource indication value is defined by

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

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

else

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

8.2 UE sounding procedure

The following Sounding Reference Symbol (SRS) parameters are UE specific semi-statically configurable by higher layers:

- Transmission comb
- Starting physical resource block assignment
- Duration of SRS transmission: single or indefinite (until disabled)
- SRS configuration index I_{SRS} for SRS periodicity and SRS subframe offset
- SRS bandwidth
- Frequency hopping bandwidth
- Cyclic shift

The SRS transmission bandwidth does not include the PUCCH region. The cell specific SRS transmission bandwidths are configured by higher layers. The allowable values are given in Section 5.5.3.2 of [3].

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

When antenna selection is enabled 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 Section 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.

For TDD, when one SC-FDMA symbol exists in UpPTS, it can be used for SRS transmission. When two SC-FDMA symbols exist in UpPTS, both can be used for SRS transmission and both can be assigned to the same UE.

A UE shall not transmit SRS whenever SRS and CQI transmissions happen to coincide in the same subframe.

A UE shall not transmit SRS whenever SRS and SR transmissions happen to coincide in the same subframe.

The parameter *Simultaneous-AN-and-SRS* provided by higher layers determine if a UE can transmit A/N on PUCCH and SRS in the same subframe. If UE is configured to support A/N and SRS transmissions in the same subframe, then the UE shall transmit A/N using a shortened PUCCH format where the A/N symbol corresponding to the SRS location is punctured as defined in Section 5.4.1 of [3]. Otherwise, the UE shall only transmit the A/N using the normal PUCCH format 1a or 1b as defined in Section 5.4.1 of [3].

The UE specific SRS configuration for SRS periodicity and SRS subframe offset is defined in Table 8.2-1 and Table 8.2-2, for FDD and TDD, respectively. The periodicity of SRS transmission is selected from {2, 5, 10, 20, 40, 80, 160, 320} ms. For the SRS periodicity of 2 ms in TDD, two SRS resources are configured in a half frame.

For TDD, SRS subframe offset 0 corresponds to the first SC-FDMA symbol in UpPTS, if UpPTS contains two SC-FDMA symbols. SRS subframe offset 1 corresponds to the second SC-FDMA symbol in UpPTS, if UpPTS contains two SC-FDMA symbols, or the only SC-FDMA symbol if UpPTS contains one SC-FDMA symbol.

Table 8.2-1: UE Specific SRS Periodicity and Subframe Offset Configuration, FDD

SRS Configuration Index I_{SRS}	SRS Periodicity (ms)	SRS Subframe 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 and Subframe Offset Configuration, TDD

Configuration Index I_{SRS}	SRS Periodicity (ms)	SRS Subframe 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

8.2.1 Sounding definition

8.3 UE ACK/NACK procedure

For Frame Structure type 1, an ACK/NACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in subframe *i*-4.

For Frame Structure type 2, an ACK/NACK received on the PHICH assigned to a UE in subframe *i* is associated with the PUSCH transmission in the subframe indicated by the following table:

[…table to be inserted…]

The physical layer in the UE shall deliver indications to the higher layers as follows:

For downlink subframe *i*, if a transport block was transmitted in the associated PUSCH subframe then:

- if an Uplink Scheduling Assignment is received in subframe *i* with NDI toggled since the previous subframe corresponding to the same HARQ process, a new transmission shall be indicated to the higher layers;
- else if an Uplink Scheduling Assignment is received in subframe *i* with NDI not toggled since the previous subframe corresponding to the same HARQ process, a re-transmission shall be indicated to the higher layers.
- else if no Uplink Scheduling Assignment is received in subframe *i*, then:
    - o if ACK is decoded on the PHICH, ACK shall be delivered to the higher layers;
    - o else NACK 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 with DCI format 0 is set to 1 otherwise no PUSCH frequency hopping is performed.

A UE performing PUSCH frequency hopping shall determine its PUSCH resource allocation 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 a corresponding PDCCH with DCI format 0 received on subframe *n-4*. For a non-adaptive retransmission of a packet on a dynamically assigned PUSCH resource a UE shall determine its hopping type based on the last received PDCCH with DCI Format 0 associated with the packet. For a PUSCH transmission on a persistently allocated resource on subframe *n* in the absence of a corresponding PDCCH with a DCI Format 0 in subframe *n-4*, the UE shall determine its hopping type based on the hopping information in the initial grant that assigned the persistent resource allocation. The initial grant is either a PDCCH with DCI Format 0 or is higher layer signaled.

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 $N_{\text{RB}}^{\text{PUSCH}} = N_{\text{RB}}^{\text{UL}} - \tilde{N}_{\text{RB}}^{\text{PUCCH}}$. For type 2 PUSCH hopping, $\tilde{N}_{\text{RB}}^{\text{PUCCH}} = N_{\text{RB}}^{\text{PUCCH}} + 1$ if $N_{\text{RB}}^{\text{PUCCH}}$ is an odd number where $N_{\text{RB}}^{\text{PUCCH}}$ defined in [3]. $\tilde{N}_{\text{RB}}^{\text{PUCCH}} = N_{\text{RB}}^{\text{PUCCH}}$ in other cases. The size of the resource allocation field in DCI format 0 after excluding either 1 or 2 bits shall be $y = \lceil \log_2(N_{\text{RB}}^{\text{UL}}(N_{\text{RB}}^{\text{UL}}+1)/2) \rceil - k$, where k = 1 or 2 bits and the number of contiguous RBs that can be assigned to a hopping user is limited to $\min(\lfloor 2^y / N_{\text{RB}}^{\text{UL}} \rfloor, \lfloor N_{\text{RB}}^{\text{PUSCH}} / N_{sb} \rfloor)$,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 section 8.4.1 and type 2 is described in section 8.4.2.

Table 8.4-1: Max PUSCH BW, and Number of Hopping Bits vs. System Bandwidth

System BW N_{RB}^{UL}	Max BW assigned to a hopping User	#Hopping bits for 2nd slot RA (k)
6-49	$\min(\lfloor 2^y / N_{\text{RB}}^{\text{UL}} \rfloor, \lfloor N_{\text{RB}}^{\text{PUSCH}} / N_{sb} \rfloor)$	1
50-110	$\min(\lfloor 2^y / N_{\text{RB}}^{\text{UL}} \rfloor, \lfloor N_{\text{RB}}^{\text{PUSCH}} / N_{sb} \rfloor)$	2

For either hopping type a single bit signaled by higher layers indicates whether PUSCH frequency hopping is inter-subframe only or both intra and inter-subframe.

8.4.1 Type 1 PUSCH Hopping

For N_{sb} =1 and PUSCH hopping type 1, the RA is L_{CRBs} contiguously allocated resource blocks (L_{CRBs}) in the first slot in subframe *i* from PRB index (RB_{START}), and L_{CRBs} contiguously allocated resource blocks (L_{CRBs}) in the second slot in subframe *i* from PRB index $N_{\text{RB}}^{\text{UL}} - L_{\text{CRBs}} - RB_{\text{START}}$.

For N_{sb} >1 and 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}) of the 1st slot RA in subframe *i* is defined as $n_{PRB}^{S1}(i) = \tilde{n}_{PRB}^{S1}(i) + \left\lceil N_{RB}^{PUCCH} / 2 \right\rceil$.

The lowest index PRB ($n_{PRB}(i)$) of the 2nd slot RA in subframe *i* is defined as $n_{PRB}(i) = \tilde{n}_{PRB}(i) + \left\lfloor N_{RB}^{PUCCH} / 2 \right\rfloor$.

For the inter-subframe only hopping case, the 1st slot RA is applied to even CURRENT_TX_NB, and the 2nd slot RA is applied to odd CURRENT_TX_NB.

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] section 5.3.4..

Table 8.4-2: PDCCH 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 procedure

If UL sequence hopping is configured in the cell, it applies to all reference symbols (SRS, PUSCH and PUCCH RS).

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 5-bit 'modulation and coding scheme and redundancy version' field (I_{MCS}) in the DCI, and
- check the 'CQI request' bit in DCI, and
- compute the total number of allocated PRBs (N_{PRB}) based on the procedure defined in Section 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 UE is to transmit the PUSCH in bundled mode, 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 is assumed to be as determined from DCI transported in the most recent PDCCH for the same transport block using $0 \le I_{\text{MCS}} \le 28$ except for the following case. If $I_{\text{MCS}} = 29$, the 'CQI request' bit in DCI format 0 is set to 1 and $N_{\text{PRB}} \le 4$, the modulation order is set to $Q_m = 2$.

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 $0 \le I_{\text{MCS}} \le 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 8.6.1-1. The UE shall then follow the procedure in Section 7.1.7.2.1 to determine the transport block size.

For $29 \le I_{\text{MCS}} \le 31$, the transport block size is assumed to be as determined from DCI transported in the initial PDCCH for the same transport block using $0 \le I_{\text{MCS}} \le 28$ except for the following case. If $I_{\text{MCS}} = 29$, the 'CQI request' bit in DCI format 0 is set to 1 and $N_{\text{PRB}} \le 4$, 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.

8.6.3 Control information MCS offset determination

$\Delta_{offset}^{HARQ-ACK}$, Δ_{offset}^{RI} and Δ_{offset}^{CQI} shall be configured to values according to Table 8.6.3-1 with the higher layer signalled indexes $I_{offset}^{HARQ-ACK}$, I_{offset}^{RI}, and I_{offset}^{CQI}, respectively.

Table 8.6.3-1: Mapping of HARQ-ACK, RI, and CQI offset values and the index signalled by higher layers

Signalled index by higher layers	$\Delta_{offset}^{HARQ-ACK}$ [dB]	Δ_{offset}^{RI} [dB]	Δ_{offset}^{CQI} [dB]
0	3	1	-1.0
1	4	2	0
2	5	3	0.5
3	6	4	1.0
4	7	5	1.5
5	8	6	2.0
6	9	7	2.5
7	10	8	3.0
8	11	9	3.5
9	12	10	4.0
10	13	11	4.5
11	reserved	12	5.0
12	reserved	13	5.5

13	reserved	reserved	6.0
14	reserved	reserved	7.0
15	reserved	reserved	8.0

8.7 UE Transmit Antenna Selection

UE transmit antenna selection when configured is only applicable with DCI Format 0 and FDD.

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 consists of a set of CCEs, numbered from 0 to $N_{\mathrm{CCE},k}-1$ according to Section 6.8.2 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 for control information in every non-DRX subframe, where monitoring implies attempting to decode each of the PDCCHs in the set according to all the monitored DCI formats. The UE is not required to decode control information on a PDCCH if the channel-code rate is larger than 3/4, where channel-code rate is defined as number of downlink control information bits (including RNTI) divided by the number of physical channel bits on the PDCCH.

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. 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, $i = 0,\cdots,L-1$ and $m = 0,\cdots,M^{(L)}-1$. $M^{(L)}$ is the number of PDCCH candidates to monitor in the given search space.

The UE shall monitor one common search space at each of the aggregation levels 4 and 8 and one UE-specific search space at each of the aggregation levels 1, 2, 4, 8. The common and UE-specific search spaces may overlap.

The aggregation levels defining the search spaces and the DCI formats that the UE shall monitor the respective search spaces are listed in Table 9.1.1-1. The notation 3/3A implies that the UE shall monitor DCI formats 3 or 3A as determined by the configuration. The DCI formats that the UE shall monitor in the UE specific search spaces is a subset of those listed in Table 9.1.1-1 and depend on the configured transmission mode as defined in Section 7.1.

Table 9.1.1-1: PDCCH candidates monitored by a UE.

Search space $S_k^{(L)}$	Number of PDCCH	DCI formats

Type	Aggregation level L	Size [in CCEs]	candidates $M^{(L)}$	
UE-specific	1	6	6	0, 1, 1A,1B, 2
	2	12	6	
	4	8	2	
	8	16	2	
Common	4	16	4	0, 1A, 1C, 3/3A
	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

$$Y_k = (A \cdot Y_{k-1}) \bmod D$$

where $Y_{-1} = n_{\mathrm{RNTI}} \neq 0$, $A = 39827$ and $D = 65537$.

9.1.2 PHICH Assignment Procedure

For scheduled PUSCH transmissions in subframe *n*, a UE shall determine the corresponding PHICH resource in subframe $n+ k_{PHICH}$, where k_{PHICH} is always 4 for FDD and is given in table 9.1.2-1 for TDD.

Table 9.1.2-1: k_{PHICH} for TDD

TDD UL/DL Configuration	UL 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 determined from lowest index PRB of the uplink resource allocation and the 3-bit uplink demodulation reference symbol (DMRS) cyclic shift associated with the PUSCH transmission, both indicated in the PDCCH with DCI format 0 granting the PUSCH transmission.

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:

$$n_{PHICH}^{group} = (I_{PRB\_RA}^{lowest\_index} + n_{DMRS}) \bmod N_{PHICH}^{group} + I_{PHICH} N_{PHICH}^{group}$$
$$n_{PHICH}^{seq} = (\lfloor I_{PRB\_RA}^{lowest\_index} / N_{PHICH}^{group} \rfloor + n_{DMRS}) \bmod 2N_{SF}^{PHICH}$$

where

- n_{DMRS} is mapped to the cyclic shift for DMRS field in DCI format 0 in [4], according to Table 9.1.2-2.
- N_{SF}^{PHICH} is the spreading factor size used for PHICH modulation as described in section 6.9.1 in [3].
- $I_{PRB\_RA}^{lowest\_index}$ is the lowest index PRB of the uplink resource allocation
- N_{PHICH}^{group} is the number of PHICH groups configured by higher layers as described in section 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 DCI format 0 in [4]

Cyclic Shift for DMRS Field in DCI format 0 in [4]	n_{DMRS}
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

10 Physical uplink control channel procedures

10.1 UE procedure for determining physical uplink control channel assignment

Uplink control information (UCI) in subframe n shall be transmitted

- on PUCCH using format 1/1a/1b or 2/2a/2b if the UE is not transmitting on PUSCH in subframe n
- on PUSCH if the UE is transmitting on PUSCH in subframe n

Throughout this section, subframes are numbered in monotonically increasing order; if the last subframe of a radio frame is denoted k, the first subframe of the next radio frame is denoted $k+1$.

The following combinations of uplink control information on PUCCH are supported:

- HARQ-ACK using PUCCH format 1a or 1b
- HARQ-ACK multiplexing using PUCCH format 1b with channel selection
- Scheduling request (SR) using PUCCH format 1
- HARQ-ACK and SR using PUCCH format 1a or 1b
- CQI using PUCCH format 2

- CQI and HARQ-ACK using PUCCH format
  - 2a or 2b for normal cyclic prefix
  - 2 for extended cyclic prefix

The parameter *Simultaneous-AN-and-CQI* provided by higher layers determine if a UE can transmit a combination of CQI and HARQ-ACK on PUCCH in the same subframe.

For TDD, two ACK/NACK feedback modes are supported by higher layer configuration.

- ACK/NACK bundling using PUCCH format 1a or 1b, which is the default mode
- ACK/NACK multiplexing using PUCCH format 1b with channel selection

TDD ACK/NACK bundling is performed per codeword across multiple DL subframes associated with a single UL subframe, by a logical AND operation of all the corresponding individual (dynamically and semi-persistently scheduled) PDSCH transmission ACK/NACKs. The bundled 1 or 2 ACK/NACK bits are transmitted using PUCCH format 1a and PUCCH format 1b, respectively.

For TDD ACK/NACK multiplexing, spatial ACK/NACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual ACK/NACKs.

For FDD, the UE shall use PUCCH resource $n^{(1)}_{\mathrm{PUCCH}}$ for transmission of HARQ-ACK in subframe n, where

- for a dynamically scheduled PDSCH indicated by the detection of a corresponding PDCCH with DCI format 1A/1/2 in subframe $n-4$, the UE shall use $n^{(1)}_{\mathrm{PUCCH}} = n_{\mathrm{CCE}} + N^{(1)}_{\mathrm{PUCCH}}$, where n_{CCE} is the number of the first CCE used for transmission of the corresponding DCI assignment and $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers.
- for a semi-persistently scheduled PDSCH transmission and where there is not a corresponding DCI detected in subframe $n-4$, the value of $n^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers.

For TDD ACK/NACK bundling, the UE shall use PUCCH resource $n^{(1)}_{\mathrm{PUCCH}}$ for transmission of HARQ-ACK in subframe n, where

- for dynamically scheduled PDSCH indicated by the detection of corresponding PDCCH(s) with DCI format 1A/1/2 within subframe(s) $n-k$, where $k \in K$ and K (defined in Table 10.1-1) 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]), the UE first selects a p value out of {0, 1, 2, 3} which makes $N_p \le n_{CCE} < N_{p+1}$ and shall use $n^{(1)}_{PUCCH} = (M - m - 1) \times N_p + m \times N_{p+1} + n_{CCE} + N^{(1)}_{PUCCH}$, where $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers, $N_p = \max\{0, \lfloor [N^{\mathrm{DL}}_{\mathrm{RB}} \times (N^{\mathrm{RB}}_{\mathrm{sc}} \times p - 4)]/36 \rfloor\}$, and n_{CCE} is the number of the first CCE used for transmission of the corresponding DCI format 1A/1/2 in subframe $n - k_m$ and the corresponding *m*, where k_m is the smallest value in set K such that UE detects a DCI format 1A/1/2 in subframe $n - k_m$.
- for a semi-persistently scheduled PDSCH transmission and where there is not a corresponding DCI detected within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1-1, the value of $n^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers.

Table 10.1-1: 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	-	-	TBD	-	-	-	-	-	-	-
6	-	-	7	7	5	-	-	7	7	-

For TDD ACK/NACK multiplexing and sub-frame n, denote $n^{(1)}_{\mathrm{PUCCH,i}}$ as the ACK/NACK 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 10.1-1) and $0 \le i \le M-1$.

- For dynamically scheduled PDSCH transmission in sub-frame $n-k_i$ where $k_i \in K$, the ACK/NACK resource $n^{(1)}_{PUCCH,i} = (M-i-1)\times N_p + i \times N_{p+1} + n_{CCE,i} + N^{(1)}_{PUCCH}$, where p is selected from {0, 1, 2, 3} such that $N_p \le n_{CCE} < N_{p+1}$, $N_p = \max\left\{0, \left\lfloor [N^{\mathrm{DL}}_{\mathrm{RB}} \times (N^{\mathrm{RB}}_{\mathrm{sc}} \times p - 4)]/36 \right\rfloor\right\}$, $n_{\mathrm{CCE,i}}$ is the number of the first CCE used for transmission of the corresponding DCI format 1A/1/2 in subframe $n-k_i$, and $N^{(1)}_{\mathrm{PUCCH}}$ is configured by higher layers.
- For a semi-persistently scheduled PDSCH transmission and where there is not a corresponding DCI detected in subframe $n-k_i$, the value of $n^{(1)}_{\mathrm{PUCCH,i}}$ is configured by higher layers.

The UE shall transmit $b(0),b(1)$ on an ACK/NACK resource $n^{(1)}_{\mathrm{PUCCH}}$ in sub-frame n using PUCCH format 1b according to section 5.4.1 in [3]. The value of $b(0),b(1)$ and the ACK/NACK resource $n^{(1)}_{\mathrm{PUCCH}}$ are generated according to Table 10.1-2, 10.1-3, and 10.1-4 for M = 2, 3, and 4, respectively. In case $b(0),b(1)$ are mapped to 'N/A,' then the UE shall not transmit ACK/NACK response in sub-frame n.

Table 10.1-2: Transmission of ACK/NACK multiplexing for M = 2

HARQ-ACK(1), HARQ-ACK(2)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0),b(1)$
ACK, ACK	$n^{(1)}_{\mathrm{PUCCH,2}}$	1, 1
ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH,1}}$	0, 1
NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH,2}}$	0, 0
NACK/DTX, NACK	$n^{(1)}_{\mathrm{PUCCH,2}}$	1, 0
NACK, DTX	$n^{(1)}_{\mathrm{PUCCH,1}}$	1, 0
DTX, DTX	N/A	N/A

Table 10.1-3: Transmission of ACK/NACK multiplexing for M = 3

HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n^{(1)}_{\mathrm{PUCCH}}$	$b(0),b(1)$

ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 1
ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},1}$	1, 1
ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	0, 1
NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	0, 0
NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},3}$	0, 0
DTX, DTX, NACK	$n^{(1)}_{\text{PUCCH},3}$	0, 1
DTX, NACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
NACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
DTX, DTX, DTX	N/A	N/A

Table 10.1-4: Transmission of ACK/NACK multiplexing for M = 4

HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3), HARQ-ACK(4)	$n^{(1)}_{\text{PUCCH}}$	$b(0), b(1)$
ACK, ACK, ACK, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
NACK/DTX,NACK/DTX,NACK,DTX	$n^{(1)}_{\text{PUCCH},3}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},2}$	1, 0
NACK, DTX, DTX, DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},2}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n^{(1)}_{\text{PUCCH},4}$	0, 1
NACK/DTX, NACK/DTX, NACK/DTX, NACK	$n^{(1)}_{\text{PUCCH},4}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\text{PUCCH},3}$	0, 1
ACK, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\text{PUCCH},1}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n^{(1)}_{\text{PUCCH},1}$	1, 1

NACK/DTX, ACK, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},4}$	0, 1
NACK/DTX, NACK, DTX, DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	1, 0
NACK/DTX, ACK, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},4}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},2}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n^{(1)}_{\mathrm{PUCCH},4}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n^{(1)}_{\mathrm{PUCCH},3}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n^{(1)}_{\mathrm{PUCCH},4}$	0, 0
DTX, DTX, DTX, DTX	N/A	N/A

The scheduling request (SR) shall be transmitted on the PUCCH resource $n^{(1)}_{\mathrm{PUCCH}} = n^{(1)}_{\mathrm{PUCCH,SRI}}$ as defined in [3], where $n^{(1)}_{\mathrm{PUCCH,SRI}}$ is UE specific and configured by higher layers. The SR configuration for SR transmission periodicity and subframe offset is defined by SR configuration index I_{SR} in Table 10.1-5. The SR transmission periodicity is selected from {5ms, 10ms, 20ms, 40ms, 80ms, OFF}, where OFF indicates an infinite SR transmission periodicity.

Table 10.1-5: UE-specific SR periodicity and subframe offset configuration

SR configuration Index I_{SR}	SR periodicity (ms)	SR subframe offset
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	OFF	N/A

10.2 Uplink ACK/NACK timing

For FDD, the UE shall upon detection of a PDSCH transmission in subframe *n-4* intended for the UE and for which an ACK/NACK shall be provided, transmit the ACK/NACK response in subframe *n*.

For TDD, the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1-1 intended for the UE and for which ACK/NACK response shall be provided, transmit the ACK/NACK response in UL subframe *n*.

For TDD, the value of Downlink Assignment Index (DAI) denotes the minimum number of dynamic downlink assignment(s) transmitted to the corresponding UE within all the subframe(s) $n-k$, where $k \in K$, and it can be updated from subframe to subframe. The value of DAI is shown in Table 10.2-2. Denote V_{DAI} as the value of DAI in subframe $n-k_m$, where k_m is the smallest value in set K such that UE detects a DCI format 1A/1/2 in subframe $n-k_m$. Further denote U_{DAI} as the number of detected dynamic downlink assignment(s) by the UE within the subframe(s) $n-k$, where $k \in K$. If $V_{DAI} \neq (U_{DAI}-1) \bmod 4 + 1$, the UE shall not transmit ACK/NACK when in ACK/NACK bundling feedback mode.

Table 10.2-2: Value of Downlink Assignment Index

DAI MSB, LSB	Value of DAI
0,0	1
0,1	2
1,0	3
1,1	4

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	RAN_37	RP-070737	-	-	Approved version	2.1.0	8.0.0
28/11/07	RAN_38	RP-070949	0001	2	Update of 36.213	8.0.0	8.1.0
05/03/08	RAN_39	RP-080145	0002	-	Update of TS36.213 according to changes listed in cover sheet	8.1.0	8.2.0
28/05/08	RAN_40	RP-080434	0003	1	PUCCH timing and other formatting and typo corrections	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0006	1	PUCCH power control for non-unicast information	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0008	-	UE ACK/NACK Procedure	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0009	-	UL ACK/NACK timing for TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0010	-	Specification of UL control channel assignment	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0011	-	Precoding Matrix for 2Tx Open-loop SM	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0012	-	Clarifications on UE selected CQI reports	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0013	1	UL HARQ Operation and Timing	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0014	-	SRS power control	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0015	1	Correction of UE PUSCH frequency hopping procedure	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0017	4	Blind PDCCH decoding	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0019	1	Tx Mode vs DCI format is clarified	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0020	-	Resource allocation for distributed VRB	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0021	2	Power Headroom	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0022	-	Clarification for RI reporting in PUCCH and PUSCH reporting modes	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0025	-	Correction of the description of PUSCH power control for TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0026	-	UL ACK/NACK procedure for TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0027	-	Indication of radio problem detection	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0028	-	Definition of Relative Narrowband TX Power Indicator	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0029	-	Calculation of $\Delta_{TF}(i)$ for UL-PC	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0030	-	CQI reference and set S definition, CQI mode removal, and Miscellanious	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0031	-	Modulation order and TBS determination for PDSCH and PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0032	-	On Sounding RS	8.2.0	8.3.0
28/05/08	RAN_40	RP-080426	0033	-	Multiplexing of rank and CQI/PMI reports on PUCCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080466	0034	-	Timing advance command responding time	8.2.0	8.3.0
09/09/08	RAN_41	RP-080670	37	2	SRS hopping pattern for closed loop antenna selection	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	39	2	Clarification on uplink power control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	41	-	Clarification on DCI formats using resource allocation type 2	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	43	2	Clarification on tree structure of CCE aggregations	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	46	2	Correction of the description of PUCCH power control for TDD	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	47	1	Removal of CR0009	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	48	1	Correction of mapping of cyclic shift value to PHICH modifier	8.3.0	8.4.0
09/09/08	RAN_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	RAN_41	RP-080670	50	-	Correction of maximum TBS sizes	8.3.0	8.4.0
09/09/08	RAN_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	RAN_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	RAN_41	RP-080670	55	1	Clarification on mapping of Differential CQI fields	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	59	1	PUSCH Power Control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	60	-	RB restriction and modulation order for CQI-only transmission on PUSCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	61	-	Modulation order determination for uplink retransmissions	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	62	2	Introducing missing L1 parameters into 36.213	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	63	2	Correcting the range and representation of delta_TF_PUCCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	64	1	Adjusting TBS sizes to for VoIP	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	67	-	Correction to the downlink resource allocation	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	68	-	Removal of special handling for PUSCH mapping in PUCCH region	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	69	-	Correction to the formulas for uplink power control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	70	1	Definition of Bit Mapping for DCI Signalling	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	71	-	Clarification on PUSCH TPC commands	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	72	1	Reference for CQI/PMI Reporting Offset	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	74	-	Correction to the downlink/uplink timing	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	75	-	Correction to the time alignment command	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	77	1	Correction of offset signalling of UL Control information MCS	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	78	2	DCI format1C	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	80	-	Correction to Precoder Cycling for Open-loop Spatial Multiplexing	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	81	1	Clarifying Periodic CQI Reporting using PUCCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	84	1	CQI reference measurement period	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	86	-	Correction on downlink multi-user MIMO	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	87	-	PUCCH Reporting	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	88	1	Handling of Uplink Grant in Random Access Response	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	89	-	Correction to UL Hopping operation	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	90	-	DRS EPRE	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	92	-	Uplink ACK/NACK mapping for TDD	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	93	-	UL SRI Parameters Configuration	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	94	-	Miscellaneous updates for 36.213	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	95	-	Clarifying Requirement for Max PDSCH Coding Rate	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	96	-	UE Specific SRS Configuration	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	97	-	DCI Format 1A changes needed for scheduling Broadcast Control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	98	-	Processing of TPC bits in the random access response	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	100	1	Support of multi-bit ACK/NAK transmission in TDD	8.3.0	8.4.0

History

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