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Foreword

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1 Scope

The present document specifies and establishes the characteristics of the physicals layer procedures for control operations in 5G-NR.

2 References

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

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

[2] 3GPP TS 38.201: "NR; Physical Layer – General Description"

[3] 3GPP TS 38.202: "NR; Services provided by the physical layer"

[4] 3GPP TS 38.211: "NR; Physical channels and modulation"

[5] 3GPP TS 38.212: "NR; Multiplexing and channel coding"

[6] 3GPP TS 38.214: "NR; Physical layer procedures for data"

[7] 3GPP TS 38.215: "NR; Physical layer measurements"

[8] 3GPP TS 38.101: "NR; User Equipment (UE) radio transmission and reception"

[9] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception"

[10] 3GPP TS 38.133: "NR; Requirements for support of radio resource management"

[11] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

[12] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification"

[13] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures"

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in [1, TR 21.905] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in [1, TR 21.905].

3.2 Symbols

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

3.3 Abbreviations

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

BWP	Bandwidth part
CB	Code block
CBG	Code block group
CCE	Control channel element
CRC	Cyclic redundancy check
CSI	Channel state information
DCI	Downlink control information
DL	Downlink
EPRE	Energy per resource element
HARQ-ACK	Hybrid automatic repeat request acknowledgement
MCG	Master cell group
MCS	Modulation and coding scheme
PBCH	Physical broadcast channel
PDCCH	Physical downlink control channel
PDSCH	Physical downlink shared channel
PRACH	Physical random access channel
PSS	Primary synchronization signal
PUCCH	Physical uplink control channel
PUSCH	Physical uplink shared channel
RB	Resource block
RE	Resource element
RS	Reference signal
RSRP	Reference signal received power
SCG	Secondary cell group
SFN	System frame number
SPS	Semi-persistent scheduling
SR	Scheduling request

SRS	Sounding reference signal
SSS	Secondary synchronization signal
TA	Timing advance
TAG	Timing advance group
UCI	Uplink control information
UE	User equipment
UL	Uplink

4 Synchronization procedures

4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell.

A UE receives the following synchronization signals (SS) in order to perform cell search: the primary synchronization signal (PSS) and secondary synchronization signal (SSS) as defined in [4, TS 38.211].

A UE shall assume that reception occasions of a physical broadcast channel (PBCH), PSS, and SSS are in consecutive symbols, as defined in [4, TS 38.211], and form a SS/PBCH block. The UE shall assume that SSS and PBCH DM-RS have same EPRE.

For a half frame with SS/PBCH blocks, the number and first symbol indexes for candidate SS/PBCH blocks are determined according to the subcarrier spacing of SS/PBCH blocks as follows.

- Case A - 15 kHz subcarrier spacing: the first symbols of the candidate SS/PBCH blocks have indexes of {2, 8} + 14*n. For carrier frequencies smaller than or equal to 3 GHz, n=0, 1. For carrier frequencies larger than 3 GHz and smaller than or equal to 6 GHz, n=0, 1, 2, 3.
- Case B - 30 kHz subcarrier spacing: the first symbols of the candidate SS/PBCH blocks have indexes {4, 8, 16, 20} + 28*n. For carrier frequencies smaller than or equal to 3 GHz, n=0. For carrier frequencies larger than 3 GHz and smaller than or equal to 6 GHz, n=0, 1.
- Case C - 30 kHz subcarrier spacing: the first symbols of the candidate SS/PBCH blocks have indexes {2, 8} + 14*n. For carrier frequencies smaller than or equal to 3 GHz, n=0, 1. For carrier frequencies larger than 3 GHz and smaller than or equal to 6 GHz, n=0, 1, 2, 3.
- Case D - 120 kHz subcarrier spacing: the first symbols of the candidate SS/PBCH blocks have indexes {4, 8, 16, 20} + 28*n. For carrier frequencies larger than 6 GHz, n=0, 1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 17, 18.
- Case E - 240 kHz subcarrier spacing: the first symbols of the candidate SS/PBCH blocks have indexes {8, 12, 16, 20, 32, 36, 40, 44} + 56*n. For carrier frequencies larger than 6 GHz, n=0, 1, 2, 3, 5, 6, 7, 8.

The candidate SS/PBCH blocks in a half frame are indexed in an ascending order in time from 0 to $L-1$. A UE shall determine the 2 LSB bits, for $L=4$, or the 3 LSB bits, for $L>4$, of a SS/PBCH block index per half frame from a one-to-one mapping with an index of the DM-RS sequence transmitted in the PBCH. For $L=64$, the UE shall determine the 3

MSB bits of the SS/PBCH block index per half frame from higher layer parameter *SSB-index-explicit*.

A UE can be configured by parameter *SSB-transmitted-SIB1*, indexes of SS/PBCH blocks for which the UE shall not receive other signals or channels in REs that overlap with REs corresponding to the SS/PBCH blocks. A UE can also be configured per serving cell, by higher layer parameter *SSB-transmitted*, indexes of SS/PBCH blocks for which the UE shall not receive other signals or channels in REs that overlap with REs corresponding to the SS/PBCH blocks. A configuration by *SSB-transmitted* overrides a configuration by *SSB-transmitted-SIB1*. A UE can be configured per serving cell by higher layer parameter *SSB-timing* a periodicity of the half frames for reception of SS/PBCH blocks per serving cell. If the UE is not configured a periodicity of the half frames for receptions of SS/PBCH blocks, the UE shall assume a periodicity of a half frame. A UE shall assume that the periodicity is same for all SS/PBCH blocks in the serving cell.

For initial cell selection, a UE may assume that half frames with SS/PBCH blocks occur with a periodicity of 2 frames.

For a serving cell without transmission of SS/PBCH blocks, a UE acquires time and frequency synchronization with the serving cell based on receptions of SS/PBCH blocks on the PCell, or on the PSCell, of the cell group for the serving cell.

4.2 Transmission timing adjustments

Upon reception of a timing advance command for a TAG containing the primary cell or PSCell, the UE shall adjust uplink transmission timing for PUCCH/PUSCH/SRS of the primary cell or PSCell based on the received timing advance command.

The UL transmission timing for PUSCH/SRS of a secondary cell is the same as the primary cell if the secondary cell and the primary cell belong to the same TAG. If the primary cell in a TAG operates with paired DL/UL spectrum and a secondary cell in the same TAG operates with unpaired DL/UL spectrum, UE may assume that $N_{\mathrm{TA}} \geq 624 \cdot 64/2^{\mu}$ for subcarrier spacing of $2^{\mu} \cdot 15$ kHz, $\mu = 0,1,2,3,4,5$.

If the UE is configured with a SCG, the UL transmission timing for PUSCH/SRS of a secondary cell other than the PSCell is the same as the PScell if the secondary cell and the PSCell belong to the same TAG.

Upon reception of a timing advance command or a timing adjustment indication for a TAG not containing the primary cell or PSCell, if all the serving cells in the TAG have the same duplex mode type, the UE shall adjust uplink transmission timing for PUSCH/SRS of all the secondary cells in the TAG based on the received timing advance command or a timing adjustment indication where the UL transmission timing for PUSCH /SRS is the same for all the secondary cells in the TAG.

Upon reception of a timing advance command or a timing adjustment indication for a TAG not containing the primary cell or PSCell, if a serving cell in the TAG has a different duplex mode type compared to the duplex mode type of another serving cell in the same TAG, the UE shall adjust uplink transmission timing for PUSCH/SRS of all the secondary cells in the TAG by using $N_{\text{TA\_offset}} = 624 \cdot 64/2^{\mu}$ regardless of the duplex mode type of the serving cells and based on the received timing advance command or a timing adjustment indication where the UL transmission timing for PUSCH /SRS is the same for all the secondary cells in the TAG. $N_{\text{TA\_offset}}$ is described in [4, TS 38.211].

The timing adjustment indication specified in [12, TS 38.331] indicates the initial N_{TA} used for a TAG. For a subcarrier spacing of $2^{\mu} \cdot 15$ kHz, the timing advance command for a TAG indicates the change of the uplink timing relative to the current uplink timing for the TAG as multiples of $16 \cdot 64 \cdot T_c / 2^{\mu}$. The start timing of the random access preamble is specified in [4, TS 38.211].

In case of random access response, a timing advance command [11, TS 38.321], T_{A}, for a TAG indicates N_{TA} values by index values of T_{A} = 0, 1, 2, ..., 256 if the UE is configured with a SCG, and T_{A} = 0, 1, 2, ..., 1282 otherwise, where an amount of the time alignment for the TAG for subcarrier spacing of $2^{\mu} \cdot 15$ kHz is given by $N_{\text{TA}} = T_{\text{A}} \cdot 16 \cdot 64/2^{\mu}$. N_{TA} is defined in [4, TS 38.211] and is relative to the subcarrier spacing of the first uplink transmission from the UE after the reception of the random access response.

In other cases, a timing advance command [11, TS 38.321], T_{A}, for a TAG indicates adjustment of the current N_{TA} value, $N_{\text{TA\_old}}$, to the new N_{TA} value, $N_{\text{TA\_new}}$, by index values of T_{A} = 0, 1, 2,..., 63, where for a subcarrier spacing of $2^{\mu} \cdot 15$ kHz, $N_{\text{TA\_new}} = N_{\text{TA\_old}} + (T_{\text{A}} - 31) \cdot 16 \cdot 64/2^{\mu}$. If a UE is configured with two UL carriers in a serving cell, where the subcarrier spacing for a first UL carrier is different than the subcarrier spacing for a second carrier, the timing advance command value is relative to the smaller subcarrier spacing.

Adjustment of N_{TA} value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing for the TAG by a given amount, respectively.

For a timing advance command received on slot n, the corresponding adjustment of the uplink transmission timing applies from the beginning of slot $n+6$. If the received downlink timing changes and is not compensated or is only partly compensated by the uplink timing adjustment without timing advance command as specified in [10, TS 38.133], the UE changes N_{TA} accordingly.

4.3 Timing for secondary cell activation / deactivation

When a UE receives an activation command [11, TS 38.321] for a secondary cell in slot *n*, the corresponding actions in [8] shall be applied no later than the minimum requirement defined in [12, TS 38.331] and no earlier than slot *n+k*, except for the following:

- the actions related to CSI reporting on a serving cell which is active in slot *n+k*
- the actions related to the *sCellDeactivationTimer* associated with the secondary cell [11, TS 38.321]

which shall be applied in slot *n+k*

- the actions related to CSI reporting on a serving cell which is not active in slot *n+k*

which shall be applied in the earliest slot after *n+k* in which the serving cell is active.

When a UE receives a deactivation command [11, TS 38.321] for a secondary cell or the *sCellDeactivationTimer* associated with the secondary cell expires in slot *n*, the corresponding actions in [11, TS 38.321] shall apply no later than the minimum requirement defined in [12, TS 38.331], except for the actions related to CSI reporting on a serving cell which is active which shall be applied in slot *n+k.*

5 Radio link monitoring

The downlink radio link quality of the primary cell shall be monitored by a UE for the purpose of indicating out-of-sync/in-sync status to higher layers. The UE is not required to monitor the downlink radio link quality in DL BWPs other than the active DL BWP on the primary cell.

If the UE is configured with a SCG, as described in [12, TS 38.331], and the parameter *rlf-TimersAndConstantsSCG* is provided by the higher layers and is not set to release, the downlink radio link quality of the PSCell of the SCG shall be monitored by the UE for the purpose of indicating out-of-sync/in-sync status to higher layers.

A UE can be configured for each SpCell [11, TS 38.321] with a set of resource indexes for radio link monitoring by higher layer parameter *RLM-RS-List*. The UE is provided by higher layer parameter *RLM-RS* an association between a resource index, from the set of resource indexes, with either a CSI-RS resource configuration or a SS/PBCH block. For a CSI-RS resource configuration, the UE is provided a corresponding index by higher layer parameter *RLM-CSIRS*. For a SS/PBCH block, the UE is provided a corresponding index by higher layer parameter *RLM-SSB*.

In non-DRX mode operation, the physical layer in the UE shall assess the radio link quality, evaluated over the previous time period defined in [10, TS 38.133] against thresholds (Q_{out} and Q_{in}) configured by higher layer parameter *RLM-IS-OOS-thresholdConfig*.

In DRX mode operation, the physical layer in the UE shall assess the radio link quality, evaluated over the previous time period defined in [10, TS 38.133], against thresholds (Q_{out} and Q_{in}).

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

the radio link quality is better than the threshold Q_{in} for any resource in the set of resources for radio link monitoring, the physical layer in the UE shall in frames where the radio link quality is assessed indicate in-sync to higher layers.

6 Link reconfiguration procedures

A UE can be configured, for a serving cell, with a set $\bar{q}_0$ of periodic CSI-RS resource configuration indexes by higher layer parameter *Beam-Failure-Detection-RS-ResourceConfig* and with a set $\bar{q}_1$ of CSI-RS resource configuration indexes and/or SS/PBCH block indexes by higher layer parameter *Candidate-Beam-RS-List* for radio link quality measurements on the serving cell. If the UE is not provided with higher layer parameter *Beam-Failure-Detection-RS-ResourceConfig*, the UE determines $\bar{q}_0$ to include SS/PBCH blocks and periodic CSI-RS configurations with same values for higher layer parameter *TCI-StatesPDCCH* as for control resource sets that the UE is configured for monitoring PDCCH as described in Subclause 10.1.

The physical layer in the UE shall assess the radio link quality according to the set $\bar{q}_0$ of resource configurations against the threshold $Q_{out,LR}$ [10, TS 38.133]. The threshold $Q_{out,LR}$ corresponds to the default value of higher layer parameter *RLM-IS-OOS-thresholdConfig* and *Beam-failure-candidate-beam-threshold*, respectively. For the set $\bar{q}_0$, the UE shall assess the radio link quality only according to periodic CSI-RS resource configurations or SS/PBCH blocks that are quasi co-located, as described in [6, TS 38.214], with the DM-RS of PDCCH receptions DM-RS monitored by the UE. The UE applies the configured $Q_{in,LR}$ threshold for the periodic CSI-RS resource configurations. The UE applies the $Q_{out,LR}$ threshold for SS/PBCH blocks after scaling a SS/PBCH block transmission power with a value provided by higher layer parameter *Pc_SS*.

The physical layer in the UE shall, in slots where the radio link quality according to the set $\bar{q}_0$ is assessed, provide an indication to higher layers when the radio link quality for all corresponding resource configurations in the set $\bar{q}_0$ that the UE uses to assess the radio link quality is worse than the threshold $Q_{out,LR}$.

The UE shall provide to higher layers information identifying a periodic CSI-RS configuration index or SS/PBCH block index q_{new} from the set $\bar{q}_1$.

A UE is configured with one control resource set by higher layer parameter *Beam-failure-Recovery-Response-CORESET*. The UE may receive from higher layers, by parameter *Beam-failure-recovery-request-RACH-Resource*, a configuration for a PRACH transmission as described in Subclause 8.1. After 4 slots from the slot of the PRACH transmission, the UE monitors PDCCH for a DCI format with CRC scrambled by C-RNTI, within a window configured by higher layer parameter *Beam-failure-recovery-request-window*, and receives PDSCH according to an antenna port quasi co-location associated with periodic CSI-RS configuration or SS/PBCH block with index q_{new} in set $\bar{q}_1$, in the control resource set configured by higher layer parameter *Beam-failure-Recovery-Response-CORESET*.

7 Uplink Power control

Uplink power control determines the transmit power of the different uplink physical channels or signals.

7.1 Physical uplink shared channel

For PUSCH, a UE first scales a linear value $\hat{P}_{\text{PUSCH},f,c}(i,j,q_d,l)$ of the transmit power $P_{\text{PUSCH},f,c}(i,j,q_d,l)$, with parameters as defined in Subclause 7.1.1, by the ratio of the number of antenna ports with a non-zero PUSCH transmission to the number of configured antenna ports for the transmission scheme. The resulting scaled power is then split equally across the antenna ports on which the non-zero PUSCH is transmitted.

7.1.1 UE behaviour

If a UE transmits a PUSCH on carrier f of serving cell c using parameter set configuration with index j and PUSCH power control adjustment state with index l, the UE shall determine the PUSCH transmission power $P_{\text{PUSCH},f,c}(i,j,q_d,l)$ in PUSCH transmission period i as

$$P_{\text{PUSCH},f,c}(i,j,q_d,l) = \min\begin{Bmatrix} P_{\text{CMAX},f,c}(i), \\ P_{\text{O\_PUSCH},f,c}(j) + 10\log_{10}(2^{\mu}\cdot M^{\text{PUSCH}}_{\text{RB},f,c}(i)) + \alpha_{f,c}(j)\cdot PL_{f,c}(q_d) + \Delta_{\text{TF},f,c}(i) + f_{f,c}(i,l) \end{Bmatrix} \text{ [dBm]}$$

where,

- $P_{\text{CMAX},f,c}(i)$ is the configured UE transmit power defined in [8, TS 38.101] for carrier f of serving cell c in PUSCH transmission period i.
- $P_{\text{O\_PUSCH},f,c}(j)$ is a parameter composed of the sum of a component $P_{\text{O\_NOMINAL\_PUSCH},f,c}(j)$ and a component $P_{\text{O\_UE\_PUSCH},f,c}(j)$ where $j \in \{0,1,...,,J-1\}$.
  - For a PUSCH (re)transmission corresponding to a random access response grant, $j=0$, $P_{\text{O\_UE\_PUSCH},f,c}(0)=0$, and $P_{\text{O\_NOMINAL\_PUSCH},f,c}(0) = P_{\text{O\_PRE}} + \Delta_{PREAMBLE\_Msg3}$, where the parameter *preambleInitialReceivedTargetPower* [11, TS 38.321] (for $P_{\text{O\_PRE}}$) and *Delta-preamble-msg3* (for $\Delta_{PREAMBLE\_Msg3}$) are provided by higher layers for carrier f of serving cell c.
  - For a PUSCH (re)transmission corresponding to a grant-free configuration or semi-persistent grant, $j=1$, $P_{\text{O\_NOMINAL\_PUSCH},f,c}(1)$ is provided by higher layer parameter *po-nominal-pusch-withoutgrant*, and $P_{\text{O\_UE\_PUSCH},f,c}(1)$ is provided by higher layer parameter *po-ue-pusch* for carrier f of serving cell c.
  - For $j \in \{2,...,,J-1\} = S_J$, a $P_{\text{O\_NOMINAL\_PUSCH},f,c}(j)$ value, applicable for all $j \in S_J$, is provided by higher layer parameter *po-nominal-pusch-withgrant* for each carrier f of serving cell c and a set of $P_{\text{O\_UE\_PUSCH},f,c}(j)$ values are provided by a set of higher layer parameters *po-pusch-alpha-set* and a respective index by higher layer

parameter *poalphasetindex* for carrier f of serving cell c where the size of the set is $J-2$ and is indicated by higher layer parameter *num-po-alpha-sets*.

- $M_{\mathrm{RB},f,c}^{\mathrm{PUSCH}}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks for PUSCH transmission period i on carrier f of serving cell c and μ is defined in [4, TS 38.211].

- For $j=0$, $\alpha_{f,c}(j)=1$. For $j=1$, $\alpha_{f,c}(1)$ is provided by higher layer parameter *alpha* . For $j\in S_J$, a set of $\alpha_{f,c}(j)$ values are provided by a set of higher layer parameters *po-pusch-alpha-set* and a respective index by higher layer parameter *poalphasetindex* for carrier f of serving cell c where the size of the set is $J-2$ and is indicated by higher layer parameter *num-po-alpha-sets*.

- $PL_{f,c}(q_d)$ is a downlink path-loss estimate in dB calculated by the UE using reference signal (RS) resource q_d for carrier f of serving cell c, where the UE is configured with a number of RS resources by higher layer parameter *num-pusch-pathlossReference-rs* and a respective set of RS configurations for the number of RS resources is provided by higher layer parameter *pusch-pathloss-Reference-rs* that includes one or both of a set of SS/PBCH block indexes provided by higher layer parameter *pusch-pathlossReference-SSB* and a set of CSI-RS configuration indexes provided by higher layer parameter *pusch-pathlossReference-CSIRS*. The UE identifies a RS resource in the set of RS resources to correspond to a SS/PBCH block or to a CSI-RS configuration as provided by higher layer parameter *pusch-pathlossreference-index*.

  If the UE is configured by higher layer parameter *SRS-SpatialRelationInfo* a mapping between a set of SRS resources and a set of RS resources for obtaining a downlink path-loss estimate, the UE uses the RS resources indicated by a value of a SRI field in DCI format 0_0 or DCI format 0_1 that schedules the PUSCH transmission [5, TS 38.212] to obtain the downlink path-loss estimate.

  $PL_{f,c}(q_d)$ = *referenceSignalPower* – higher layer filtered RSRP, where *referenceSignalPower* is provided by higher layers and RSRP is defined in [7, TS 38.215] for the reference serving cell and the higher layer filter configuration is defined in [12, TS 38.331] for the reference serving cell.

  For $j=0$, *referenceSignalPower* is configured by higher layer parameter *SS-PBCHBlockPower*. For $j>0$, *referenceSignalPower* is configured by either higher layer parameter *SS-PBCHBlockPower* or, when periodic CSI-RS transmission is configured, by higher layer parameter *Pc-SS* providing an offset of the CSI-RS transmission power relative to the SS/PBCH block transmission power [6, TS 38.214].

- $\Delta_{\mathrm{TF},f,c}(i)=10\log_{10}\left(\left(2^{\mathrm{BPRE}\cdot K_s}-1\right)\cdot\beta_{\mathrm{offset}}^{\mathrm{PUSCH}}\right)$ for $K_S=1.25$ and $\Delta_{\mathrm{TF},f,c}(i)=0$ for $K_S=0$ where K_S is provided by higher layer parameter *deltaMCS-Enabled* provided for each carrier f and serving cell c. If the PUSCH transmission is over more than one layers [6, TS

38.214], $\Delta_{\mathrm{TF},f,c}(i)=0$. BPRE and $\beta_{\mathrm{offset}}^{\mathrm{PUSCH}}$, for each carrier f and each serving cell c, are computed as below.

- $\mathrm{BPRE}=\sum_{r=0}^{C-1} K_r / N_{\mathrm{RE}}$ for PUSCH with UL-SCH data and $\mathrm{BPRE}=O_{\mathrm{CSI}}/N_{\mathrm{RE}}$ for CSI transmission in a PUSCH without UL-SCH data, where
  - C is the number of code blocks, K_r is the size for code block r, O_{CSI} is the number of CSI part 1 bits including CRC bits, and N_{RE} is the number of resource elements determined as $N_{\mathrm{RE}}=M_{\mathrm{RB},f,c}^{\mathrm{PUSCH}}(i)\cdot N_{\mathrm{symb},f,c}^{\mathrm{PUSCH}}(i)$ excluding REs used for DM-RS transmission, where $N_{\mathrm{symb},f,c}^{\mathrm{PUSCH}}(i)$ is a number of symbols for PUSCH transmission period i on carrier f of serving cell c and C, K_r are defined in [5, TS 38.212].
- $\beta_{\mathrm{offset}}^{\mathrm{PUSCH}}=1$ when the PUSCH includes UL-SCH data and $\beta_{\mathrm{offset}}^{\mathrm{PUSCH}}=\beta_{\mathrm{offset}}^{\mathrm{CSI},1}$, as described in Subclause 9.3, when the PUSCH includes CSI and does not include UL-SCH data.

- For the PUSCH power control adjustment state for carrier f of serving cell c in PUSCH transmission period i
  - $\delta_{\mathrm{PUSCH},f,c}(i-K_{\mathrm{PUSCH}},l)$ is a correction value, also referred to as a TPC command, and is included in a PDCCH with DCI format 0_0 or DCI format 0_1 that schedules the PUSCH transmission period i on carrier f of serving cell c or jointly coded with other TPC commands in a PDCCH with DCI format 2_2 having CRC parity bits scrambled by TPC-PUSCH-RNTI that is last received by the UE prior to the PUSCH transmission;
  - $f_{f,c}(i,l)=f_{f,c}(i-1,l)+\delta_{\mathrm{PUSCH},f,c}(i-K_{\mathrm{PUSCH}},l)$ is the PUSCH power control adjustment state for carrier f of serving cell c and PUSCH transmission period i if accumulation is enabled based on the parameter *Accumulation-enabled* provided by higher layers, where
    - $l\in\{1,2\}$ if the UE is configured with higher layer parameter *num-pusch-pcadjustment-states*; otherwise, $l=1$.
      - For a PUSCH (re)transmission corresponding to a grant-free configuration or semi-persistent grant, the value of $l\in\{1,2\}$ is provided to the UE by higher layer parameter *PUSCH-closed-loop-index*;
    - $\delta_{\mathrm{PUSCH},f,c}(i-K_{\mathrm{PUSCH}},l)=0$ dB if the UE does not detect a TPC command for carrier f of serving cell c.
    - If the PUSCH transmission is in response to a PDCCH decoding with DCI format 0_0 or DCI format 0_1, or 2_2 having CRC parity bits scrambled by TPC-PUSCH-RNTI, the respective $\delta_{\mathrm{PUSCH},f,c}$ accumulated values are given in Table 7.1.1-1.

- $f_{f,c}(0,l)$ is the first value after reset of accumulation.
- If the UE has reached $P_{\text{CMAX},f,c}(i)$ for carrier f of serving cell c, positive TPC commands for carrier f of serving cell c shall not be accumulated.
- If UE has reached minimum power for carrier f of serving cell c, negative TPC commands for carrier f of serving cell c shall not be accumulated.
- A UE can reset accumulation for carrier f of serving cell c
  - When $P_{\text{O\_UE\_PUSCH},f,c}(j)$ value is changed by higher layers;
  - When $\alpha_{f,c}(j)$ value is changed by higher layers;

- $f_{f,c}(i,l) = \delta_{\text{PUSCH},f,c}(i - K_{\text{PUSCH}}, l)$ is the PUSCH power control adjustment state for carrier f of serving cell c and PUSCH transmission period i if accumulation is not enabled based on the parameter *Accumulation-enabled* provided by higher layers, where
  - If the PUSCH transmission is in response to a PDCCH decoding with DCI format 0_0 or DCI format 0_1, or 2_2 having CRC parity bits scrambled by TPC-PUSCH-RNTI, the respective $\delta_{\text{PUSCH},c}$ absolute values are given in Table 7.1.1-1.
  - $f_{f,c}(i,l) = f_{f,c}(i-1,l)$ for a PUSCH transmission period where the UE does not detect a DCI format 0_0 or DCI format 0_1, or 2_2 having CRC parity bits scrambled by TPC-PUSCH-RNTI for carrier f of serving cell c.
- For both types of $f_{f,c}(*)$ (accumulation or current absolute) the first value is set as follows:
  - If $P_{\text{O\_UE\_PUSCH},f,c}(j)$ value is changed by higher layers and serving cell c is the primary cell or, if $P_{\text{O\_UE\_PUSCH},f,c}(j)$ value is received by higher layers and serving cell c is a secondary cell
    - $f_{f,c}(0,l) = 0$
  - Else, if the UE receives the random access response message for carrier f of serving cell c
    - $f_{f,c}(0,l) = \Delta P_{rampup,f,c} + \delta_{msg2,f,c}$, where
      - $\delta_{msg2,f,c}$ is the TPC command indicated in the random access response corresponding to the random access preamble transmitted for carrier f in the serving cell c, and

- $\Delta P_{rampup,f,c} = \min\left[\left\{\max\left(0, P_{\mathrm{CMAX},f,c} - \left(\begin{array}{c} 10\log_{10}(2^{\mu}\cdot M_{\mathrm{RB},f,c}^{\mathrm{PUSCH}}(0)) \\ + P_{\mathrm{O\_PUSCH},f,c}(0) + \alpha_{f,c}(0)\cdot PL_c \\ + \Delta_{\mathrm{TF},f,c}(0) + \delta_{msg2,f,c} \end{array}\right)\right)\right\}, \quad \Delta P_{rampuprequested,c}\right]$

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

Table 7.1.1-1: Mapping of TPC Command Field in DCI format 0_0, DCI format 0_1, or DCI format 2_2, or DCI format 2_3 having CRC parity bits scrambled by TPC-PUSCH-RNTI or TPC-SRS-RNTI, to absolute and accumulated $\delta_{\mathrm{PUSCH},c}$ values

TPC Command Field	Accumulated $\delta_{\mathrm{PUSCH},c}$ [dB]	Absolute $\delta_{\mathrm{PUSCH},c}$ [dB]
0	-1	-4
1	0	-1
2	1	1
3	3	4

7.2 Physical uplink control channel

If the UE is configured with a SCG, the UE shall apply the procedures described in this subclause for both MCG and SCG.

- When the procedures are applied for MCG, the term 'serving cell' in this subclause refers to serving cell belonging to the MCG.

When the procedures are applied for SCG, the term 'serving cell' in this subclause refers to serving cell belonging to the SCG. The term 'primary cell' in this subclause refers to the PSCell of the SCG. If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this subclause for both primary PUCCH group and secondary PUCCH group.

- When the procedures are applied for the primary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the primary PUCCH group.
- When the procedures are applied for the secondary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the secondary PUCCH group. The term 'primary cell' in this subclause refers to the PUCCH-SCell of the secondary PUCCH group.

7.2.1 UE behaviour

If a UE transmits a PUCCH on carrier f in the primary cell c using PUCCH power control adjustment state with index l, the UE shall determine the PUCCH transmission power $P_{\text{PUCCH},f,c}(i,q_u,q_d,l)$ in PUCCH transmission period i as

$$P_{\text{PUCCH},f,c}(i,q_u,q_d,l) = \min\begin{Bmatrix} P_{\text{CMAX},f,c}(i), \\ P_{\text{O\_PUCCH},f,c}(q_u) + PL_{f,c}(q_d) + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{\text{TF},f,c}(i) + g_{f,c}(i,l) \end{Bmatrix} \text{ [dBm]}$$

where

- $P_{\text{CMAX},f,c}(i)$ is the configured UE transmit power defined in [8, TS 38.101] for carrier f of serving cell c in PUCCH transmission period i.
- $P_{\text{O\_PUCCH},f,c}(q_u)$ is a parameter composed of the sum of a component $P_{\text{O\_NOMINAL\_PUCCH}}$, provided by higher layer parameter *P0-nominal-PUCCH* for carrier f of primary cell c, and a component $P_{\text{O\_UE\_PUCCH}}(q_u)$ provided by higher layer parameter *P0-PUCCH*, where $0 \le q_u < Q_u$. Q_u is a size for a set of $P_{\text{O\_UE\_PUCCH}}$ values provided by higher layer parameter *num-p0-pucch*. The set of $P_{\text{O\_UE\_PUCCH}}$ values is provided by higher layer parameter *p0-pucch-set*.
- $PL_{f,c}(q_d)$ is a downlink path-loss estimate in dB calculated by the UE for carrier f of the primary cell c using RS resource q_d, where $0 \le q_d < Q_d$. Q_d is a size for a set of RS resources provided by higher layer parameter *num-pucch-pathlossReference-rs*. The set of RS resources is provided by higher layer parameter *pucch-pathlossReference-rs*. The set of RS resources can include one or both of a set of SS/PBCH block indexes provided by higher layer parameter *pucch-pathlossReference-SSB* and a set of CSI-RS configuration indexes provided by higher layer parameter *pucch-pathlossReference-CSIRS*. The UE identifies a RS resource in the set of RS resources to correspond to a SS/PBCH block or to a CSI-RS configuration as provided by higher layer parameter *pucch-pathlossreference-index*.
- The parameter $\Delta_{\text{F\_PUCCH}}(F)$ is provided by higher layer parameter *deltaF-pucch-f0* for PUCCH format 0, *deltaF-pucch-f1* for PUCCH format 1, *deltaF-pucch-f2* for PUCCH format 2, *deltaF-pucch-f3* for PUCCH format 3, and *deltaF-pucch-f4* for PUCCH format 4.
- $\Delta_{\text{TF},f,c}(i)$ is a PUCCH transmission power adjustment component for carrier f of primary cell c.
- For the PUCCH power control adjustment state for carrier f of primary cell c and PUCCH transmission period i
  - $\delta_{\text{PUCCH},f,c}(i-K_{\text{PUCCH}},l)$ is a correction value, also referred to as a TPC command, and is included in a PDCCH with DCI format 1_0 or DCI format 1_1 for carrier f of the primary cell c that the UE detects in PUCCH transmission period $i-K_{\text{PUCCH}}$, or

jointly coded with other TPC commands in a PDCCH with DCI format 2_2 having CRC parity bits scrambled by TPC-PUCCH-RNTI [5, TS 36.212], and $l \in \{1, 2\}$ as indicated by higher layer parameter *num-pucch-pcadjustment-states*;

- The $\delta_{\text{PUCCH},f,c}$ dB values signaled on PDCCH with DCI format 1_0 or DCI format 1_1 or DCI format 2_2 having CRC parity bits scrambled by TPC-PUCCH-RNTI are given in Table 7.2.1-1.
- $\delta_{\text{PUCCH},f,c}(i - K_{\text{PUCCH}}, l) = 0$ dB if the UE does not detect a TPC command for carrier f of the primary cell c.

- $g_{f,c}(i,l) = g_{f,c}(i-1,l) + \delta_{\text{PUCCH},f,c}(i - K_{\text{PUCCH}}, l)$ is the current PUCCH power control adjustment state and $g_{f,c}(0,l) = 0$ is the first value after reset
  - If $P_{\text{O\_UE\_PUCCH},f,c}$ value is changed by higher layers,
    - $g_{f,c}(0,l) = 0$
  - Else,
    - $g_{f,c}(0,l) = \Delta P_{rampup,f,c} + \delta_{msg2,f,c}$, where

      $\delta_{msg2,f,c}$ is the TPC command indicated in the random access response corresponding to the random access preamble transmitted for carrier f in the serving cell c, and,

      if the UE transmits PUCCH,

      $\Delta P_{rampup,f,c} = \min\left[\left\{\max\left(0,\ P_{\text{CMAX},f,c} - \left(P_{\text{O\_PUCCH},f,c} + PL_c + \Delta_{\text{F\_PUCCH}}(F) + \Delta_{\text{TF},f,c} + \delta_{msg2,f,c}\right)\right)\right\},\ \ \Delta P_{rampuprequested,f,c}\right]$;

      otherwise, $\Delta P_{rampup,f,c} = \min\left[\left\{\max\left(0,\ P_{\text{CMAX},f,c} - \left(P_{\text{O\_PUCCH},f,c} + PL_c\right)\right)\right\},\ \ \Delta P_{rampuprequested,f,c}\right]$ and $\Delta P_{rampuprequested,f,c}$ is provided by higher layers and corresponds to the total power ramp-up requested by higher layers from the first to the last preamble for carrier f in primary cell c, and $\Delta_{\text{F\_PUCCH}}(F)$ corresponds to PUCCH format 0 or PUCCH format 1.
  - If the PUSCH transmission is in response to a PDCCH detection with DCI format 1_0 or DCI format 1_1, the $\delta_{\text{PUSCH},c}$ accumulated values are given in Table 7.1.1-1.
  - If the UE has reached $P_{\text{CMAX,c}}(i)$ for carrier f in primary cell c, the UE does not accumulate positive TPC commands for carrier f in primary cell c.
  - If the UE has reached minimum power for carrier f in primary cell c, the UE does not accumulate negative TPC commands for carrier f in primary cell c.
  - The UE can reset accumulation for carrier f in primary cell c

- When $P_{\text{O\_UE\_PUCCH},f,c}$ value is changed by higher layers.

Table 7.2.1-1: Mapping of TPC Command Field in DCI format 1_0 or DCI format 1_1 or DCI format 2_2 having CRC parity bits scrambled by TPC-PUCCH-RNTI to accumulated $\delta_{\text{PUCCH},c}$ values

TPC Command Field	Accumulated $\delta_{\text{PUSCH},f,c}$ [dB]
0	-1
1	0
2	1
3	3

7.3 Sounding reference signals

For SRS, the linear value $\hat{P}_{\text{SRS},f,c}(i,q_s,l)$ of the transmit power $P_{\text{SRS},f,c}(i,q_s,l)$ is split equally across the configured antenna ports for SRS.

7.3.1 UE behaviour

If a UE transmits SRS on carrier f of serving cell c using SRS power control adjustment state with index l, the UE shall determine the SRS transmission power $P_{\text{SRS},f,c}(i,q_s,l)$ in SRS transmission period i as

$$P_{\text{SRS},f,c}(i,q_s,l) = \min\begin{Bmatrix} P_{\text{CMAX},f,c}(i), \\ P_{\text{O\_SRS},f,c}(q_s) + 10\log_{10}(2^{\mu}\cdot M_{\text{SRS},f,c}(i)) + \alpha_{\text{SRS},f,c}(q_s)\cdot PL_{f,c}(q_s) + h_{f,c}(i,l) \end{Bmatrix} \text{ [dBm]}$$

where,

- $P_{\text{CMAX},f,c}(i)$ is the configured UE transmit power defined in [8, TS 38.101] for carrier f of serving cell c in SRS transmission period i.
- $P_{\text{O\_SRS},f,c}(q_s)$ is provided by higher layer parameter *p0-srs* for SRS resource set q_s.
- $M_{\text{SRS},f,c}(i)$ is the SRS bandwidth expressed in number of resource blocks for SRS transmission period i on carrier f of serving cell c and μ is defined in [4, TS 38.211].
- $\alpha_{\text{SRS},f,c}(q_s)$ is provided by higher layer parameter *alpha-srs* for SRS resource set q_s.
- $PL_{f,c}(q_s)$ is a downlink path-loss estimate in dB calculated by the UE for carrier f of serving cell c and SRS resource set q_s [6, TS 38.214] using a RS resource provided by higher layer parameter *srs-pathlossReference-rs*. The RS resource is from a set of RS resources that include a set of SS/PBCH block indexes provided by higher layer parameter *srs-pathlossReference-SSB* and a set of CSI-RS configuration indexes provided by higher layer parameter *srs-pathlossReference-CSIRS*.

- For the SRS power control adjustment state for carrier f of serving cell c and SRS transmission period i
  - $h_{f,c}(i,l) = f_{f,c}(i,l)$, as described in Subclause 7.1.1, if higher layer parameter *srs-pcadjustment-state-config* indicates a same power control adjustment state for SRS transmissions and PUSCH transmissions; or
  - $h_{f,c}(i) = h_{f,c}(i-1) + \delta_{\text{SRS},f,c}(i - K_{\text{SRS}})$ if higher layer parameter *srs-pcadjustment-state-config* indicates a separate power control adjustment state between SRS transmissions and PUSCH transmissions and if accumulation is enabled based on the parameter *Accumulation-enabled-srs* provided by higher layers, where $\delta_{\text{SRS},f,c}(i - K_{\text{SRS}})$ is jointly coded with other TPC commands in a PDCCH with DCI format 2_3 having CRC parity bits scrambled by TPC-SRS-RNTI that is last received by the UE prior to the SRS transmission and accumulative values of $\delta_{\text{SRS},f,c}(i - K_{\text{SRS}})$ are provided in Table 7.1.1-1, where
    - $\delta_{\text{SRS},f,c}(i - K_{\text{SRS}}) = 0$ dB if the UE does not detect a TPC command for serving cell c.
    - $h_{f,c}(0)$ is the first value after reset of accumulation.
    - If the UE has reached $P_{\text{CMAX},f,c}(i)$ for carrier f of serving cell c, positive TPC commands for serving cell c shall not be accumulated.
    - If UE has reached minimum power for carrier f of serving cell c, negative TPC commands shall not be accumulated.
    - A UE can reset accumulation for carrier f of serving cell c
      - When $P_{\text{O\_SRS},f,c}$ value is changed by higher layers;
      - When $\alpha_{\text{SRS},f,c}$ value is changed by higher layers.
  - $h_{f,c}(i) = \delta_{\text{SRS},f,c}(i - K_{\text{SRS}})$ if higher layer parameter *srs-pcadjustment-state-config* indicates a separate power control adjustment state between SRS transmissions and PUSCH transmissions and if accumulation is not enabled based on the parameter *Accumulation-enabled-srs* provided by higher layers, jointly coded with other TPC commands in a PDCCH with DCI format 2_3 having CRC parity bits scrambled by TPC-SRS-RNTI that is last received by the UE prior to the SRS transmission and absolute values of $\delta_{\text{SRS},f,c}(i - K_{\text{SRS}})$ are provided in Table 7.1.1-1, where
    - If DCI format 2_3 having CRC scrambled by TPC-SRS-RNTI the $\delta_{\text{PUSCH},c}$ absolute values are given in Table 7.1.1-1.
    - $h_{f,c}(i) = h_{f,c}(i-1)$ for a SRS transmission period i where the UE does not detect a DCI format 2_3 having CRC scrambled by TPC-SRS-RNTI for carrier f of serving cell c.

7.4 Physical random access channel

A UE determines a transmission power for a physical random access channel (PRACH) for carrier f of serving cell c in transmission period i as

$$P_{\text{PRACH},f,c}(i) = \min\left\{P_{\text{CMAX},f,c}(i), P_{\text{PRACH,target}} + PL_{f,c}\right\} \text{ [dBm]},$$

where $P_{\text{CMAX},f,c}(i)$ is the configured UE transmission power defined in [8, TS 38.101] for carrier f of serving cell c within transmission period i, $P_{\text{PRACH,target}}$ is provided by higher layer parameter *preambleReceivedTargetPower*, and $PL_{f,c}$ is a pathloss calculated by the UE for carrier f of serving cell c in dB calculated as *referenceSignalPower* – higher layer filtered RSRP, where RSRP is defined in [7, TS 38.215], the higher layer filter configuration is defined in [12, TS 38.331], and *referenceSignalPower* is *SS-PBCHBlockPower*, where *SS-PBCHBlockPower* is provided by *SystemInformationBlockType1*.

If the UE transmits PRACH to convey link reconfiguration request, as described in Subclause 6, $P_{\text{PRACH,target}}$ is provided by higher layer parameter *preambleReceivedTargetPower-BFR*.

If within a random access response window, as described in Subclause 8.2, the UE does not receive a random access response that contains a preamble identifier corresponding to the preamble sequence transmitted by the UE, the UE shall determine a transmission power for a subsequent PRACH transmission, if any, as described in [11, TS 38.321].

7.5 Carrier aggregation

If a total UE transmit power for a PUSCH or PUCCH or PRACH or SRS transmission in a respective transmission period i would exceed $\hat{P}_{\text{CMAX}}(i)$, the UE allocates power to PUSCH/PUCCH/PRACH/SRS transmissions according to the following priority order (in descending order) so that the total UE transmit power is smaller than or equal than $\hat{P}_{\text{CMAX}}(i)$ in every symbol of transmission period i. The total UE transmit power is defined as the sum of the linear values of UE transmit powers for PUSCH, PUCCH, PRACH, and SRS. In case of same priority order, transmission on the primary cell of the MCG or the SCG is prioritized over transmission on a secondary cell and transmission on the PCell is prioritized over transmission on the PSCell.

- PRACH transmission on the PCell;
- PUCCH transmission with HARQ-ACK/SR or PUSCH transmission with HARQ-ACK;
- PUCCH transmission with CSI or PUSCH transmission with CSI;
- PUSCH transmission without HARQ-ACK or CSI;
- SRS transmission or PRACH transmission on a serving cell other than the PCell.

7.6 Dual connectivity

If a UE is configured with a MCG using LTE radio access and with a SCG using NR radio access, the UE is configured by higher layer parameter *p-MCG* a fraction $\gamma_{\text{MCG}} \le 1$ of $\hat{P}_{\text{CMAX}}$ for transmissions on the MCG and is configured by higher layer parameter *p-SCG* a fraction $\gamma_{\text{SCG}} \le 1$ of $\hat{P}_{\text{CMAX}}$ for transmissions on the SCG, where $\hat{P}_{\text{CMAX}}$ is the linear value of P_{CMAX} as defined in [8, TS 38.101].

If a UE is provided a higher layer parameter *suo-duo-mode* that is set to *case1* and if $\gamma_{\text{MCG}} + \gamma_{\text{SCG}} > 1$, the UE does not transmit in a slot on the SCG for which a corresponding subframe on the MCG includes UL symbols. If a UE is configured a higher layer parameter *suo-duo-mode* that is set to *dual*, denoting by $\hat{P}_{\text{MCG}}$ and by $\hat{P}_{\text{SCG}}$ the linear values of the total UE transmit power that the UE calculates according to [13, TS 36.213] for the MCG and according to Subclauses 7.1 through 7.5 for transmissions on the MCG and on the SCG, respectively, and if the UE is not configured for operation with shortened TTI and processing time on the MCG [13, TS 36.213], the UE sets $\hat{P}_{\text{MCG}}(i_1) = \min\left(\hat{P}_{\text{MCG}}(i_1), \gamma_{\text{MCG}} \cdot \hat{P}_{\text{CMAX}}\right)$ in subframe i_1 and then sets $\hat{P}_{\text{SCG}}(i_2) = \min\left(\min\left(\hat{P}_{\text{SCG}}(i_2), \gamma_{\text{SCG}} \cdot \hat{P}_{\text{CMAX}}\right), \hat{P}_{\text{CMAX}} - \hat{P}_{\text{MCG}}(i_1)\right)$ in slot i_2.

7.7 Power headroom report

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

If the UE is configured with a SCG,

- For computing power headroom for cells belonging to MCG, the term 'serving cell' in this subclause refers to serving cell belonging to the MCG.
- For computing power headroom for cells belonging to SCG, the term 'serving cell' in this subclause refers to serving cell belonging to the SCG. The term 'primary cell' in this subclause refers to the PSCell of the SCG.

If the UE is configured with a PUCCH-SCell,

- For computing power headroom for cells belonging to primary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the primary PUCCH group.
- For computing power headroom for cells belonging to secondary PUCCH group, the term 'serving cell' in this subclause refers to serving cell belonging to the secondary PUCCH group. The term 'primary cell' in this subclause refers to the PUCCH-SCell of the secondary PUCCH group.

7.7.1 Power headroom for PUSCH

Type 1 PH report: In a PUSCH transmission period i UE computes a power headroom for a Type 1 report for a carrier f of serving cell c as

$$PH_{\text{type1},f,c}(i,j,q_d,l) = P_{\text{CMAX},f,c}(i) - \left\{ P_{\text{O\_PUSCH},f,c}(j) + 10\log_{10}(2^{\mu}\cdot M_{\text{RB},f,c}^{\text{PUSCH}}(i)) + \alpha_{f,c}(j)\cdot PL_{f,c}(q_d) + \Delta_{\text{TF},f,c}(i) + f_{f,c}(i,l) \right\}$$ [dB]

where $P_{\text{CMAX},f,c}(i)$, $P_{\text{O\_PUSCH},f,c}(j)$, $M_{\text{RB},f,c}^{\text{PUSCH}}(i)$, $\alpha_{f,c}(j)$, $PL_{f,c}(q_d)$, $\Delta_{\text{TF},f,c}(i)$ and $f_{f,c}(i,l)$ are defined in Subclause 7.1.1.

7.7.2 Power headroom for SRS

Type 2 PH report: In a SRS transmission period i, a UE computes a power headroom for a Type 2 report for a carrier f of serving cell c as

if the UE transmits SRS in SRS transmission period i for carrier f of serving cell c, the UE computes power headroom for a Type 2 report as

$$PH_{\text{type2},f,c}(i,q_s,l) = P_{\text{CMAX},f,c}(i) - \left\{ P_{\text{O\_SRS},f,c}(q_s) + 10\log_{10}(2^{\mu}\cdot M_{\text{SRS},f,c}(i)) + \alpha_{\text{SRS},f,c}(q_s)\cdot PL_{f,c}(q_s) + h_{f,c}(i,l) \right\}$$ [dB]

where $P_{\text{CMAX},f,c}(i)$, $P_{\text{O\_SRS},f,c}(q_s)$, $M_{\text{SRS},f,c}(i)$, $\alpha_{\text{SRS},f,c}(q_s)$, $PL_{f,c}(q_s)$ and $h_{f,c}(i,l)$ are defined in Subclause 7.3.1;

if the UE does not transmit SRS in SRS transmission period i for carrier f of serving cell c, the UE computes power headroom for a Type 2 report as

$$PH_{\text{type2},f,c}(i,q_s,l) = \widetilde{P}_{\text{CMAX},f,c}(i) - \left\{ P_{\text{O\_SRS},f,c}(q_{s0}) + \alpha_{\text{SRS},f,c}(q_{s0})\cdot PL_{f,c}(q_{s0}) + h_{f,c}(i,l) \right\}$$ [dB]

where q_{s0} is a SRS resource set provided to the UE by higher layers and $P_{\text{O\_SRS},f,c}(q_{s0})$, $\alpha_{\text{SRS},f,c}(q_{s0})$, $PL_{f,c}(q_{s0})$ and $h_{f,c}(i,l)$ are defined in Subclause 7.3.1. $\widetilde{P}_{\text{CMAX},f,c}(i)$ is computed based on the requirements in [8, TS 38.101] assuming a SRS transmission in SRS transmission period i, and assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and ⍰T_C =0dB. MPR , A-MPR, P-MPR and ⍰T_C are defined in [8, TS 38.101]. For this case, the physical layer delivers $\widetilde{P}_{\text{CMAX},f,c}(i)$ instead of $P_{\text{CMAX},f,c}(i)$ to higher layers.

8 Random access procedure

Prior to initiation of the physical random access procedure, Layer 1 shall receive from higher layers a set of SS/PBCH block indexes and shall provide to higher layers a corresponding set of RSRP measurements.

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

- Configuration of physical random access channel (PRACH) transmission parameters (PRACH preamble format, time resources, and frequency resources for PRACH transmission).

- Parameters for determining the root sequences and their cyclic shifts in the PRACH preamble sequence set (index to logical root sequence table, cyclic shift (N_{CS}), and set type (unrestricted, restricted set A, or restricted set B)).

From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble (Msg1) in a PRACH, random access response (RAR) in a PDSCH (Msg2), Msg3 PUSCH, and PDSCH for contention resolution.

If a UE is not configured with two UL carriers and a random access procedure is initiated by a "PDCCH order" to the UE, a random access preamble transmission is with a same subcarrier spacing as a random access preamble transmission initiated by higher layers.

If a UE is configured with two UL carriers for a serving cell and the UE detects a "PDCCH order", the UE uses the UL/SUL indicator field value from the detected "PDCCH order" to determine the UL carrier for the corresponding random access preamble transmission and the random access preamble transmission is with the subcarrier spacing the UE is configured for the corresponding UL carrier.

8.1 Random access preamble

Layer 1 procedure is triggered upon request of a PRACH transmission by higher layers. A configuration by higher layers for a PRACH transmission includes the following:

- A configuration for PRACH transmission [4, TS 38.211].
- A preamble index, a preamble subcarrier spacing, $P_{\text{PRACH,target}}$, a corresponding RA-RNTI, and a PRACH resource.

A preamble is transmitted using the selected PRACH format with transmission power P_{PRACH}, as described in Subclause 7.4, on the indicated PRACH resource.

8.2 Random access response

In response to a PRACH transmission, a UE attempts to detect a PDCCH with a corresponding RA-RNTI during a window controlled by higher layers [11, TS 38.321]. The window starts at the first symbol of the earliest control resource set the UE is configured for Type1-PDCCH common search space, as defined in Subclause 10.1, that is $\left\lceil \left(\Delta \cdot N_{\text{slot}}^{\text{subframe},\mu} \cdot N_{\text{symb}}^{\text{slot}}\right) / T_{sf} \right\rceil \cdot T_{sf} / \left(N_{\text{slot}}^{\text{subframe},\mu} \cdot N_{\text{symb}}^{\text{slot}}\right)$ symbols after the last symbol of the preamble sequence transmission. The length of the window in number of slots, based on the sub-carrier spacing and cyclic prefix for Type0-PDCCH common search space as defined in Subclause 10.1, is provided by higher layer parameter *rar-WindowLength*.

If the UE detects the PDCCH with the corresponding RA-RNTI and a corresponding DL-SCH transport block within the window, the UE passes the transport block to higher layers. The higher layers parse the transport block for a random access preamble identity (RAPID) associated with the PRACH transmission and, if the RAPID is identified, indicate the uplink grant to the physical layer. This is referred to as random access

response (RAR) grant in the physical layer. A UE shall receive the PDCCH and the PDSCH that includes the DL-SCH transport block with same subcarrier spacing and same cyclic prefix as for the reception of PDCCH Type0-PDCCH common search space and with DM-RS antenna port quasi co-location properties as described in [6, 38.214].

Unless a UE is configured a subcarrier spacing, the UE receives subsequent PDSCH using same subcarrier spacing as for the PDSCH reception providing the random access response.

If the UE does not detect the PDDCH or a corresponding DL-SCH transport block within the window, the UE procedure is as described in [11, TS 38.321].

8.3 Msg3 PUSCH

Higher layer parameter *msg3-tp* indicates to a UE whether or not the UE shall apply transform precoding, as described in [4, TS 38.211], for an Msg3 PUSCH transmission.

The subcarrier spacing for Msg3 PUSCH transmission is provided by higher layer parameter *msg3-scs*. A UE shall transmit PRACH and Msg3 PUSCH on a same serving cell.

An UL BWP, as described in Subclause 12 and in [4, TS 38.211], for Msg3 PUSCH transmission is indicated by *SystemInformationBlockType1*.

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9 UE procedure for reporting control information

If a UE is configured with a SCG, the UE shall apply the procedures described in this subclause for both MCG and SCG.

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group

- When the procedures are applied for the primary PUCCH group, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the primary PUCCH group respectively.
- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PUCCH-SCell), serving cell,

serving cells belonging to the secondary PUCCH group respectively. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group.

If a UE would transmit a PUCCH that has a same first symbol and duration with a PUSCH transmission, the UE multiplexes the UCI in the PUSCH transmission and does not transmit the PUCCH.

9.1 HARQ-ACK codebook determination

9.1.1 CBG-based HARQ-ACK codebook determination

If a UE is configured per serving cell with higher layer parameter *CBG-DL = ON*, the UE receives PDSCHs that include code block groups (CBGs) of a transport block. If the UE is configured by higher layer parameter *CBG-DL = ON*, the UE is configured by higher layer parameter *CBGs-per-TB-DL* per serving cell a maximum number $N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}}$ of CBGs for generating respective HARQ-ACK information bits for a transport block reception.

For a number of C code blocks (CBs) in a transport block, the UE determines a number of CBGs as $N_{\text{HARQ-ACK}}^{\text{CBG/TB}} = \min\left(N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}}, C\right)$. Each of the first $N_{\text{HARQ-ACK}}^{\text{CBG/TB,1}} = \text{mod}\left(C, N_{\text{HARQ-ACK}}^{\text{CBG/TB}}\right)$ CBGs includes $\left\lceil C/N_{\text{HARQ-ACK}}^{\text{CBG/TB}} \right\rceil$ CBs, where CBG $n_{\text{CBG}}, 0 \le n_{\text{CBG}} < N_{\text{HARQ-ACK}}^{\text{CBG/TB,1}}$, includes CBs $n_{\text{CBG}} \cdot \left\lceil C/N_{\text{HARQ-ACK}}^{\text{CBG/TB}} \right\rceil + n_{\text{CB}}, 0 \le n_{\text{CB}} < \left\lceil C/N_{\text{HARQ-ACK}}^{\text{CBG/TB}} \right\rceil$, and each of the last $N_{\text{HARQ-ACK}}^{\text{CBG/TB,2}} = N_{\text{HARQ-ACK}}^{\text{CBG/TB}} - \text{mod}\left(C, N_{\text{HARQ-ACK}}^{\text{CBG/TB}}\right)$ CBGs includes $\left\lfloor C/N_{\text{HARQ-ACK}}^{\text{CBG/TB}} \right\rfloor$ CBs, where CBG $n_{\text{CBG}}, N_{\text{HARQ-ACK}}^{\text{CBG/TB,1}} \le n_{\text{CBG}} < N_{\text{HARQ-ACK}}^{\text{CBG/TB,1}} + N_{\text{HARQ-ACK}}^{\text{CBG/TB,2}}$, includes CBs $N_{\text{HARQ-ACK}}^{\text{CBG/TB,1}} \cdot \left\lceil C/N_{\text{HARQ-ACK}}^{\text{CBG/TB}} \right\rceil + \left(n_{\text{CBG}} - N_{\text{HARQ-ACK}}^{\text{CBG/TB,1}}\right) \cdot \left\lfloor C/N_{\text{HARQ-ACK}}^{\text{CBG/TB}} \right\rfloor + n_{\text{CB}}, 0 \le n_{\text{CB}} < \left\lfloor C/N_{\text{HARQ-ACK}}^{\text{CBG/TB}} \right\rfloor$. The UE generates $N_{\text{HARQ-ACK}}^{\text{CBG/TB,1}} + N_{\text{HARQ-ACK}}^{\text{CBG/TB,2}}$ HARQ-ACK information bits through a one-to-one mapping with the $N_{\text{HARQ-ACK}}^{\text{CBG/TB,1}} + N_{\text{HARQ-ACK}}^{\text{CBG/TB,2}}$ CBGs. If the UE receives two transport blocks, the UE concatenates the HARQ-ACK information bits for the second transport block after the HARQ-ACK information bits for the first transport block.

A retransmission of a transport block to a UE, corresponding to a same HARQ process as a previous transmission of the transport block to the UE, includes the same CBs in a CBG as the initial transmission of the transport block.

If a DCI format scheduling the retransmission of the transport block includes a CBG transmission information (CBGTI) field of $N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}}$ bits where the first $N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ bits of the CBGTI field have a one-to-one mapping with the $N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ CBGs, the UE determines whether or not a CBG is retransmitted based on a corresponding value of the CBGTI field.

If a UE is configured with higher layer parameter *HARQ-ACK-codebook=semi-static*, the HARQ-ACK codebook includes the $N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}}$ HARQ-ACK information bits and, if $N_{\text{HARQ-ACK}}^{\text{CBG/TB}} < N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}}$ for a transport block, the UE generates a NACK value for the last $N_{\text{HARQ-ACK}}^{\text{CBG/TB,max}} - N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ HARQ-ACK information bits for the transport block in the HARQ-ACK codebook.

If the UE generates a HARQ-ACK codebook in response to a retransmission of a transport block, corresponding to a same HARQ process as a previous transmission of the transport block, the UE generates an ACK for each CBG that the UE correctly decoded in a previous transmission of the transport block.

If a UE correctly detects each of the $N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ CBGs and does not correctly detect the transport block for the $N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ CBGs, the UE generates a NACK value for each of the $N_{\text{HARQ-ACK}}^{\text{CBG/TB}}$ CBGs.

If a UE receives a PDSCH that is scheduled by a PDCCH with DCI format 1_0, the UE generates HARQ-ACK information only for the transport block in the PDSCH.

If a UE is not configured with higher layer parameter *CBG-DL = ON*, the UE generates one HARQ-ACK information bit per transport block.

9.1.2 Type-1 HARQ-ACK codebook determination

If a UE is configured with higher layer parameter *HARQ-ACK-codebook=semi-static* and, based on maximum and minimum slot timing values provided to a UE by higher layer parameter *DL-data-DL-acknowledgement* and on a number of possible slot timing values, the UE determines a number M of PDCCH monitoring occasion(s) for PDCCH with DCI format 1_0 or DCI format 1_1, for which the UE transmits a corresponding HARQ-ACK codebook in a same PUCCH or PUSCH. The determination for the number M of PDCCH monitoring occasion(s) is based on the PDCCH monitoring periodicity, the PDCCH monitoring offset, and the PDCCH monitoring pattern within a slot for each control resource set in the set of control resource sets configured to the UE as described in Subclause 10.1. For a serving cell and for a HARQ-ACK codebook determination, PDCCH monitoring occasions are indexed in an ascending order in time.

For a UE monitoring occasion of a PDCCH with DCI format 1_1 and if higher layer parameter *Number-MCS-HARQ-DL-DCI* indicates reception of two transport blocks, when the UE receives a PDSCH with one transport block, the HARQ-ACK response is associated with the first transport block and the UE generates a NACK for the second transport block if spatial bundling is not applied (*HARQ-ACK-spatial-bundling-PUCCH =*

FALSE or *HARQ-ACK-spatial-bundling-PUSCH = FALSE*) and generates HARQ-ACK value of ACK for the second transport block if spatial bundling is applied.

If a UE is configured with higher layer parameter *HARQ-ACK-codebook=semi-static*, the UE shall determine $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ HARQ-ACK information bits of a HARQ-ACK codebook for transmission in a PUCCH according to the following pseudo-code. In the following pseudo-code, if the UE does not receive a transport block or a CBG, due to the UE not detecting a corresponding PDCCH with DCI format 1_0 or DCI format 1_1, the UE generates a NACK value for the transport block or the CBG.

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

Set $m = 0$ – PDCCH with DCI format 1_0 or DCI format 1_1 monitoring occasion index: lower index corresponds to earlier PDCCH with DCI format 1_0 or DCI format 1_1 monitoring occasion where $0 \le m < M$

Set $j = 0$ - HARQ-ACK bit index

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

while $m < M$

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

if m is a monitoring occasion for PDCCH with DCI format 1_0 or DCI format 1_1 on serving cell c,

if *HARQ-ACK-spatial-bundling-PUCCH = FALSE*, *CBG-DL = OFF*, m is a monitoring occasion for PDCCH with DCI format 1_1, and the UE is configured by higher layer parameter *Number-MCS-HARQ-DL-DCI* with reception of two transport blocks on serving cell c,

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to a first transport block of this cell;

$j = j + 1$;

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to a second transport block of this cell;

$j = j + 1$;

elseif *HARQ-ACK-spatial-bundling-PUCCH = TRUE*, and the UE is configured by higher layer parameter *Number-MCS-HARQ-DL-DCI* with reception of two transport blocks in serving cell c,

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to first and second transport blocks of this cell - if the UE receives one transport block, the UE assumes ACK for the second transport block;

$j = j + 1$;

elseif *CBG-DL = ON*, and $N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}}$ CBGs indicated by higher layer parameter *CBGs-per-TB-DL* for serving cell c,

Set $n_{\text{CBG}} = 0$ - CBG index

while $n_{\text{CBG}} < N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}}$

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to CBG n_{CBG} of this cell;

$j = j + 1$;

$n_{\text{CBG}} = n_{\text{CBG}} + 1$;

end while

else

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

$j = j + 1$;

end if

end if

$c = c + 1$;

end while

$m = m + 1$;

end while

For HARQ-ACK transmission in a PUSCH, the UE shall determine a HARQ-ACK codebook according to the previous pseudo-code except that *HARQ-ACK-spatial-bundling-PUCCH* is replaced by *HARQ-ACK-spatial-bundling-PUSCH*.

9.1.3 Type-2 HARQ-ACK codebook determination

9.1.3.1 Type-2 HARQ-ACK codebook in physical uplink control channel

If a UE is configured with higher layer parameter *HARQ-ACK-codebook=dynamic*, with higher layer parameter *CBG-DL = OFF* or is not configured higher layer parameter *CBG-DL*, a value of the counter downlink assignment indicator (DAI) field in DCI format 1_0 or DCI format 1_1 denotes the accumulative number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH reception(s) associated with DCI format 1_0 or DCI format 1_1 or DCI format 1_0 indicating downlink SPS release is present, up to the current serving cell and current PDCCH monitoring occasion, first in increasing order of serving cell index and then in increasing order of PDCCH monitoring occasion index m, where $0 \le m < M$. The UE determines the value of M as described in Subclause 9.1.2 except that the maximum slot timing value is replaced by the slot timing value indicated

in a first DCI format 1_0 or DCI format 1_1 that the UE detects and the minimum slot timing value is replaced by the slot timing value indicated in a last DCI format 1_0 or DCI format 1_1 that the UE detects and for which the UE transmits HARQ-ACK in a same PUCCH.

The value of the total DAI in DCI format 1_0 or DCI format 1_1 denotes the total number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH reception(s) associated with DCI format 1_0 or DCI format 1_1 or associated with DCI format 1_0 indicating downlink SPS release is present, up to the current PDCCH monitoring occasion m and shall be updated from PDCCH monitoring occasion to PDCCH monitoring occasion.

Denote $V_{\text{C-DAI,c,m}}^{\text{DL}}$ as the value of the counter DAI in DCI format 1_0 or DCI format 1_1 scheduling PDSCH reception or indicating downlink SPS release for serving cell c in PDCCH monitoring occasion m according to Table 9.1.3-1. Denote $V_{\text{T-DAI,m}}^{\text{DL}}$ as the value of the total DAI in DCI format 1_0 or DCI format 1_1 scheduling PDSCH reception or indicating downlink SPS release in PDCCH monitoring occasion m according to Table 9.1.3-1. The UE shall assume a same value of total DAI in all DCI formats 1_0 or DCI format 1_1 scheduling PDSCH reception(s) and DCI format 1_0 indicating downlink SPS release in PDCCH monitoring occasion m.

If the UE transmits HARQ-ACK using PUCCH format 2 or PUCCH format 3 or PUCCH format 4, the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the following pseudo-code:

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

Set $m = 0$ – PDCCH with DCI format 1_0 or DCI format 1_1 monitoring occasion index: lower index corresponds to earlier PDCCH with DCI format 1_0 or DCI format 1_1 monitoring occasion

Set $j = 0$

Set $V_{temp} = 0$

Set $V_{temp2} = 0$

Set $V_s = \varnothing$

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

Set M to the number of PDCCH monitoring occasion(s)

while $m < M$

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

if there is a PDSCH on serving cell c associated with PDCCH in PDCCH monitoring occasion m, or there is a PDCCH indicating downlink SPS release on serving cell c

if $V_{C-DAI,c,m}^{DL} \le V_{temp}$

$j = j+1$

end if

$V_{temp} = V_{C-DAI,c,m}^{DL}$

if $V_{T-DAI,m}^{DL} = \varnothing$

$V_{temp2} = V_{C-DAI,c,m}^{DL}$

else

$V_{temp2} = V_{T-DAI,m}^{DL}$

if the higher layer parameter *HARQ-ACK-spatial-bundling-PUCCH* = *FALSE* and m is a monitoring occasion for PDCCH with DCI format 1_1 and the UE is configured by higher layer parameter *Number-MCS-HARQ-DL-DCI* with reception of two transport blocks in at least one configured serving cell,

$\tilde{o}_{8j+2\left(V_{C-DAI,c,m}^{DL}-1\right)}^{ACK}$ = HARQ-ACK bit corresponding to the first transport block of this cell

$\tilde{o}_{8j+2\left(V_{C-DAI,c,m}^{DL}-1\right)+1}^{ACK}$ = HARQ-ACK bit corresponding to the second transport block of this cell

$V_s = V_s \cup \left\{8j+2\left(V_{C-DAI,c,m}^{DL}-1\right), 8j+2\left(V_{C-DAI,c,m}^{DL}-1\right)+1\right\}$

elseif the higher layer parameter *HARQ-ACK-spatial-bundling-PUCCH* = *TRUE* and m is a monitoring occasion for PDCCH with DCI format 1_1 and the UE is configured by higher layer parameter *Number-MCS-HARQ-DL-DCI* with reception of two transport blocks in at least one configured serving cell,

$\tilde{o}_{4j+V_{C-DAI,c,m}^{DL}-1}^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second transport blocks of this cell

$V_s = V_s \cup \left\{4j+V_{C-DAI,c,m}^{DL}-1\right\}$

else

$\tilde{o}_{4j+V_{C-DAI,c,m}^{DL}-1}^{ACK}$ = HARQ-ACK bit of this cell

$V_s = V_s \cup \left\{4j+V_{C-DAI,c,m}^{DL}-1\right\}$

end if

$c = c + 1$

end while

$m = m + 1$

end while

if $V_{temp2} < V_{temp}$

$j = j + 1$

end if

if the higher layer parameter *HARQ-ACK-spatial-bundling-PUCCH = FALSE* and m is a monitoring occasion for PDCCH with DCI format 1_1 and the UE is configured by higher layer parameter *Number-MCS-HARQ-DL-DCI* with reception of two transport blocks in at least one configured serving cell,

$O^{ACK} = 2 \cdot \left(4 \cdot j + V_{temp2}\right)$

else

$O^{ACK} = 4 \cdot j + V_{temp2}$

$\tilde{o}_i^{ACK} = \text{NACK}$ for any $i \in \left\{0,1,...,O^{ACK} - 1\right\} \setminus V_s$

if SPS PDSCH transmission is activated for a UE and the UE is configured to receive SPS PDSCH in a slot within the M monitoring occasions

$O^{ACK} = O^{ACK} + 1$

$o_{O^{ACK}-1}^{ACK}$ = HARQ-ACK bit associated with the SPS PDSCH reception

end if

For a monitoring occasion of a PDCCH with DCI format 1_1 in at least one serving cell, when a UE receives a PDSCH with one transport block and the value of higher layer parameter *Number-MCS-HARQ-DL-DCI* is 2, the HARQ-ACK response is associated with the first transport block and the UE generates a NACK for the second transport block if spatial bundling is not applied (*HARQ-ACK-spatial-bundling-PUCCH = FALSE* or *HARQ-ACK-spatial-bundling-PUSCH = FALSE*) and generates HARQ-ACK value of ACK for the second transport block if spatial bundling is applied.

If a UE transmits HARQ-ACK using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 and the UE is configured with

- higher layer parameter *HARQ-ACK-codebook=dynamic*;
- higher layer parameter *CBG-DL = ON* for $N_{cells}^{DL,CBG}$ serving cells; and

- higher layer parameter *CBG-DL = OFF*, or is not configured with higher layer parameter *CBG-DL*, for $N_{cells}^{DL,TB}$ serving cells where $N_{cells}^{DL,TB} + N_{cells}^{DL,CBG} = N_{cells}^{DL}$

the UE shall determine the $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ according to the previous pseudo-code with the following modifications

- N_{cells}^{DL} is used for the determination of a first HARQ-ACK sub-codebook for TB-based PDSCH receptions;
- N_{cells}^{DL} is replaced by $N_{cells}^{DL,CBG}$ for the determination of a second HARQ-ACK sub-codebook corresponding to the $N_{cells}^{DL,CBG}$ serving cells for CBG-based PDSCH receptions, and
  - Instead of generating one HARQ-ACK information bit per transport block for a serving cell from the $N_{cells}^{DL,CBG}$ serving cells, the UE generates $N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}}$ HARQ-ACK information bits per transport block as described in Subclause 9.1.1 for two transport blocks if a monitoring occasion includes PDCCH with DCI format 1_1 and the value of higher layer parameter *Number-MCS-HARQ-DL-DCI* is 2, or generates $N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}}$ HARQ-ACK information bits for one transport block if a monitoring occasion includes PDCCH with DCI format 1_0 and does not include PDCCH with DCI format 1_1 or if the value of higher layer parameter *Number-MCS-HARQ-DL-DCI* is 1 as described in Subclause 9.1.1, where $N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}}$ is the maximum value of $N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}}$ across all $N_{cells}^{DL,CBG}$ serving cells and, if for a serving cell c it is $N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}} < N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}}$, the UE generates NACK for the last $N_{\text{HARQ-ACK,max}}^{\text{CBG/TB,max}} - N_{\text{HARQ-ACK},c}^{\text{CBG/TB,max}}$ HARQ-ACK information bits for serving cell c;
  - The pseudo-code operation for *HARQ-ACK-spatial-bundling-PUCCH = TRUE* is not applicable;
- The UE generates the HARQ-ACK codebook by appending the second HARQ-ACK sub-codebook to the first HARQ-ACK sub-codebook.

Table 9.1.3-1: Value of counter DAI and total DAI in DCI format 1_0 or DCI format 1_1

DAI MSB, LSB	V_{C-DAI}^{DL} or V_{T-DAI}^{DL}	Number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH transmission(s) associated with PDCCH or PDCCH indicating downlink SPS release is present, denoted as Y and $Y \geq 1$
0,0	1	$\text{mod}(Y-1,4)+1=1$
0,1	2	$\text{mod}(Y-1,4)+1=2$
1,0	3	$\text{mod}(Y-1,4)+1=3$
1,1	4	$\text{mod}(Y-1,4)+1=4$

9.1.3.2 Type-2 HARQ-ACK codebook in physical uplink shared channel

If a UE multiplexes HARQ-ACK in a PUSCH transmission that is not scheduled by a DCI format or is scheduled by DCI format 0_0, the UE generates the HARQ-ACK codebook in the same manner as when the UE transmits HARQ-ACK using PUCCH format 2 or PUCCH format 3 or PUCCH format 4, as described in Subclause 9.1.3.1, except that *HARQ-ACK-spatial-bundling-PUCCH* is replaced by *HARQ-ACK-spatial-bundling-PUSCH*.

If a UE multiplexes HARQ-ACK in a PUSCH transmission that is scheduled by DCI format 0_1, the UE generates the HARQ-ACK codebook in the same manner as when the UE transmits HARQ-ACK using PUCCH format 2 or PUCCH format 3 or PUCCH format 4, as described in Subclause 9.1.3.1, with the following modifications:

- For $0 \le m < M-1$, $V_{T-DAI,m}^{DL} = \varnothing$ and for $m = M-1$, $V_{T-DAI,m}^{DL}$ is replaced by $V_{T-DAI,m}^{UL}$ where $V_{T-DAI,m}^{UL}$ is the value of the DAI field in DCI format 0_1 according to Table 9.1.3-2;
  - For the case of first and second HARQ-ACK sub-codebooks, DCI format 0_1 includes a first DAI field corresponding to the first HARQ-ACK sub-codebook and a second DAI field corresponding to the second HARQ-ACK sub-codebook;
  - *HARQ-ACK-spatial-bundling-PUCCH* is replaced by *HARQ-ACK-spatial-bundling-PUSCH*.

Table 9.1.3-2: Value of DAI in DCI format 0_1

DAI MSB, LSB	V_{T-DAI}^{UL}	Number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH transmission(s) associated with PDCCH or PDCCH indicating downlink SPS release is present, denoted as X and $X \ge 1$
0,0	1	$\mathrm{mod}(X-1,4)+1=1$
0,1	2	$\mathrm{mod}(X-1,4)+1=2$
1,0	3	$\mathrm{mod}(X-1,4)+1=3$
1,1	4	$\mathrm{mod}(X-1,4)+1=4$

9.2 UCI reporting in physical uplink control channel

UCI types reported in a PUCCH include HARQ-ACK, SR, and CSI. UCI bits include HARQ-ACK information bits, if any, SR information bit, if any, and CSI bits, if any.

9.2.1 PUCCH Resource Sets

A UE is provided by higher layers with one or more of the following higher layer parameters:

- *PUCCH-resource-config-PF0* providing resources for PUCCH transmission with PUCCH format 0;

- *PUCCH-resource-config-PF1* providing resources for PUCCH transmission with PUCCH format 1;
- *PUCCH-resource-config-PF2* providing resources for PUCCH transmission with PUCCH format 2;
- *PUCCH-resource-config-PF3* providing resources for PUCCH transmission with PUCCH format 3;
- *PUCCH-resource-config-PF4* providing resources for PUCCH transmission with PUCCH format 4.

A PUCCH resource includes the following:

- an index of the first symbol
  - for PUCCH format 0 or PUCCH format 2 the index of the first symbol index is indicated by higher layer parameter *PUCCH-F0-F2-starting symbol*;
  - for PUCCH format 1, PUCCH format 3, or PUCCH format 4, the index of the first symbol is indicated by higher layer parameter *PUCCH-F1-F3-F4-starting-symbol*;
- a number of symbols
  - for PUCCH format 0 or PUCCH format 2, the number of symbols is indicated by higher layer parameter *PUCCH-F0-F2-number-of-symbols*;
  - for PUCCH format 1 or PUCCH format 3, or PUCCH format 4, the number of symbols is indicated by higher layer parameter *PUCCH-F1-F3-F4-number-of-symbols*;
- an index of the first PRB prior to frequency hopping or for no frequency hopping by higher layer parameter *PUCCH-starting-PRB*;
- an index of the first PRB after frequency hopping by higher layer parameter *PUCCH-2nd-hop-PRB*;
- a number of PRBs (for PUCCH format 2 or PUCCH format 3)
  - for PUCCH format 2, the number of PRBs is indicated by higher layer parameter *PUCCH-F2-number-of-PRBs*;
  - for PUCCH format 3, the number of PRBs is indicated by higher layer parameter *PUCCH-F3-number-of-PRBs*;
- frequency hopping
  - frequency hopping for a PUCCH resource is either enabled or disabled and is indicated by higher layer parameter *PUCCH-frequency-hopping*;
- an index of the cyclic shift (for PUCCH format 0 or PUCCH format 1)

  - for PUCCH format 0 or PUCCH format 1, the index of the cyclic shift is indicated by higher layer parameter *PUCCH-F0-F1-initial-cyclic-shift*;

- an index of an orthogonal cover code in case of PUCCH format 1

  - the index of the orthogonal cover code is from a set determined as described in [4, TS 38.211] and is indicated by higher layer parameter *PUCCH-F1-time-domain-OCC*;

- an index of an orthogonal cover code in case of PUCCH format 4

  - the index of the orthogonal cover code is from a set of {0, 1, 2, 3} as described in [4, TS 38.211] and is indicated by higher layer parameter *PUCCH-F4-preDFT-OCC-index*;

- a length for an orthogonal cover code in case of PUCCH format 4

  - the length of the orthogonal cover code is from a set of {2, 4} as described in [4, TS 38.211] and is indicated by higher layer parameter *PUCCH-F4-preDFT-OCC-length*;

- a spatial setting by higher layer parameter *PUCCH-Spatialrelationinfo*.

A UE can be configured a number of sets of PUCCH resources by higher layer parameter *PUCCH-resource-set*, where the number of PUCCH resources in each set of PUCCH resources is provided by higher layer parameter *PUCCH-resource-set-size* and where a PUCCH resource in a set of PUCCH resources is indicated by higher layer parameter *PUCCH-resource-index*.

If the UE transmits N_{UCI} UCI bits, the UE determines a PUCCH resource set to be

- a first set of PUCCH resources if $N_{\text{UCI}} \leq 2$, or

- a second set of PUCCH resources, if any, if $2 < N_{\text{UCI}} \leq N_2$ where N_2 is provided by higher layer parameter *N_2*, or

- a third set of PUCCH resources, if any, if $N_2 < N_{\text{UCI}} \leq N_3$ where N_3 is provided by higher layer parameter *N_3*, or

- a fourth set of PUCCH resources, if any, if $N_3 < N_{\text{UCI}} \leq N_4$.

If a UE is not configured with higher layer parameter *PUCCH-resource-set*, an UL BWP for PUCCH transmission with HARQ-ACK information is indicated by *SystemInformationBlockType1* and a set of PUCCH resources is provided by higher layer parameter *PUCCH-resource-common* in *SystemInformationBlockType1*.

9.2.2 PUCCH Formats for UCI transmission

If a UE is not transmitting PUSCH, and the UE is transmitting UCI, the UE shall transmit UCI

- on PUCCH format 0 if
  - the transmission is over 1 symbol or 2 symbols,
  - the number of UCI bits is 1 or 2
- on PUCCH format 1 if
  - the transmission is over 4 or more symbols,
  - the number of UCI bits is 1 or 2
- on PUCCH format 2 if
  - the transmission is over 1 symbol or 2 symbols,
  - the number of UCI bits is more than 2
- on PUCCH format 3 if
  - the transmission is over 4 or more symbols,
  - the number of UCI bits is more than 2
- on PUCCH format 4 if
  - the transmission is over 4 or more symbols,
  - the number of UCI bits is more than 2,
  - a PUCCH resource includes an orthogonal cover code

For PUCCH format 3 or for PUCCH format 4, a UE can be configured by higher layer parameter *PUCCH-F3-F4-additional-DMRS* a number of symbols used for DM-RS transmission as described in [4, TS 38.211].

9.2.3 UE procedure for reporting HARQ-ACK

A UE may transmit one or more PUCCHs on a serving cell in different symbols within a slot of $N_{\text{symb}}^{\text{slot}}$ symbols as defined in [4, TS 38.211]. With reference to slots for PUCCH transmissions, if the UE detects a DCI format 1_0 or a DCI format 1_1 that includes a PDSCH-to-HARQ-timing-indicator field [5, TS 38.212] and schedules a PDSCH reception or DL SPS release over a number of symbols where the last symbol is within slot $n-k$, the UE shall provide corresponding HARQ-ACK information in a PUCCH transmission within slot n, where k is a number of slots and is indicated by the PDSCH-to-HARQ-timing-indicator field in the DCI format. The PDSCH-to-HARQ-timing-indicator field values map to values for a number of slots indicated by higher layer parameter *DL-data-DL-acknowledgement* as defined in Table 9.2.1-1 from a set of number of slots provided by higher layer parameter *Slot-timing-value-K1*. If the UE detects a DCI format that does not include a PDSCH-to-HARQ-timing-indicator field and schedules a PDSCH reception over a number of symbols where the last symbol is within slot $n-k$, the UE shall provide corresponding HARQ-ACK information in a PUCCH transmission within slot $n-k+4$.

Table 9.2.1-1: Mapping of PDSCH-to-HARQ_feedback timing indicator field values to numbers of slots

PDSCH-to-HARQ_feedback timing indicator	Number of slots k
'000'	1st value provided by *DL-data-DL-acknowledgement*
'001'	2nd value provided by *DL-data-DL-acknowledgement*
'010'	3rd value provided by *DL-data-DL-acknowledgement*
'011'	4th value provided by *DL-data-DL-acknowledgement*
'100'	5th value provided by *DL-data-DL-acknowledgement*
'101'	6th value provided by *DL-data-DL-acknowledgement*
'110'	7th value provided by *DL-data-DL-acknowledgement*
'111'	8th value provided by *DL-data-DL-acknowledgement*

For transmission of HARQ-ACK information in a PUCCH by a UE, the UE determines a PUCCH resource after determining a set of PUCCH resources, as described in Subclause 9.2.1. The PUCCH resource determination is based on a PUCCH resource indicator field [5, TS 38.212] in a last DCI format 1_0 or DCI format 1_1 that the UE detects and for which the UE transmits corresponding HARQ-ACK information in the PUCCH where detected DCI formats are indexed in an ascending order first across cells indexes and then across PDCCH monitoring occasion indexes. The PUCCH resource indicator field values map to values of PUCCH resource indexes provided by higher layer parameter *PUCCH-resource-index* as defined in Table 9.2.1-2 from a number of indexes provided by higher layer parameter *PUCCH-resource-set-size*.

If the *PUCCH-resource-set-size* is larger than four and the PUCCH resource indicator field indicates two PUCCH resources, the UE determines a PUCCH resource from the two PUCCH resources through a mapping function to other parameters.

Table 9.2.1-2: Mapping of PUCCH resource indication field values to a PUCCH resource in a PUCCH resource set

PUCCH resource indicator	PUCCH resource
'00'	{1st, 5th} resource provided by *PUCCH-resource-index*
'01'	{2nd, 6th} resource provided by *PUCCH-resource-index*
'10'	{3rd, 7th} resource provided by *PUCCH-resource-index*
'11'	{4th, 8th} resource provided by *PUCCH-resource-index*

If a UE receives a PDSCH without a corresponding PDCCH, a PUCCH resource for corresponding HARQ-ACK transmission is provided by higher layer parameter *n1PUCCH-AN*.

If a UE transmits HARQ-ACK using PUCCH format 0, the UE determines a value m_{CS} for computing a value of cyclic shift α [4, TS 38.211] as $m_{\text{CS}} = m + m_0$ where m_0 is provided by higher layer parameter *PUCCH-F0-F1-initial-cyclic-shift* of *PUCCH-F0-resource-config*, and m is determined from the value of one HARQ-ACK bit or from the values of two HARQ-ACK bits as in Table 9.2.1-3 and Table 9.2.1-4, respectively, where a NACK value is mapped to '0' and an ACK value is mapped to '1'.

Table 9.2.1-3: Mapping of values for one HARQ-ACK bit to sequences

HARQ-ACK Value	0	1
Sequence cyclic shift	$m = 0$	$m = 6$

Table 9.2.1-4: Mapping of values for two HARQ-ACK bits to sequences

HARQ-ACK Value	{0, 0}	{0, 1}	{1, 1}	{1, 0}
Sequence cyclic shift	$m = 0$	$m = 3$	$m = 6$	$m = 9$

If a UE transmits O_{ACK} HARQ-ACK bits and O_{CRC} bits using PUCCH format 2 or PUCCH format 3, the UE determines a number of PRBs $M_{\text{RB,min}}^{\text{PUCCH}}$ for the PUCCH transmission to be the minimum number of PRBs, that is smaller than or equal to a number of PRBs provided respectively by higher layer parameter *PUCCH-F2-number-of-PRBs* or *PUCCH-F3-number-of-PRBs* and starts from the first PRB from the number of PRBs, that results to $\left(O_{\text{ACK}} + O_{\text{CRC}}\right) \le M_{\text{RB,min}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$ and, if $M_{\text{RB}}^{\text{PUCCH}} > 1$,

$(O_{\text{ACK}} + O_{\text{CRC}}) > (M_{\text{RB,min}}^{\text{PUCCH}} - 1) \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$, where $N_{\text{sc,ctrl}}^{\text{RB}}$, $N_{\text{symb}}^{\text{PUCCH}}$, Q_m, and r are defined in Subclause 9.2.5.2.

9.2.4 UE procedure for reporting SR

A UE is configured by higher layer paremater *SR-configurations* a set of configurations for SR transmission.

The UE is configured by higher layers to convey a SR in a PUCCH transmission using either PUCCH format 0 or PUCCH format 1 byhigher layer parameter *SR-configurations*, a PUCCH resource by higher layer parameter *SR-resource* providing a PUCCH format 0 resource through higher layer parameter *PUCCH-resource-config-PF0* or a PUCCH format 1 resource through higher layer parameter *PUCCH-resource-config-PF1*, a periodicity $SR_{\text{PERIODICITY}}$ in symbols by higher layer parameter *SR-periodicity*, and an offset SR_{OFFSET} in symbols by higher layer parameter *SR-offset* for a PUCCH transmission conveying SR as defined in Table 9.2.4.

Table 9.2.4: UE-specific SR periodicity and offset configuration

UE-specific SR periodicity and offset configuration (in symbols)			
μ	**CP**		
0	Normal	$SR_{\text{PERIODICITY}}$	2, 7, n*14, where n={1, 2, 5, 10, 20, 32, 40, 64, 80}
		SR_{OFFSET}	
1	Normal	$SR_{\text{PERIODICITY}}$	2, 7, n*14, where n={1, 2, 5, 10, 20, 32, 40, 64, 80, 160}
		SR_{OFFSET}	
2	Normal	$SR_{\text{PERIODICITY}}$	2, 7, n*14, where n={1, 2, 5, 10, 20, 32, 40, 64, 80, 160, 320}
		SR_{OFFSET}	
2	Extended	$SR_{\text{PERIODICITY}}$	2, 6, n*12, where n={1, 2, 5, 10, 20, 32, 40, 64, 80, 160, 320}
		SR_{OFFSET}	
3	Normal	$SR_{\text{PERIODICITY}}$	2, 7, n*14, where n={1, 2, 5, 10, 20, 32, 40, 64, 80, 160, 320, 640}
		SR_{OFFSET}	

9.2.5 UE procedure for reporting multiple UCI types

9.2.5.1 UE procedure for multiplexing HARQ-ACK or CSI and SR

In the following, a SR transmission occasion from a UE is assumed to have a same first symbol and duration with a HARQ-ACK transmission from the UE or a same first symbol and duration with a CSI transmission from the UE.

If a UE transmits HARQ-ACK and positive SR using PUCCH format 0, the UE transmits the PUCCH format 0 in PRB(s) indicated by DCI format 1_0 or DCI format 1_1 for HARQ-ACK transmission. The UE determines a value of m_{CS} for computing a value of cyclic shift α [4, TS 38.211] as $m_{\text{CS}} = m + m_0$ where m_0 is provided by higher layer parameter *PUCCH-F0-F1-initial-cyclic-shift*, and m is determined from the value of one HARQ-ACK bit or from the values of two HARQ-ACK bits as in Table 9.2.5-1 and Table 9.2.5-2, respectively, where a NACK value is mapped to '0' and an ACK value is mapped to '1'.

If the UE transmits HARQ-ACK and negative SR using PUCCH format 0, the UE transmits the PUCCH format 0 in PRB(s) indicated by DCI format 1_0 or DCI format 1_1 for HARQ-ACK transmission using the mapping for the value of m for the set of sequences $\{x_i(n)\}_{i=0}^{2^{M_{\text{bit}}}-1}$, where $M_{\text{bit}} \in \{1,2\}$ and m_0 [4, TS 38.211] is provided by higher layer parameter *PUCCH-F0-F1-initial-cyclic-shift*, to the values of one HARQ-ACK bit or to the values of two HARQ-ACK bits as described in Subclause 9.2.3.

Table 9.2.5-1: Mapping of values for one HARQ-ACK bit and positive SR to sequences

HARQ-ACK Value	0	1
Sequence cyclic shift	$m = 3$	$m = 9$

Table 9.2.5-2: Mapping of values for two HARQ-ACK bits and positive SR to sequences

HARQ-ACK Value	{0, 0}	{0, 1}	{1, 1}	{1, 0}
Sequence cyclic shift	$m = 1$	$m = 4$	$m = 7$	$m = 10$

If a UE transmits HARQ-ACK and negative SR using PUCCH format 1, the UE transmits the PUCCH format 1 using a PUCCH resource indicated by DCI format 1_0 or DCI format 1_1 for HARQ-ACK transmission. If the UE transmits HARQ-ACK and positive SR using PUCCH format 1, the UE transmits the PUCCH format 1 using a PUCCH resource provided by higher layer parameter *SR-resource* for SR transmission.

If a UE transmits HARQ-ACK using PUCCH format 2 or PUCCH format 3 or PUCCH format 4, one bit representing a SR value is appended to the HARQ-ACK bits.

If a UE transmits periodic CSI or semi-persistent CSI using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 and, respectively, *PUCCH-F2-simultaneous-HARQ-ACK-CSI* = TRUE, *PUCCH-F3-simultaneous-HARQ-ACK-CSI* = TRUE, or *PUCCH-F4-simultaneous-HARQ-ACK-CSI* = TRUE, one bit representing a SR value is appended to the CSI bits as described in Subclause 9.2.5.2. If a UE transmits O_{ACK} HARQ-ACK bits, $O_{\text{SR}} = 1$ SR bit, and O_{CRC} bits using PUCCH format 2 or PUCCH format 3, the UE determines a number of PRBs $M_{\text{RB,min}}^{\text{PUCCH}}$ for the PUCCH transmission to be the minimum number of PRBs, that is smaller than or equal to a number of PRBs provided respectively by higher layer parameter *PUCCH-F2-*

number-of-PRBs or *PUCCH-F3-number-of-PRBs* and starts from the first PRB from the number of PRBs, that results to $(O_{\text{ACK}}+O_{\text{SR}}+O_{\text{CRC}}) \le M_{\text{RB,min}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$ and, if $M_{\text{RB}}^{\text{PUCCH}} > 1$, $(O_{\text{ACK}}+O_{\text{SR}}+O_{\text{CRC}}) > (M_{\text{RB,min}}^{\text{PUCCH}} - 1) \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$, where $N_{\text{sc,ctrl}}^{\text{RB}}$, $N_{\text{symb}}^{\text{PUCCH}}$, Q_m, and r are defined in Subclause 9.2.5.2.

9.2.5.2 UE procedure for multiplexing HARQ-ACK/SR and CSI

For a UE transmitting a PUCCH using PUCCH format 2, PUCCH format 3, or PUCCH format 4 to convey HARQ-ACK/SR and periodic CSI reports

- if the UE transmits PUCCH using PUCCH format 2 to convey the HARQ-ACK/SR, the UE transmits HARQ-ACK/SR and periodic/semi-persistent CSI report(s) in the PUCCH if the parameter *PUCCH-F2-simultaneous-HARQ-ACK-CSI* provided by higher layers is set *TRUE*; otherwise, the UE drops the periodic CSI report(s) and conveys only HARQ-ACK/SR in the PUCCH as described in Subclause 9.2.5.1;
- if the UE transmits PUCCH using PUCCH format 3 to convey the HARQ-ACK/SR, the UE transmits HARQ-ACK/SR and periodic/semi-persistent CSI report(s) in the PUCCH if the parameter *PUCCH-F3-simultaneous-HARQ-ACK-CSI* provided by higher layers is set *TRUE*; otherwise, the UE drops the periodic CSI report(s) and conveys only HARQ-ACK/SR in the PUCCH as described in Subclause 9.2.5.1;
- if the UE transmits PUCCH using PUCCH format 4 to convey the HARQ-ACK/SR, the UE transmits HARQ-ACK/SR and periodic/semi-persistent CSI report(s) in the PUCCH if the parameter *PUCCH-F4-simultaneous-HARQ-ACK-CSI* provided by higher layers is set *TRUE*; otherwise, the UE drops the periodic CSI report(s) and conveys only HARQ-ACK/SR in the PUCCH as described in Subclause 9.2.5.1.

A UE is configured by higher layer parameter *PUCCH-F2-maximum-coderate* a code rate for transmission of HARQ-ACK/SR and periodic/semi-persistent CSI report(s) in PUCCH format 2.

A UE is configured by higher layer parameter *PUCCH-F3-maximum-coderate* a code rate for transmission of HARQ-ACK/SR and periodic/semi-persistent CSI report(s) in PUCCH format 3.

A UE is configured by higher layer parameter *PUCCH-F4-maximum-coderate* a code rate for transmission of HARQ-ACK/SR and periodic/semi-persistent CSI report(s) in PUCCH format 4.

If a UE has periodic/semi-persistent CSI reports and HARQ-ACK/SR to transmit in a PUCCH and the UE does not determine a PUCCH format 2 or 3 or 4 to transmit HARQ-ACK/SR and the UE is configured to transmit periodic/semi-persistent CSI report(s) in a PUCCH using PUCCH format 2 or PUCCH format 3 or PUCCH format 4, respectively, and *PUCCH-F2-simultaneous-HARQ-ACK-CSI = TRUE*, or *PUCCH-F3-simultaneous-HARQ-ACK-CSI = TRUE*, or *PUCCH-F4-simultaneous-HARQ-ACK-CSI*, respectively

- if the UE is configured with $J \geq 1$ PUCCH format 2 resources, or with $J \geq 1$ PUCCH format 3 resources, or with $J \geq 1$ PUCCH format 4 resources, as described in Subclause 9.2.1, where the resources are indexed according to an ascending order for a number of corresponding REs,
  - if $(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}) \leq M_{\text{RB},0}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb},0}^{\text{PUCCH}} \cdot Q_m \cdot r$, the PUCCH uses PUCCH format 2 resource 0, or the PUCCH format 3 resource 0, or the PUCCH format 4 resource 0 by selecting the minimum number $M_{\text{RB},0,\min}^{\text{PUCCH}}$ of PRBs from the $M_{\text{RB},0}^{\text{PUCCH}}$ PRBs satisfying $(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}) \leq M_{\text{RB},0,\min}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb},0}^{\text{PUCCH}} \cdot Q_m \cdot r$ as described in Subclauses 9.2.3 and 9.2.5.1;
  - else if $(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}) > M_{\text{RB},j}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb},j}^{\text{PUCCH}} \cdot Q_m \cdot r$ and $(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}) \leq M_{\text{RB},j+1}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb},j+1}^{\text{PUCCH}} \cdot Q_m \cdot r$, $0 \leq j < J$, the UE transmits a PUCCH conveying HARQ-ACK/SR and periodic/semi-persistent CSI report(s) in a respective PUCCH where the PUCCH uses PUCCH format 2 resource $j+1$, or the PUCCH format 3 resource $j+1$, or the PUCCH format 4 resource $j+1$ by selecting the minimum number $M_{\text{RB},j+1,\min}^{\text{PUCCH}}$ of PRBs from the $M_{\text{RB},j+1}^{\text{PUCCH}}$ PRBs satisfying $(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}) \leq M_{\text{RB},j+1,\min}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb},0}^{\text{PUCCH}} \cdot Q_m \cdot r$ as described in Subclauses 9.2.3 and 9.2.5.1;
  - else the PUCCH uses PUCCH format 2 resource $J-1$, or the PUCCH format 3 resource $J-1$, or the PUCCH format 4 resource $J-1$ by selecting the minimum number $M_{\text{RB},J-1,\min}^{\text{PUCCH}}$ of PRBs from the $M_{\text{RB},J-1}^{\text{PUCCH}}$ PRBs satisfying $(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}) \leq M_{\text{RB},J-1,\min}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb},0}^{\text{PUCCH}} \cdot Q_m \cdot r$ as described in Subclauses 9.2.3 and 9.2.5.1, where
    - O_{ACK} is the total number of HARQ-ACK bits;
    - $O_{\text{SR}} = 0$ if there is no scheduling request bit; otherwise, $O_{\text{SR}} = 1$;
    - O_{CSI} is the total number of CSI reports bits;
    - O_{CRC} is the total number of CRC bits, if any;
    - r is the code rate given by higher layer parameter *PUCCH-F2-maximum-coderate* for PUCCH format 2, or *PUCCH-F3-maximum-coderate* for PUCCH format 3, or *PUCCH-F4-maximum-coderate* for PUCCH format 4, respectively, as in Table 9.2.5.2-1.
    - $M_{\text{RB}}^{\text{PUCCH}}$ is the number of PRBs for PUCCH format 2, or PUCCH format 3, or PUCCH format 4, respectively, where $M_{\text{RB}}^{\text{PUCCH}}$ is provided by higher layer parameter *PUCCH-F2-number-of-PRBs* for PUCCH format 2 or by higher layer parameter *PUCCH-F3-number-of*-PRBs for PUCCH format 3, and $M_{\text{RB}}^{\text{PUCCH}} = 1$ for PUCCH format 4;

- $N_{\text{sc,ctrl}}^{\text{RB}} = N_{\text{sc}}^{\text{RB}} - 4$ for PUCCH format 2 and $N_{\text{sc,ctrl}}^{\text{RB}} = N_{\text{sc}}^{\text{RB}}$ for PUCCH format 3 and PUCCH format 4;
  - $N_{\text{symb}}^{\text{PUCCH}}$ is the number of symbols for PUCCH format 2 ($N_{\text{symb}}^{\text{PUCCH,2}}$), or PUCCH format 3 ($N_{\text{symb}}^{\text{PUCCH,3}}$), or PUCCH format 4 ($N_{\text{symb}}^{\text{PUCCH,4}}$), respectively, where $N_{\text{symb}}^{\text{PUCCH}}$ is provided by higher layer parameter *PUCCH-F0-F2-number-of-symbols* for PUCCH format 2, and is determined by higher layer parameter *PUCCH-F1-F3-F4-number-of-symbols* for PUCCH format 3 or for PUCCH format 4 after excluding a number of symbols used for DM-RS transmission for PUCCH format 3 or for PUCCH format 4, respectively [4, TS 38.211];
- $Q_m = 1$ if pi/2-BPSK is the modulation scheme and $Q_m = 2$ if QPSK is the modulation scheme as indicated by higher layer parameter *PUCCH-PF3-PF4-pi/2BPSK* for PUCCH format 3 or PUCCH format 4. For PUCCH format 2, $Q_m = 2$.

If a UE has periodic/semi-persistent CSI reports to transmit in a PUCCH and the UE determines a PUCCH format 2 to transmit HARQ-ACK/SR and *PUCCH-F2-simultaneous-HARQ-ACK-CSI = TRUE*

- if $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}\right) \le M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$, the UE shall transmit the HARQ-ACK/SR and periodic/semi-persistent CSI bits using PUCCH format 2 by selecting the minimum number $M_{\text{RB,min}}^{\text{PUCCH}}$ of the $M_{\text{RB}}^{\text{PUCCH}}$ PRBs satisfying $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}\right) \le M_{\text{RB,min}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$ as described in Subclauses 9.2.3 and 9.2.5.1;
- else, the UE selects $N_{\text{CSI}}^{\text{reported}}$ CSI report(s) for transmission together with HARQ-ACK/SR in ascending order of $\text{Pri}_{\text{CSI}}(y,s,c,t)$, where $\text{Pri}_{\text{CSI}}(y,s,c,t)$ is determined according to [6, TS 38.214]; the value of $N_{\text{CSI}}^{\text{reported}}$ satisfies $\left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{reported}}} O_{\text{CSI},n} + O_{\text{CRC}}\right) \le M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$ and $\left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{reported}}+1} O_{\text{CSI},n} + O_{\text{CRC}}\right) > M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc,ctrl}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$, where $O_{\text{CSI},n}$ is the number of CSI report bits for the n_{th} CSI report in ascending order of $\text{Pri}_{CSI}(y,s,c,t)$.

If a UE has $N_{\text{CSI}}^{\text{total}}$ periodic/semi-persistent CSI reports to transmit in a PUCCH and the UE determines either a PUCCH format 3 or a PUCCH format 4 to transmit HARQ-ACK/SR, and *PUCCH-F3-simultaneous-HARQ-ACK-CSI = TRUE*, or *PUCCH-F4-simultaneous-HARQ-ACK-CSI = TRUE*, respectively

- if $\left(O_{\text{ACK}} + O_{\text{SR}} + O_{\text{CSI}} + O_{\text{CRC}}\right) \le M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$ for the $N_{\text{CSI}}^{\text{total}}$ periodic/semi-persistent CSI reports, where $\sum_{n=1}^{N_{\text{CSI}}^{\text{total}}} \left(O_{\text{CSI-part1},n} + O_{\text{CSI-part2},n}\right) = O_{\text{CSI}}$ and $O_{\text{CRC,CSI-part1}} + O_{\text{CRC,CSI-part2}} = O_{\text{CRC}}$, the UE shall transmit the HARQ-ACK/SR and the $N_{\text{CSI}}^{\text{total}}$

periodic/semi-persistent CSI report bits using either PUCCH format 3 or PUCCH format 4;

- else,
  - if for $N_{\text{CSI-part2}}^{\text{reported}} > 0$ CSI part 2 report(s), it is

$$\sum_{n=1}^{N_{\text{CSI-part2}}^{\text{reported}}} O_{\text{CSI-part2},n} + O_{\text{CRC-part2}} \le \left(M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} - \left\lceil \left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{total}}} O_{\text{CSI-part1},n} + O_{\text{CRC,CSI-part1}} \right) \Big/ \left(Q_m \cdot r \right) \right\rceil \right) \cdot Q_m \cdot r$$

and

$$\sum_{n=1}^{N_{\text{CSI-part2}}^{\text{reported}}+1} O_{\text{CSI-part2},n} + O_{\text{CRC-part2}} > \left(M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} - \left\lceil \left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI}}^{\text{total}}} O_{\text{CSI-part1},n} + O_{\text{CRC,CSI-part1}} \right) \Big/ \left(Q_m \cdot r \right) \right\rceil \right) \cdot Q_m \cdot r,$$

    the UE selects $N_{\text{CSI-part2}}^{\text{reported}}$ CSI part 2 report(s), in ascending order of $\text{Pri}_{\text{CSI}}(y,s,c,t)$, where $\text{Pri}_{\text{CSI}}(y,s,c,t)$ is determined according to [6, TS 38.214], for transmission together with the HARQ-ACK/SR and $N_{\text{CSI}}^{\text{total}}$ CSI part 1 reports using either PUCCH format 3 or PUCCH format 4, where $O_{\text{CSI-part1},n}$ is the number of CSI part 1 report bits for the n_{th} CSI report and $O_{\text{CSI-part2},n}$ is the number of CSI part 2 report bits for the n_{th} CSI report in ascending order of $\text{Pri}_{CSI}(y,s,c,t)$, and $O_{\text{CRC,CSI-part1}} + O_{\text{CRC,CSI-part2}} = O_{\text{CRC}}$;
  - else, the UE drops all CSI part2 reports and selects $N_{\text{CSI,part1}}^{\text{reported}}$ CSI part 1 report(s), in ascending order of $\text{Pri}_{\text{CSI}}(y,s,c,t)$, where $\text{Pri}_{\text{CSI}}(y,s,c,t)$ is determined according to [6, TS 38.214], for transmission together with the HARQ-ACK/SR bits using either in PUCCH format 3 or in PUCCH format 4 where the value of $N_{\text{CSI,pat1}}^{\text{reported}}$ satisfies $\left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI-part1}}^{\text{reported}}} O_{\text{CSI-part1},n} + O_{\text{CRC}} \right) \le M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$ and $\left(O_{\text{ACK}} + O_{\text{SR}} + \sum_{n=1}^{N_{\text{CSI-part1}}^{\text{reported}}+1} O_{\text{CSI-part1},n} + O_{\text{CRC}} \right) > M_{\text{RB}}^{\text{PUCCH}} \cdot N_{\text{sc}}^{\text{RB}} \cdot N_{\text{symb}}^{\text{PUCCH}} \cdot Q_m \cdot r$, where $O_{\text{CSI-part1},n}$ is the number of CSI report bits for the n_{th} CSI part 1 report in ascending order of $\text{Pri}_{CSI}(y,s,c,t)$ and $O_{\text{CRC,CSI-part1}} = O_{\text{CRC}}$.

Table 9.2.5.2-1: Code rate r corresponding to higher layer parameter *PUCCH-F2-maximum-coderate, or PUCCH-F3-maximum-coderate, or PUCCH-F4-maximum-coderate*

Value of *PUCCH-F2-maximum-coderate*	
Value of *PUCCH-F3-maximum-coderate*	**Code rate** r
Value of *PUCCH-F4-maximum-coderate*	

0	0.08
1	0.15
2	0.25
3	0.35
4	0.45
5	0.60
6	0.80
7	Reserved

9.2.6 UCI repetition procedure

For PUCCH formats 1, 3, or 4, a UE can be configured a number of slots, $N_{\text{PUCCH}}^{\text{repeat}}$, for a PUCCH transmission by respective higher layer parameters *PUCCH-F1-number-of-slots* , *PUCCH-F3-number-of-slots*, or *PUCCH-F4-number-of-slots*.

For $N_{\text{PUCCH}}^{\text{repeat}} > 1$,

- the UE repeats the UCI in the PUCCH transmission in the first slot of the $N_{\text{PUCCH}}^{\text{repeat}}$ slots in the PUCCH transmission in each of the remaining $N_{\text{PUCCH}}^{\text{repeat}} - 1$ slots;
- a PUCCH transmission has the same number of consecutive symbol, as provided by higher layer parameter *PUCCH-F1-F3-F4-number-of-symbols*, in each of the $N_{\text{PUCCH}}^{\text{repeat}}$ slots;
- a PUCCH transmission has a same first symbol, as provided by higher layer parameter *PUCCH-F1-F3-F4-starting-symbol*, in each of the $N_{\text{PUCCH}}^{\text{repeat}}$ slots;
- the UE is configured by higher layer parameter *PUCCH-F1-F3-F4-interslot-FH* whether or not to perform frequency hopping for PUCCH transmissions in different slots. If *PUCCH-F1-F3-F4-interslot-FH = ON*, a first PRB for PUCCH transmission is provided by higher layer parameter *PUCCH-starting-PRB* and a second PRB for PUCCH transmission is provided by higher layer parameter *PUCCH-2nd-hop-PRB*.
  - If the UE is configured to perform frequency hopping for PUCCH transmissions in different slots,
    - the UE performs frequency hopping per slot;
    - the UE is not expected to be configured to perform frequency hopping for a PUCCH transmission within a slot.

If a UE is provided higher layer parameter *UL-DL-configuration-common* or is additionally provided higher layer parameter *UL-DL-configuration-dedicated* for the slot format per slot over the number of slots, as described in Subclause 11.1, the UE determines the $N_{\text{PUCCH}}^{\text{repeat}}$ slots for a PUCCH transmission as the first slots starting from a slot indicated to the UE as described in Subclause 9.2.3 and having

- an UL symbol for a symbol provided by higher layer parameter *PUCCH-F1-F3-F4-starting-symbol* is an UL symbol, and
- consecutive UL symbols, starting from the symbol, equal to a number of symbols provided higher layer parameter *PUCCH-F1-F3-F4-number-of-symbols*.

If a UE is not provided higher layer parameter *UL-DL-configuration-common*, the UE determines the $N_{\text{PUCCH}}^{\text{repeat}}$ slots for a PUCCH transmission as the $N_{\text{PUCCH}}^{\text{repeat}}$ consecutive slots starting from a slot indicated to the UE as described in Subclause 9.2.3.

9.3 UCI reporting in physical uplink shared channel

Offset values are defined for a UE to determine a number of resources for multiplexing HARQ-ACK and for multiplexing CSI in a PUSCH. The offset values are signalled to a UE either by a DCI format scheduling the PUSCH transmission or by higher layers.

For offset values signalled to the UE by higher layers, PUSCH transmission offsets $\beta_{\text{offset}}^{\text{HARQ-ACK}}$ shall be configured to values according to Table 9.3-1 with the higher layer signalled index $I_{\text{offset,0}}^{\text{HARQ-ACK}}$ if the UE transmits up to 2 HARQ-ACK bits on a PUSCH, $I_{\text{offset,1}}^{\text{HARQ-ACK}}$ if the UE transmits more than 2 and up to 11 HARQ-ACK bits on a PUSCH, and $I_{\text{offset,2}}^{\text{HARQ-ACK}}$ if the UE transmits more than [11] HARQ-ACK bits on a PUSCH.

PUSCH transmission offsets $\beta_{\text{offset}}^{\text{CSI-1}}$ and $\beta_{\text{offset}}^{\text{CSI-2}}$ shall be configured to values according to Table 9.3-2 for CSI part-1 and CSI part-2 transmission in a PUSCH, respectively, with the respective higher layer signalled indexes $I_{\text{offset,0}}^{\text{CSI-1}}$ or $I_{\text{offset,0}}^{\text{CSI-2}}$ if the UE transmits up to 11 bits for CSI part-1 or CSI part-2 on a PUSCH, and with the respective higher layer signalled indexes $I_{\text{offset,1}}^{\text{CSI-1}}$ or $I_{\text{offset,1}}^{\text{CSI-2}}$, if the UE transmits more than 11 bits for CSI part-1 or CSI part 2 on a PUSCH.

If DCI format 0_1 scheduling a PUSCH transmission to a UE includes a UCI offset indicator field, the UE determines a set of four $I_{\text{offset}}^{\text{HARQ-ACK}}$ indexes, a set of four $I_{\text{offset}}^{\text{CSI-1}}$ indexes and a set of four $I_{\text{offset}}^{\text{CSI-2}}$ indexes from Table 9.3-1 and 9.3-2, respectively, for transmitting HARQ-ACK, CSI part-1, and CSI part-2, respectively, in the PUSCH transmission. The UCI offset indicator field indicates a $I_{\text{offset}}^{\text{HARQ-ACK}}$ value, a $I_{\text{offset}}^{\text{CSI-1}}$ value and a $I_{\text{offset}}^{\text{CSI-2}}$ value from the respective sets of values, with the mapping defined in Table 9.3-3. If the PUSCH transmission is configured by DCI format 0_0, the UE applies the $\beta_{\text{offset}}^{\text{HARQ-ACK}}$ and/or $\beta_{\text{offset}}^{\text{CSI-1}}$ and $\beta_{\text{offset}}^{\text{CSI-2}}$ values that are configured by higher layers for the corresponding HARQ-ACK and/or CSI part 1 and CSI part 2 payloads.

Table 9.3-1: Mapping of HARQ-ACK offset values and the index signalled by higher layers

$I_{\text{offset},0}^{\text{HARQ-ACK}}$ **or** $I_{\text{offset},1}^{\text{HARQ-ACK}}$ **or** $I_{\text{offset},2}^{\text{HARQ-ACK}}$	$\beta_{\text{offset}}^{\text{HARQ-ACK}}$
0	1.000
1	2.000
2	2.500
3	3.125
4	4.000
5	5.000
6	6.250
7	8.000
8	10.000
9	12.625
10	15.875
11	20.000
12	31.000
13	50.000
14	80.000
15	126.000
16	Reserved
17	Reserved
18	Reserved
19	Reserved
20	Reserved
21	Reserved
22	Reserved
23	Reserved
24	Reserved
25	Reserved

26	Reserved
27	Reserved
28	Reserved
29	Reserved
30	Reserved
31	Reserved

Table 9.3-2: Mapping of CSI offset values and the index signalled by higher layers

$I_{\text{offset},0}^{\text{CSI-1}}$ or $I_{\text{offset},1}^{\text{CSI-2}}$ $I_{\text{offset},0}^{\text{CSI-2}}$ or $I_{\text{offset},1}^{\text{CSI-2}}$	$\beta_{\text{offset}}^{\text{CSI-1}}$ $\beta_{\text{offset}}^{\text{CSI-2}}$
0	1.125
1	1.250
2	1.375
3	1.625
4	1.750
5	2.000
6	2.250
7	2.500
8	2.875
9	3.125
10	3.500
11	4.000
12	5.000
13	6.250
14	8.000
15	10.000
16	15.875
17	20.000
18	Reserved
19	Reserved
20	Reserved
21	Reserved
22	Reserved
23	Reserved
24	Reserved
25	Reserved

26	Reserved
27	Reserved
28	Reserved
29	Reserved
30	Reserved
31	Reserved

Table 9.3-3: Mapping of UCI offset indicator values to offset indexes

UCI offset indicator	($I_{\text{offset},0}^{\text{HARQ-ACK}}$ or $I_{\text{offset},1}^{\text{HARQ-ACK}}$ or $I_{\text{offset},2}^{\text{HARQ-ACK}}$), ($I_{\text{offset},0}^{\text{CSI-1}}$ or $I_{\text{offset},0}^{\text{CSI-2}}$), ($I_{\text{offset},1}^{\text{CSI-1}}$ or $I_{\text{offset},1}^{\text{CSI-2}}$)
'00'	1st offset index
'01'	2nd offset index
'10'	3rd offset index
'11'	4th offset index

10 UE procedure for receiving control information

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

A UE shall monitor a set of PDCCH candidates in one or more control resource sets on the active DL BWP on each activated serving cell according to corresponding search spaces where monitoring implies decoding each PDCCH candidate according to the monitored DCI formats.

A UE can be configured by higher layer parameter *SSB-periodicity-serving-cell* a periodicity of half frames for transmission of SS/PBCH blocks in a serving cell. If the UE has received *SSB-transmitted-SIB1* and has not received *SSB-transmitted* and if REs for a PDCCH reception overlap with REs corresponding to SS/PBCH block indexes indicated by *SSB-transmitted-SIB1*, the UE receives the PDCCH by excluding REs corresponding to SS/PBCH block indexes indicated by *SSB-transmitted-SIB1*. If a UE has received *SSB-*

transmitted and if REs for a PDCCH reception overlap with REs corresponding to SS/PBCH block indexes indicated by *SSB-transmitted*, the UE receives the PDCCH by excluding REs corresponding to SS/PBCH block indexes indicated by *SSB-transmitted*.

If a carrier aggregation capability for a UE, as included in *UE-NR-Capability*, is larger than X, the UE includes in *UE-NR-Capability* an indication for a maximum number of PDCCH candidates the UE can monitor per slot when the UE is configured for carrier aggregation operation over more than X cells. When the UE is configured for carrier aggregation operation over more than X cells, the UE is not expected to be configured with a number of PDCCH candidates to monitor per slot that is larger than the maximum number.

10.1 UE procedure for determining physical downlink control channel assignment

A set of PDCCH candidates for a UE to monitor is defined in terms of PDCCH search spaces. A search space can be a common search space or a UE-specific search space. A UE shall monitor PDCCH candidates in non-DRX slots in one or more of the following search spaces

- a Type0-PDCCH common search space for a DCI format with CRC scrambled by a SI-RNTI on a primary cell;
- a Type0A-PDCCH common search space for a DCI format with CRC scrambled by a SI-RNTI on a primary cell;
- a Type1-PDCCH common search space for a DCI format with CRC scrambled by a RA-RNTI, or a TC-RNTI, or a C-RNTI on a primary cell;
- a Type2-PDCCH common search space for a DCI format with CRC scrambled by a P-RNTI on a primary cell;
- a Type3-PDCCH common search space for a DCI format with CRC scrambled by INT-RNTI, or SFI-RNTI, or TPC-PUSCH-RNTI, or TPC-PUCCH-RNTI, or TPC-SRS-RNTI, or C-RNTI, or CS-RNTI(s); and
- a UE-specific search space for a DCI format with CRC scrambled by C-RNTI or CS-RNTI(s).

A UE is provided a configuration for a control resource set for Type0-PDCCH common search space by higher layer parameter *RMSI-PDCCH-Config* and a subcarrier spacing by higher layer parameter *RMSI-scs* for PDCCH reception. The UE determines the control resource set and the monitoring occasions for Type0-PDCCH common search space as described in Subclause 14. The Type0-PDCCH common search space is defined by the CCE aggregation levels and the number of candidates per CCE aggregation level given in Table 10.1-1.

The UE may assume that the DM-RS antenna port associated with PDCCH reception in the Type0-PDCCH common search space and the Type2-PDCCH common search space, and for corresponding PDSCH receptions, and the DM-RS antenna port associated with

SS/PBCH reception are quasi co-located with respect to delay spread, Doppler spread, Doppler shift, average delay, and spatial Rx parameters. The value for the DM-RS scrambling sequence initialization is the cell ID.

For Type0A-PDCCH common search space or for Type-2 PDCCH common search space, the control resource set is same as the control resource set for Type0-PDCCH common search space. A UE is provided a configuration for Type0A-PDCCH common search space by higher layer parameter *osi-SearchSpace*. A UE is provided a configuration for Type2-PDCCH common search space by higher layer parameter *paging-SearchSpace*.

A subcarrier spacing and a CP length for PDCCH reception with Type0A-PDCCH common search space, or Type1-PDCCH common search space, or Type-2 PDCCH common search space are same as for PDCCH reception with Type0-PDCCH common search space.

A UE may assume that the DM-RS antenna port associated with PDCCH reception in the Type0A-PDCCH common search space and the DM-RS antenna port associated with SS/PBCH reception are quasi co-located with respect to delay spread, Doppler spread, Doppler shift, average delay, and spatial Rx parameters.

A UE may assume that the DM-RS antenna port associated with PDCCH reception and associated PDSCH reception in the Type1-PDCCH common search space are quasi co-located with the DM-RS antenna port of the SS/PBCH reception associated with a corresponding PRACH transmission.

If a value for the DM-RS scrambling sequence initialization for Type0A-PDCCH common search space, or Type1-PDCCH common search space, or Type-2 PDCCH common search space is not provided by higher layer parameter *PDCCH-DMRS-Scrambling-ID* in *SystemInformationBlockType1*, the value is the cell ID.

If a UE is configured for downlink bandwidth part (BWP) operation, as described in Subclause 12, the above configurations for the common search spaces apply for the initial active DL BWP. The UE can be additionally configured a control resource set for Type0-PDCCH common search space, Type0A-PDCCH common search space, Type1-PDCCH common search space, or Type2-PDCCH common search space for each configured DL BWP on the primary cell, other than the initial active DL BWP, as described in Subclause 12.

Table 10.1-1: CCE aggregation levels and number of candidates per CCE aggregation level for PDCCH scheduling *SystemInformationBlockType1* in Type0-PDCCH common search space

CCE Aggregation Level	Number of Candidates
4	4
8	2
16	X

For a serving cell, higher layer signalling provides a UE with P control resource sets. For control resource set p, $0 \le p < P$ where a UE-specific search space, a Type2-PDCCH common search space, or a Type3-PDCCH common search space is mapped, the higher layer signalling provides:

- a control resource set index by higher layer parameter *CORESET-ID*;
- a DM-RS scrambling sequence initialization value by higher layer parameter *PDCCH-DMRS-Scrambling-ID*;
- a number of consecutive symbols provided by higher layer parameter *CORESET-time-duration*;
- a set of resource blocks provided by higher layer parameter *CORESET-freq-dom*;
- a CCE-to-REG mapping provided by higher layer parameter *CORESET-CCE-to-REG-mapping-type*;
- a REG bundle size, in case of interleaved CCE-to-REG mapping, provided by higher layer parameter *CORESET-REG-bundle-size*;
- a cyclic shift for the REG bundle interleaver [4, 38.211] by higher layer parameter *CORESET-shift-index*;
- an antenna port quasi co-location, from a set of antenna port quasi co-locations provided by higher layer parameter *TCI-StatesPDCCH*, indicating quasi co-location information of the DM-RS antenna port for PDCCH reception;
- an indication for a presence or absence of a transmission configuration indication (TCI) field for DCI format 1_0 or DCI format 1_1 transmitted by a PDCCH in control resource set p, by higher layer parameter *TCI-PresentInDCI*.

For each control resource set in a DL BWP of a serving cell, a respective higher layer parameter *CORESET-freq-dom* provides a bitmap. The bits of the bitmap have a one-to-one mapping with non-overlapping groups of 6 PRBs, in ascending order of the PRB index in the DL BWP bandwidth of $N_{\mathrm{RB}}^{\mathrm{BWP}}$ PRBs where the first PRB of the first group of 6 PRBs has index $6 \cdot \lceil N_{\mathrm{RB}}^{\mathrm{BWP}} / 6 \rceil$.

If the UE has not received an indication for an antenna port quasi co-location from the set of antenna port quasi co-locations provided by *TCI-StatesPDCCH*, the UE assumes that the DM-RS antenna port associated with PDCCH reception in the UE-specific search space is quasi co-located with the DM-RS antenna port associated with PBCH reception with respect to delay spread, Doppler spread, Doppler shift, average delay, and spatial Rx parameters.

For each serving cell that a UE is configured to monitor PDCCH in a search space other than Type0-PDCCH common search space, the UE is configured the following:

- a number of search space sets by higher layer parameter *search-space-config*;

- for each search space set in a control resource set p
  - an indication that the search space set is a common search space set or a UE-specific search space set by higher layer parameter *Common-search-space-flag*;
  - a number of PDCCH candidates $M_p^{(L)}$ per CCE aggregation level L by higher layer parameters *Aggregation-level-1*, *Aggregation-level-2*, *Aggregation-level-4*, *Aggregation-level-8*, and *Aggregation-level-16*, for CCE aggregation level 1, CCE aggregation level 2, CCE aggregation level 4, CCE aggregation level 8, and CCE aggregation level 16, respectively;
  - a PDCCH monitoring periodicity of k_p slots by higher layer parameter *Monitoring-periodicity-PDCCH-slot*;
  - a PDCCH monitoring offset of o_p slots, where $0 \le o_p < k_p$, by higher layer parameter *Monitoring-offset-PDCCH-slot*;
  - a PDCCH monitoring pattern within a slot, indicating first symbol(s) of the control resource set within a slot for PDCCH monitoring, by higher layer parameter *Monitoring-symbols-PDCCH-within-slot*.

A UE determines a PDCCH monitoring occasion from the PDCCH monitoring periodicity, the PDCCH monitoring offset, and the PDCCH monitoring pattern within a slot.

A PDCCH UE-specific search space $S_{k_p}^{(L)}$ at CCE aggregation level $L \in \{1, 2, 4, 8, 16\}$ is defined by a set of PDCCH candidates for CCE aggregation level L.

If a UE is configured with higher layer parameter *CrossCarrierSchedulingConfig* for a serving cell the carrier indicator field value corresponds to the value indicated by *CrossCarrierSchedulingConfig.*

For a serving cell on which a UE monitors PDCCH candidates in a UE-specific search space, if the UE is not configured with a carrier indicator field, the UE shall monitor the PDCCH candidates without carrier indicator field. For a serving cell on which a UE monitors PDCCH candidates in a UE-specific search space, if a UE is configured with a carrier indicator field, the UE shall monitor the PDCCH candidates with carrier indicator field.

A UE is not expected to monitor PDCCH candidates on a secondary cell if the UE is configured to monitor PDCCH candidates with carrier indicator field corresponding to that secondary cell in another serving cell. For the serving cell on which the UE monitors PDCCH candidates, the UE shall monitor PDCCH candidates at least for the same serving cell.

For a control resource set p, the CCEs corresponding to PDCCH candidate $m_{n_{CI}}$ of the search space for a serving cell corresponding to carrier indicator field value n_{CI} are given by

$$L \cdot \left\{ \left(Y_{p,k_p} + \left\lfloor \frac{m_{n_{CI}} \cdot N_{\mathrm{CCE},p}}{L \cdot M_{p,\max}^{(L)}} \right\rfloor + n_{CI} \right) \bmod \left\lfloor N_{\mathrm{CCE},p} / L \right\rfloor \right\} + i$$

where

for any common search space, $Y_{p,k_p} = 0$;

for a UE-specific search space, $Y_{p,k_p} = \left(A_p \cdot Y_{p,k_p-1}\right) \bmod D$, $Y_{p,-1} = n_{\mathrm{RNTI}} \neq 0$, $A_0 = 39827$, $A_1 = 39829$, and $D = 65537$;

$i = 0, \cdots, L-1$;

n_{CI} is the carrier indicator field value if the UE is configured with a carrier indicator field for the serving cell on which PDCCH is monitored; otherwise, including for any common search space, $n_{CI} = 0$;

$N_{\mathrm{CCE},p}$ is the number of CCEs, numbered from 0 to $N_{\mathrm{CCE},p} - 1$, in control resource set p;

$m_{n_{CI}} = 0, \ldots, M_{p,n_{CI}}^{(L)} - 1$, where $M_{p,n_{CI}}^{(L)}$ is the number of PDCCH candidates the UE is configured to monitor for aggregation level L for a serving cell corresponding to n_{CI};

for any common search space, $M_{p,\max}^{(L)} = M_{p,0}^{(L)}$;

for a UE-specific search space, $M_{p,\max}^{(L)}$ is the maximum of $M_{p,n_{CI}}^{(L)}$ for all corresponding DCI formats over all configured n_{CI} values for a CCE aggregation level L in control resource set p;

the RNTI value used for n_{RNTI} is defined in [5, TS 38.212] and in [6, TS 38.214].

A UE configured to monitor PDCCH candidates in a serving cell with a DCI format size with carrier indicator field and CRC scrambled by C-RNTI, where the PDCCH candidates may have one or more possible values of carrier indicator field for the DCI format size, shall assume that an PDCCH candidate with the DCI format size may be transmitted in the serving cell in any PDCCH UE specific search space corresponding to any of the possible values of carrier indicator field for the DCI format size.

11 UE-group common signalling

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary

cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

11.1 Slot configuration

A slot format includes downlink symbols, uplink symbols, and flexible symbols.

For each serving cell

If a UE is provided higher layer parameter *UL-DL-configuration-common*, the UE shall set the slot format per slot over a number of slots as indicated by higher layer parameter *UL-DL-configuration-common*. If the UE is additionally provided higher layer parameter *UL-DL-configuration-dedicated* for the slot format per slot over the number of slots, the parameter *UL-DL-configuration-dedicated* overrides only flexible symbols per slot over the number of slots as provided by *UL-DL-configuration-common*. The UE determines a duration of each slot in the number of slots, in each BWP of the configured BWPs as described in Subclause 12, based on a subcarrier spacing value [4, TS38.211] provided by higher layer parameter *ref-scs*. The UE considers symbols in a slot indicated as downlink by higher layer parameter *UL-DL-configuration-common* or by higher layer parameter *UL-DL-configuration-dedicated* as available for receptions. The UE considers symbols in a slot indicated as uplink by higher layer parameter *UL-DL-configuration-common* or by higher layer parameter *UL-DL-configuration-dedicated* as available for transmissions.

For a set of symbols of a slot that are indicated as flexible by higher layer parameter *UL-DL-configuration-common* and, when provided, by higher layer parameter *UL-DL-configuration-dedicated*

- A UE shall receive SS/PBCH, PDCCH, PDSCH, or CSI-RS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format with CRC scrambled by C-RNTI or a configuration by higher layers.
- A UE shall transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format with CRC scrambled by C-RNTI or a configuration by higher layers.
- A UE configured for reception of PDCCH or periodic/semi-persistent CSI-RS in the set of symbols of the slot shall receive the PDCCH or the periodic/semi-persistent CSI-RS if the UE does not detect a DCI format with CRC scrambled by C-RNTI or TPC-SRS-RNTI that indicates to the UE to transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot; otherwise, the UE shall not receive the PDCCH or the periodic/semi-persistent CSI-RS in the set of symbols of the slot and shall transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot.
- A UE configured for transmission of trigger type 0 SRS or of PUCCH configured by higher layers in the set of symbols in the slot, shall transmit trigger type 0 SRS or PUCCH configured by higher layers in the set of symbols of the slot if the UE does not detect a DCI format with CRC scrambled by C-RNTI that indicates to the UE to

receive PDSCH or CSI-RS in the set of symbols in the slot; otherwise, the UE shall not transmit the trigger type 0 SRS or PUCCH in the set of symbols of the slot.

For a set of symbols of a slot that are indicated as uplink by higher layer parameter *UL-DL-configuration-common* or, when provided, by higher layer parameter *UL-DL-configuration-dedicated*, the UE is not expected to be indicated by a DCI format with CRC scrambled by C-RNTI or be configured by higher layers to receive PDCCH, PDSCH, or CSI-RS in the set of symbols of the slot.

For a set of symbols of a slot that are indicated as downlink by higher layer parameter *UL-DL-configuration-common* or, when provided, by higher layer parameter *UL-DL-configuration-dedicated*, the UE is not expected to be indicated by a DCI format with CRC scrambled by C-RNTI or be configured by higher layers to transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot.

If a UE is configured by higher layers with the parameter *Slot-MainConfig*, the UE shall determine the slot format for each slot over a number of slots as described in Subclause 11.1.1.

11.1.1 UE procedure for determining slot format

If a UE is configured by higher layers with parameter *SFI-PDCCH*, the UE is configured with a SFI-RNTI provided by higher layer parameter *SFI-RNTI* and with a set of serving cells by higher layer parameter *SFI- cell-to-SFI* for monitoring PDCCH conveying DCI format 2_0. Per serving cell in the set of serving cells, the UE can be configured

- control resource sets by higher layer parameter *SFI-SS* for monitoring PDCCH conveying DCI format 2_0;
- a payload size of DCI format 2_0by higher layer parameter *SFI-DCI-payload-length*;
- a location of a field in DCI format 2_0 by higher layer parameter *cell-to-SFI*;
- a set of combinations for slot formats [4, TS 38.211] by higher layer parameter *SFI-set*;
- a number of PDCCH candidates for CCE aggregation level L for DCI format 2_0by higher layer parameter *SFI-Num-PDCCH-cand*;
- a CCE aggregation level L for the PDCCH candidates with DCI format 2_0 by higher layer parameter *SFI-aggregation-level*;
- a monitoring periodicity for PDCCH with DCI format 2_0 by higher layer parameter *SFI-monitoring-periodicity*.

If a UE detects a DCI format 2_0 in slot mT_{SFI}, the slot format for each of the slots $\{mT_{\mathrm{SFI}}, mT_{\mathrm{SFI}}+1, ..., (m+1)T_{\mathrm{SFI}}-1\}$ in a serving cell is given by the combination for slot formats indicated for the serving cell by a respective field for the serving cell in the DCI format 2_0 at a location provided by higher layer parameter *cell-to-SFI*, where T_{SFI} is the value of

the parameter *SFI-monitoring-periodicity* configured to a UE by higher layers for a DCI format 2_0.

For each serving cell that a UE is configured by higher layers with the parameter *SFI-applicable-cells*

For a set of symbols of a slot, a UE is not expected to detect a DCI format 2_0 and indicating the set of symbols of the slot as uplink and to detect a DCI format with CRC scrambled by C-RNTI and indicating to the UE to receive PDSCH or CSI-RS in the set of symbols of the slot.

For a set of symbols of a slot, a UE is not expected to detect a DCI format 2_0 and indicating the set of symbols in the slot as downlink and to detect a DCI format with CRC scrambled by C-RNTI and indicating to the UE to transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot.

For a set of symbols of a slot that are indicated as downlink/uplink by higher layer parameter *UL-DL-configuration-common* or, when provided, by higher layer parameter *UL-DL-configuration-dedicated*, a UE is not expected to detect a DCI format 2_0 and indicating the set of symbols of the slot as uplink/downlink, respectively, or as flexible.

For a set of symbols of a slot that are indicated as flexible by higher layer parameter *UL-DL-configuration-common* and, when provided, by higher layer parameter *UL-DL-configuration-dedicated*

- A UE assumes that flexible symbols in a control resource set configured to the UE for PDCCH monitoring are downlink symbols.
- If a UE detects a DCI format 2_0 and indicating the set of symbols of the slot as flexible and the UE detects a DCI format 1_0 or DCI format 1_1 indicating to the UE to receive PDSCH or CSI-RS in the set of symbols of the slot, the UE follows the indication of the DCI format 1_0 or DCI format 1_1.
- If a UE detects a DCI format 2_0 and indicating the set of symbols of the slot as flexible and the UE detects a DCI format with CRC scrambled by C-RNTI indicating to the UE to transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot the UE follows the indication of the DCI format with CRC scrambled by C-RNTI.
- If a UE detects a DCI format 2_0 and indicating the set of symbols of the slot as flexible and the set of symbols of the slot are also indicated as flexible by higher layer parameter *UL-DL-configuration-common* or, when provided, by higher layer parameter *UL-DL-configuration-dedicated*, the UE considers the set of symbols as reserved.
- If a UE is configured by higher layers reception of PDCCH or periodic/semi-persistent CSI-RS or SPS PDSCH in the set of symbols of the slot, the UE shall receive PDCCH or periodic/semi-persistent CSI-RS or SPS PDSCH in the set of symbols of the slot only if the UE detects a DCI format 2_0 that indicates the set of symbols of the slot as downlink.

- If a UE is configured by higher layers transmission of trigger type 0 SRS, or PUCCH, or PUSCH without UL grant, or PRACH in the set of symbols of the slot, the UE shall transmit trigger type 0 SRS, or PUCCH, or PUSCH without UL grant, or PRACH in the set of symbols of the slot only if the UE detects a DCI format 2_0 that indicates the set of symbols of the slot as uplink.

11.2 Discontinuous transmission indication

If a UE is provided higher layer parameter *Preemp-DL* and *Preemp-DL= ON*, the UE is configured with an INT-RNTI provided by higher layer parameter *INT-RNTI* for monitoring PDCCH conveying DCI format 2_1 [5, TS 38.212]. The UE is additionally configured:

- control resource set(s) and respective search space sets for monitoring PDCCH with DCI format 2_1 as described in Subclause 10.1;
- a set of serving cells by higher layer parameter *INT-cell-to-INT*;
- a mapping for each serving cell in the set of serving cells to a field in DCI format 2_1 by higher layer parameter *cell-to-INT*;
- an information payload size for DCI format 2_1 by higher layer parameter *INT-DCI-payload-length*;
- a monitoring periodicity for PDCCH with DCI format 2_1 by higher layer parameter *INT-monitoring-periodicity*;
- an indication granularity for time-frequency resources by higher layer parameter *INT-TF-unit.*

If a UE detects a DCI format 2_1 for a serving cell from the configured set of serving cells, the UE may assume that no transmission to the UE is present in PRBs and in symbols, from a set of PRBs and a set of symbols of the last monitoring period, that are indicated by the DCI format.

The set of PRBs is equal to the active DL BWP as defined in Subclause 12 and includes B_{INT} PRBs.

If a UE detects a DCI format 2_1 in a PDCCH transmitted in a control resource set in slot $m \cdot T_{\mathrm{INT}}$, the set of symbols indicated by a field in DCI format 2_1 includes the last $14 \cdot T_{\mathrm{INT}}$ symbols prior to the first symbol of the control resource set in slot $m \cdot T_{\mathrm{INT}}$ where T_{INT} is the value of the parameter *INT-monitoring-periodicity* and m is a natural number.

If the UE is configured with higher layer parameter *UL-DL-configuration-common*, symbols indicated as uplink by *UL-DL-configuration-common* are excluded from the last $14 \cdot T_{\mathrm{INT}}$ symbols prior to the $O_{\mathrm{symbol}}^{\mathrm{CORESET}}$ symbol in slot $m \cdot T_{\mathrm{INT}}$. The resulting set of symbols includes a number of symbols that is denoted as N_{INT}.

The UE is configured the indication granularity for the set of PRBs and for the set of symbols by higher layer parameter *INT-TF-unit*.

If the value of *INT-TF-unit* is 0, 14 bits of a field in DCI format 2_1 have a one-to-one mapping with 14 groups of consecutive symbols from the set of symbols where each of the first $N_{\text{INT}} - \lfloor N_{\text{INT}}/14 \rfloor \cdot 14$ symbol groups includes $\lceil N_{\text{INT}}/14 \rceil$ symbols, each of the last $14 - N_{\text{INT}} + \lfloor N_{\text{INT}}/14 \rfloor \cdot 14$ symbol groups includes $\lfloor N_{\text{INT}}/14 \rfloor$ symbols, a bit value of 0 indicates transmission to the UE in the corresponding symbol group and a bit value of 1 indicates no transmission to the UE in the corresponding symbol group.

If the value of *INT-TF-granularity* is 1, 7 pairs of bits of a field in the DCI format 2_1 have a one-to-one mapping with 7 groups of consecutive symbols where each of the first $N_{\text{INT}} - \lfloor N_{\text{INT}}/7 \rfloor \cdot 7$ symbol groups includes $\lceil N_{\text{INT}}/7 \rceil$ symbols, each of the last $7 - N_{\text{INT}} + \lfloor N_{\text{INT}}/7 \rfloor \cdot 7$ symbol groups includes $\lfloor N_{\text{INT}}/7 \rfloor$ symbols, a first bit in a pair of bits for a symbol group is applicable to the subset of $\lceil B_{\text{INT}}/2 \rceil$ first PRBs from the set of B_{INT} PRBs, a second bit in the pair of bits for the symbol group is applicable to the subset of last $\lfloor B_{\text{INT}}/2 \rfloor$ PRBs from the set of B_{INT} PRBs, a bit value of 0 indicates transmission to the UE in the corresponding symbol group and subset of PRBs, and a bit value of 1 indicates no transmission to the UE in the corresponding symbol group and subset of PRBs.

11.3 SRS switching

If a UE is configured by higher layers with parameter *SRS-TPC-PDCCH-Config*, the UE is configured with a TPC-SRS-RNTI provided by higher layer parameter *srs-TPC-RNTI* and with a set of serving cells by higher layer parameter *SRS-monitoring-cells* for monitoring PDCCH conveying DCI format 2_3with CRC scrambled by TPC-SRS-RNTI. Per serving cell the UE is configured

- control resource set(s) and respective search space sets for monitoring PDCCH with DCI format 2_3;
- a mapping for a serving cell to a field in DCI format 2_3 by higher layer parameter *SRS-cell-to-SFI*;
- a location of a field in DCI format 2_3 for a serving cell by higher layer parameter *startingBitOfFormatX*;
- a monitoring periodicity for PDCCH with DCI format 2_3 by higher layer parameter *SRS-monitoring-periodicity*.

For a serving cell where a UE is not configured for PUSCH/PUCCH transmission or for a serving cell where higher layer parameter *srs-pcadjustment-state-config* indicates a separate power control adjustment state between SRS transmissions and PUSCH transmissions, DCI format 2_3 includes one block of bits for {SRS request, TPC command, … TPC command} fields for the UE if the UE is configured with higher layer parameter *typeA-SRS-TPC-PDCCH-Group* where the SRS request field applies to a set of serving cells provided by higher layer parameter *cc-SetIndex* and each TPC command applies to a

respective serving cell index provided by higher layer parameter *cc-IndexInOneCC-Set*. Otherwise, if the UE is configured with higher layer parameter *typeB-SRS-TPC-PDCCH-Group,* DCI format 2_3 includes one or more blocks of bits for {SRS request, TPC command} as described in [5, TS 38.212] where each block applies to a serving cell. The SRS request field is not present if a value of higher layer parameter *fieldTypeFormat2_3* is 0; otherwise, the SRS request field is present in DCI format 2_3.

A UE configured with higher layer parameter *typeA-SRS-TPC-PDCCH-Group* is provided by higher layer parameter *srs-CC-SetIndexlist* a number of sets of serving cells without PUSCH/PUCCH transmission. For each set of serving cells, the UE is provided an index for the set by higher layer parameter *cc-SetIndex* and an index for each serving cell in the set by higher layer parameter *cc-IndexInOneCC-Set*.

For a 2 bit SRS request field in DCI format 2_3 for serving cells without PUSCH/PUCCH transmission, the SRS request field indicates the SRS parameter set given in Table 11.3-1 with the three sets of SRS parameters are provided by higher layer parameter *srs-ConfigApDCI-FormatX* for a serving cell if type 1 SRS is triggered.

Table 11.3-1: SRS request value for trigger type 1 in DCI format 2_3 for serving cells without PUSCH/PUCCH transmissions

Value of SRS request field	Description
'00'	No type 1 SRS trigger
'01'	Type 1 SRS trigger for a 1st set of serving cells configured by higher layers
'10'	Type 1 SRS trigger for a 2nd set of serving cells configured by higher layers
'11'	Type 1 SRS trigger for a 3rd set of serving cells configured by higher layers

12 Bandwidth part operation

If the UE is configured with a SCG, the UE shall apply the procedures described in this clause for both MCG and SCG

- When the procedures are applied for MCG, the terms 'secondary cell', 'secondary cells' , 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell, serving cells belonging to the MCG respectively.
- When the procedures are applied for SCG, the terms 'secondary cell', 'secondary cells', 'serving cell', 'serving cells' in this clause refer to secondary cell, secondary cells (not including PSCell), serving cell, serving cells belonging to the SCG respectively. The term 'primary cell' in this clause refers to the PSCell of the SCG.

A UE configured for operation in bandwidth parts (BWPs) of a serving cell, is configured by higher layers for the serving cell a set of at most four bandwidth parts (BWPs) for receptions by the UE (DL BWP set) in a DL bandwidth by parameter *DL-BWP* and a set of at most four BWPs for transmissions by the UE (UL BWP set) in an UL bandwidth by parameter *UL-BWP* for the serving cell.

An initial active DL BWP is defined by a location and number of contiguous PRBs, a subcarrier spacing, and a cyclic prefix, for the control resource set for Type0-PDCCH common search space. For operation on the primary cell, a UE is provided by higher layer parameter *initial-UL-BWP* an initial UL BWP for a random access procedure. If the UE is configured with a secondary carrier on the primary cell, the UE can be configured with an initial BWP for random access procedure on the secondary carrier.

For unpaired spectrum operation, a UE can expect that the center frequency for a DL BWP is same as the center frequency for a UL BWP.

For each DL BWP or UL BWP in a set of DL BWPs or UL BWPs, respectively, the UE is configured the following parameters for the serving cell as defined in [4, TS 38.211] or [6, TS 38.214]:

- a subcarrier spacing provided by higher layer parameter *DL-BWP-mu* or *UL-BWP-mu*;
- a cyclic prefix provided by higher layer parameter *DL-BWP-CP* or *UL-BWP-CP*;
- a number of contiguous PRBs provided by higher layer parameter *DL-BWP-BW* or *UL-BWP-BW*;
- an index in the set of DL BWPs or UL BWPs by respective higher layer parameters *DL-BWP-index* or *UL-BWP-index* for paired spectrum operation, or a link between a DL BWP and an UL BWP from the set of configured DL BWPs and UL BWPs by higher layer parameter *BWP-pair-index* for unpaired spectrum operation;
- a DCI 1_0 or DCI 1_1 detection to a PDSCH reception timing by higher layer parameter *DL-data-time-domain*, a PDSCH reception to a HARQ-ACK transmission timing value by higher layer parameter *DL-data-DL-acknowledgement*, a DCI 0_0 or DCI 0_1 detection to a PUSCH transmission timing value by higher layer parameter *UL-data-time-domain*;
- an offset of the first PRB of the DL bandwidth or the UL bandwidth, respectively, relative to a first PRB of a bandwidth by higher layer parameter *DL-BWP-loc* or *UL-BWP-loc*
  - For the downlink of the primary cell, the first PRB of the bandwidth is the first RPB of the SS/PBCH block used by the UE for initial cell selection;
  - For the uplink of the primary cell for paired spectrum operation, the first PRB of the bandwidth is the first PRB of the UL bandwidth indicated by *SystemInformationBlockType1*;

- For the uplink of the primary cell for unpaired, the first PRB of the bandwidth is the first PRB of the SS/PBCH block used by the UE for initial cell selection;
- For a secondary cell or carrier, the first PRB of the DL bandwidth or of the UL bandwidth is indicated to the UE by the higher layer configuration for the secondary cell or carrier.

For each DL BWP in a set of DL BWPs on the primary cell, a UE can be configured control resource sets for every type of common search space and for UE-specific search space as described in Subclause 10.1. The UE is not expected to be configured without a common search space on the PCell, or on the PSCell, in the active DL BWP.

For each UL BWP in a set of UL BWPs, the UE is configured resource sets for PUCCH transmissions as described in Subclause 9.2.

A UE receives PDCCH and PDSCH in a DL BWP according to a configured subcarrier spacing and CP length for the DL BWP. A UE transmits PUCCH and PUSCH in an UL BWP according to a configured subcarrier spacing and CP length for the UL BWP.

If a bandwidth path indicator field is configured in DCI format 1_1, the bandwidth path indicator field value indicates the active DL BWP, from the configured DL BWP set, for DL receptions. If a bandwidth path indicator field is configured in DCI format 0_1, the bandwidth path indicator field value indicates the active UL BWP, from the configured UL BWP set, for UL transmissions.

For the primary cell, a UE can be provided by higher layer parameter *Default-DL-BWP* a default DL BWP among the configured DL BWPs. If a UE is not provided a default DL BWP by higher layer parameter *Default-DL-BWP*, the default BWP is the initial active DL BWP.

A UE can be provide by higher layer parameter *BWP-InactivityTimer* a timer value for the primary cell, as described in [11, TS 38.321] and then the UE starts the timer each time the UE detects a DCI format 1_1 indicating an active DL BWP, other than the default DL BWP, for paired spectrum operation or each time the UE detects DCI format 1_1 or DCI format 0_1 indicating an active DL BWP or UL BWP, other than the default DL BWP or UL BWP, for unpaired spectrum operation. The UE increments the timer every interval of 1 millisecond for carrier frequencies smaller than or equal to 6 GHz or every interval of 0.5 milliseconds for carrier frequencies larger than 6 GHz if the UE does not detect any DCI format 1_1 for paired spectrum operation or if the UE does not detect any DCI format 1_1 or DCI format 0_1 for unpaired spectrum operation during the interval. The timer expires when the timer is equal to the *BWP-InactivityTimer* value. The UE switches to the default DL BWP from an active DL BWP when the timer expires.

If a UE is configured for a secondary cell with higher layer parameter *Default-DL-BWP* indicating a default DL BWP among the configured DL BWPs and the UE is configured with higher layer parameter *BWP-InactivityTimer* indicating a timer value, the UE procedures on the secondary cell are same as on the primary cell using the timer value for the secondary cell and the default DL BWP for the secondary cell.

If the UE is configured by higher layer parameter *Active-BWP-DL-SCell* a first active DL BWP and by higher layer parameter *Active-BWP-UL-SCell* a first active UL BWP on a secondary cell or carrier, the UE uses the indicated DL BWP and the indicated UL BWP on the secondary cell as the respective first active DL BWP and first active UL BWP on the secondary cell or carrier.

For paired spectrum operation, a UE is not expected to transmit HARQ-ACK if the UE changes its active UL BWP between a time of a detection of a DCI format 1_1 and a time of a corresponding HARQ-ACK transmission.

A UE is not expected to monitor PDCCH when the UE performs measurements over a bandwidth that is not within the DL BWP for the UE.

13 UE procedure for monitoring Type0-PDCCH common search space

A UE determines a number of consecutive resource blocks and a number of consecutive symbols for the control resource set of Type0-PDCCH common search space from the first four bits of *RMSI-PDCCH-Config* as described in Tables 13-1 through 13-8 and determines PDCCH monitoring occasions from the second four bits of *RMSI-PDCCH-Config* as described in Tables 13-9 through 13-13 where SFN_C and n_C are the SFN and slot of the control resource set and SFN_SSB and n_SSB are the SFN and slot of the SS/PBCH block, respectively.

The offset in Tables 13-1 through 13-8 is defined with respect to the subcarrier spacing of the control resource set and is the difference between the smallest RB index of the SS/PBCH block and the smallest RB index of the control resource set for Type0-PDCCH common search space. Condition A or condition B in Tables 13-1 through 13-8 corresponds to the case of PRG [6, TS 38.214] alignment or non-alignment, respectively, between SS/PBCH block RBs and RBs of the control resource set for Type0-PDCCH common search space.

For a first SS/PBCH block and control resource set (CORESET) multiplexing pattern, a UE monitors PDCCH in the Type0-PDCCH common search space over two consecutive slots $\{n_0, n_0+1\}$. For SS/PBCH block with index i, the UE determines an index of the first slot n_0 as $n_0 = \left(O \cdot 2^\mu + \lfloor i \cdot M \rfloor\right) \bmod N_{\text{slot}}^{\text{frame},\mu}$ located in a frame with system frame number (SFN) satisfying $\text{SFN} \bmod 2 = 0$ if $\left\lfloor \left(O \cdot 2^\mu + \lfloor i \cdot M \rfloor\right) / N_{\text{slot}}^{\text{frame},\mu} \right\rfloor = 0$ or in a frame with SFN satisfying $\text{SFN} \bmod 2 = 1$ if $\left\lfloor \left(O \cdot 2^\mu + \lfloor i \cdot M \rfloor\right) / N_{\text{slot}}^{\text{frame},\mu} \right\rfloor = 1$.

Table 13-1: Set of resource blocks and slot symbols of control resource set for Type0-PDCCH search space when {SS/PBCH block, PDCCH} subcarrier spacing is {15, 15} kHz

Index	SS/PBCH block and control resource set multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	24	2	0
1	1	24	2	2
2	1	24	2	4
3	1	24	3	0
4	1	24	3	2
5	1	24	3	4
6	1	48	1	12
7	1	48	1	16
8	1	48	2	12
9	1	48	2	16
10	1	48	3	12
11	1	48	3	16
12	1	96	1	38
13	1	96	2	38
14	1	96	3	38
15	Reserved			

Table 13-2: Set of resource blocks and slot symbols of control resource set for Type0-PDCCH search space when {SS/PBCH block, PDCCH} subcarrier spacing is {15, 30} kHz

Index	SS/PBCH block and control resource set multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	24	2	6
1	1	24	2	7
2	1	24	2	8
3	1	24	3	6
4	1	24	3	7
5	1	24	3	8
6	1	48	1	18
7	1	48	1	20
8	1	48	2	18
9	1	48	2	20
10	1	48	3	18
11	1	48	3	20
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-3: Set of resource blocks and slot symbols of control resource set for Type0-PDCCH search space when {SS/PBCH block, PDCCH} subcarrier spacing is {30, 15} kHz

Index	SS/PBCH block and control resource set multiplexing pattern	Number of RBs $N_{RB}^{CORESET}$	Number of Symbols $N_{symb}^{CORESET}$	Offset (RBs)
0	1	48	1	2
1	1	48	1	6
2	1	48	2	2
3	1	48	2	6
4	1	48	3	2
5	1	48	3	6
6	1	96	1	28
7	1	96	2	28
8	1	96	3	28
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-4: Set of resource blocks and slot symbols of control resource set for Type0-PDCCH search space when {SS/PBCH block, PDCCH} subcarrier spacing is {30, 30} kHz

Index	SS/PBCH block and control resource set multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	24	2	0
1	1	24	2	1
2	1	24	2	2
3	1	24	2	3
4	1	24	2	4
5	1	24	3	0
6	1	24	3	1
7	1	24	3	2
8	1	24	3	3
9	1	24	3	4
10	1	48	1	12
11	1	48	1	14
12	1	48	1	16
13	1	48	2	12
14	1	48	2	14
15	1	48	2	16

Table 13-5: Set of resource blocks and slot symbols of control resource set for Type0-PDCCH search space when {SS/PBCH block, PDCCH} subcarrier spacing is {120, 60} kHz

Index	SS/PBCH block and control resource set multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	48	1	0
1	1	48	1	8
2	1	48	2	0
3	1	48	2	8
4	1	48	3	0
5	1	48	3	8
6	1	96	1	28
7	1	96	2	28
8	2	48	1	-41 if condition A -42 if condition B
9	2	48	1	49
10	2	48	2	-41 if condition A -42 if condition B
11	2	48	2	49
12	2	96	1	-41 if condition A -42 if condition B
13	2	96	1	97
14	2	96	2	-41 if condition A -42 if condition B
15	2	96	2	97

Table 13-6: Set of resource blocks and slot symbols of control resource set for Type0-PDCCH search space when {SS/PBCH block, PDCCH} subcarrier spacing is {120, 120} kHz

Index	SS/PBCH block and control resource set multiplexing pattern	Number of RBs $N_{RB}^{CORESET}$	Number of Symbols $N_{symb}^{CORESET}$	Offset (RBs)
0	1	24	2	0
1	1	24	2	4
2	1	48	1	14
3	1	48	2	14
4	3	48	3	-20 if condition A -21 if condition B
5	3	48	3	24
6	3	96	1	-20 if condition A -21 if condition B
7	3	96	2	48
8	Reserved			
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-7: Set of resource blocks and slot symbols of control resource set for Type0-PDCCH search space when {SS/PBCH block, PDCCH} subcarrier spacing is {240, 60} kHz

Index	SS/PBCH block and control resource set multiplexing pattern	Number of RBs $N_{RB}^{CORESET}$	Number of Symbols $N_{symb}^{CORESET}$	Offset (RBs)
0	1	96	1	0
1	1	96	1	16
2	1	96	2	0
3	1	96	2	16
4	Reserved			
5	Reserved			
6	Reserved			
7	Reserved			
8	Reserved			
9	Reserved			
10	Reserved			
11	Reserved			
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-8: Set of resource blocks and slot symbols of control resource set for Type0-PDCCH search space when {SS/PBCH block, PDCCH} subcarrier spacing is {240, 120} kHz

Index	SS/PBCH block and control resource set multiplexing pattern	Number of RBs $N_{\mathrm{RB}}^{\mathrm{CORESET}}$	Number of Symbols $N_{\mathrm{symb}}^{\mathrm{CORESET}}$	Offset (RBs)
0	1	48	1	0
1	1	48	1	8
2	1	48	2	0
3	1	48	2	8
4	2	24	1	-41 if condition A -42 if condition B
5	2	24	1	25
6	2	24	2	-41 if condition A -42 if condition B
7	2	24	2	25
8	2	48	1	-41 if condition A -42 if condition B
9	2	48	1	49
10	2	48	2	-41 if condition A -42 if condition B
11	2	48	2	49
12	Reserved			
13	Reserved			
14	Reserved			
15	Reserved			

Table 13-9: Parameters for PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing type 1 and carrier frequencies smaller than or equal to 6 GHz

Index	O	Number of search space sets per slot	M	First symbol index
0	0	1	1	0
1	0	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
2	2	1	1	0
3	2	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
4	5	1	1	0
5	5	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
6	7	1	1	0
7	7	2	1/2	{0, if i is even}, {$N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
8	0	1	2	0
9	5	1	2	0
10	0	1	1	1
11	0	1	1	2
12	2	1	1	1
13	2	1	1	2
14	5	1	1	1
15	5	1	1	2

Table 13-10: Parameters for PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing type 1 and carrier frequencies smaller above 6 GHz

Index	O	Number of search space sets per slot	M	First symbol index
0	0	1	1	0
1	0	2	1/2	{0, if i is even}, {7, if i is odd}
2	2.5	1	1	0
3	2.5	2	1/2	{0, if i is even}, {7, if i is odd}
4	5	1	1	0
5	5	2	1/2	{0, if i is even}, {7, if i is odd}
6	0	2	1/2	{0, if i is even}, { $N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
7	2.5	2	1/2	{0, if i is even}, { $N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
8	5	2	1/2	{0, if i is even}, { $N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
9	7.5	1	1	0
10	7.5	2	1/2	{0, if i is even}, {7, if i is odd}
11	7.5	2	1/2	{0, if i is even}, { $N_{\text{symb}}^{\text{CORESET}}$, if i is odd}
12	0	1	2	0
13	5	1	2	0
14	Reserved			
15	Reserved			

Table 13-11: PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing type 2 and {SS/PBCH block, PDCCH} subcarrier spacing {120, 60} kHz

Index	PDCCH monitoring occasions (SFN and slot number)	First symbol index (k = 0, 1, … 15)
0	$\mathrm{SFN}_{\mathrm{C}} = \mathrm{SFN}_{\mathrm{SSB}}$ $n_{\mathrm{C}} = n_{\mathrm{SSB}}$	0, 1, 6, 7 for $i = 4k$, $i = 4k+1$, $i = 4k+2$, $i = 4k+3$
1	Reserved	
2	Reserved	
3	Reserved	
4	Reserved	
5	Reserved	
6	Reserved	
7	Reserved	
8	Reserved	
9	Reserved	
10	Reserved	
11	Reserved	
12	Reserved	
13	Reserved	
14	Reserved	
15	Reserved	

Table 13-12: PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing type 2 and {SS/PBCH block, PDCCH} subcarrier spacing {240, 120} kHz

Index	PDCCH monitoring occasions (SFN and slot number)	First symbol index (k = 0, 1, … 15)
0	$\mathrm{SFN}_{\mathrm{C}} = \mathrm{SFN}_{\mathrm{SSB}}$ $n_{\mathrm{C}} = n_{\mathrm{SSB}}$ or $n_{\mathrm{C}} = n_{\mathrm{SSB}} - 1$	0, 1, 2 in $i = 8k$, $i = 8k+1$, $i = 8k+2$ ($n_{\mathrm{C}} = n_{\mathrm{SSB}}$) 3, 12, 13, 0, 1 in $i = 8k+3$, $i = 8k+4$, $i = 8k+5$, $i = 8k+6$, $i = 8k+7$ ($n_{\mathrm{C}} = n_{\mathrm{SSB}} - 1$)
1	Reserved	
2	Reserved	
3	Reserved	
4	Reserved	
5	Reserved	
6	Reserved	
7	Reserved	
8	Reserved	
9	Reserved	
10	Reserved	
11	Reserved	
12	Reserved	
13	Reserved	
14	Reserved	
15	Reserved	

Table 13-13: PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing type 3 and {SS/PBCH block, PDCCH} subcarrier spacing {120, 120} kHz

Index	PDCCH monitoring occasions (SFN and slot number)	First symbol index (k = 0, 1, … 15)
0	$\mathrm{SFN}_{\mathrm{C}} = \mathrm{SFN}_{\mathrm{SSB}}$ $n_{\mathrm{C}} = n_{\mathrm{SSB}}$	4, 8, 2, 6 in $i = 4k$, $i = 4k+1$, $i = 4k+2$, $i = 4k+3$
1	Reserved	
2	Reserved	
3	Reserved	
4	Reserved	
5	Reserved	
6	Reserved	
7	Reserved	
8	Reserved	
9	Reserved	
10	Reserved	
11	Reserved	
12	Reserved	
13	Reserved	
14	Reserved	
15	Reserved	

Annex A (informative):
Change history

Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	New version
2017-04	RAN1#89	R1-1707925			Draft skeleton	0.0.0
2017-07	AH_NR2	R1-1712015			Inclusion of agreements until RAN1-adhoc#2	0.0.1
2017-08	RAN1#90	R1-1714553			Inclusion of agreements on CA and first revisions	0.0.2
2017-08	RAN1#90	R1-1714565			Second revisions	0.0.3
2017-08	RAN1#90	R1-1714658			Endorsed by RAN1#90	0.1.0
2017-08	RAN1#90	R1-1715323			Inclusion of agreements from RAN1#90	0.1.1
2017-08	RAN1#90	R1-1715330			Updated editor's version	0.1.2
2017-09	RAN#77	RP-171995			For information to plenary	1.0.0
2017-09	RAN1#90bis	R1-1716929			Inclusion of agreements until RAN1-adhoc#3	1.0.1
2017-10	RAN1#90bis	R1-1719107			Endorsed by RAN1#90bis	1.1.0
2017-11	RAN1#90bis	R1-1719226			Inclusion of agreements from RAN1#90bis	1.1.1
2017-11	RAN1#90bis	R1-1719243			Updated editor's version	1.1.2
2017-11	RAN1#90bis	R1-1721050			Endorsed by RAN1#90bis	1.2.0
2017-12	RAN1#91	R1-1721343			Inclusion of agreements from RAN1#91	1.3.0
2017-12	RAN#78	RP-172703			Endorsed version for approval by plenary	2.0.0
2017-12	RAN#78				Approved by plenary – Rel-15 spec under change control	15.0.0