3GPP TS 38.213 V15.2.0 (2018-06)

Technical Specification

3rd Generation Partnership Project;

Technical Specification Group Radio Access Network;

NR;  
Physical layer procedures for control

(Release 15)

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Keywords

3GPP, New Radio, Layer 1

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# Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

# 1 Scope

The present document specifies and establishes the characteristics of the physical 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"

[8-1] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"

[8-2] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone"

[8-3] 3GPP TS 38.101-3: "NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios"

[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

DAI Downlink assignment index

DC Dual connectivity

DCI Downlink control information

DL Downlink

DL-SCH Downlink shared channel

EPRE Energy per resource element

EN-DC E-UTRA NR dual connectivity with MCG using E-UTRA and SCG using NR

FR Frequency range

GSCN Global synchronization channel number

HARQ-ACK Hybrid automatic repeat request acknowledgement

MCG Master cell group

MCS Modulation and coding scheme

PBCH Physical broadcast channel

PCell Primary cell

PDCCH Physical downlink control channel

PDSCH Physical downlink shared channel

PRACH Physical random access channel

PRB Physical resource block

PRG Physical resource block group

PSCell Primary secondary cell

PSS Primary synchronization signal

PUCCH Physical uplink control channel

PUCCH-SCell PUCCH SCell

PUSCH Physical uplink shared channel

QCL Quasi-collocation

RB Resource block

RE Resource element

RRM Radio resource management

RS Reference signal

RSRP Reference signal received power

SCG Secondary cell group

SFN System frame number

SPS Semi-persistent scheduling

SR Scheduling request

SRI SRS resource indicator

SRS Sounding reference signal

SSS Secondary synchronization signal

TA Timing advance

TAG Timing advance group

UCI Uplink control information

UE User equipment

UL Uplink

UL-SCH Uplink shared channel

# 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 assumes 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 assumes that SSS, PBCH DM-RS, and PBCH data have the same EPRE. The UE may assume that the ratio of PSS EPRE to SSS EPRE in a SS/PBCH block in a corresponding cell is either 0 dB or 3 dB. If the UE has not been provided dedicated higher layer parameters, the UE may assume that the ratio of PDCCH DMRS EPRE to SSS EPRE is within -8 dB and 8 dB when the UE monitors PDCCHs for a DCI format 1\_0 with CRC scrambled by SI-RNTI, P-RNTI, or RA-RNTI.

For a half frame with SS/PBCH blocks, the first symbol indexes for candidate SS/PBCH blocks are determined according to the subcarrier spacing of SS/PBCH blocks as follows, where index 0 corresponds to the first symbol of the first slot in a half-frame.

- 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.

From the above cases, the applicable ones for a cell depend on a respective frequency band, as provided in [8-1, TS 38.101-1] and [8-2, TS 38.101-2]. A same case applies for all SS/PBCH blocks on the cell.

The candidate SS/PBCH blocks in a half frame are indexed in an ascending order in time from 0 to . A UE determines the 2 LSB bits, for , or the 3 LSB bits, for , 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 , the UE determines the 3 MSB bits of the SS/PBCH block index per half frame by PBCH payload bits  as described in [4, TS 38.212].

For SS/PBCH blocks providing higher layer parameter *MasterInformationBlock* to a UE, the UE can be configured by higher layer parameter *ssb-PositionsInBurst* in *SystemInformationBlockType1*, indexes of the SS/PBCH blocks for which the UE does not receive other signals or channels in REs that overlap with REs corresponding to the SS/PBCH blocks. The UE can also be configured per serving cell, by higher layer parameter *ssb-PositionsInBurst* in *ServingCellConfigCommon*, indexes of the SS/PBCH blocks for which the UE does not receive other signals or channels in REs that overlap with REs corresponding to the SS/PBCH blocks. A configuration by *ssb-PositionsInBurst* in *ServingCellConfigCommon* overrides a configuration by *ssb-PositionsInBurst* in *SystemInformationBlockType1*. A UE can be configured per serving cell by higher layer parameter *ssb-periodicityServingCell* a periodicity of the half frames for reception of the SS/PBCH blocks per serving cell. If the UE is not configured a periodicity of the half frames for receptions of the SS/PBCH blocks, the UE assumes a periodicity of a half frame. A UE assumes 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. Upon detection of a SS/PBCH block, the UE determines that a control resource set for Type0-PDCCH common search space is present if  [4, TS 38.211] for FR1 and if  for FR2. The UE determines that a control resource set for Type0-PDCCH common search space is not present if  for FR1 and if  for FR2.

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

If a UE is configured with two UL carriers in a serving cell, a same value of  applies to both carriers. The value of  is determined from the non-supplementary UL carrier. is described in [10, TS 38.133].

Upon reception of a timing advance command for a TAG containing the primary cell or PSCell, the UE adjusts 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/PUCCH 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, a UE may assume that  for FR1 and  for FR2 [10, TS 38.133].

If the UE is configured with a SCG, the UL transmission timing for PUSCH/SRS/PUCCH 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 adjusts uplink transmission timing for PUSCH/SRS/PUCCH 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/PUCCH 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 adjusts uplink transmission timing for PUSCH/SRS/PUCCH of all the secondary cells in the TAG by using  for FR1 and  for FR2 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/PUCCH is the same for all the secondary cells in the TAG.

For carrier aggregation operation with paired spectrum operation on one or more serving cells and unpaired spectrum operation on one or more other serving cells and in a TAG without PCell or PSCell, a UE adjusts a transmission time for all SCells in the TAG using the largest TA offset value within the TAG.

The timing adjustment indication specified in [11, TS 38.321] indicates the initial  used for a TAG. For a subcarrier spacing of  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 . 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], , for a TAG indicates values by index values of  = 0, 1, 2, ..., 3846, where an amount of the time alignment for the TAG for subcarrier spacing of  kHz is given by . 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], , for a TAG indicates adjustment of the current value, , to the new value, , by index values of  = 0, 1, 2,..., 63, where for a subcarrier spacing of  kHz, .

If a UE has multiple active UL BWPs, as described in Subclause 12, in a same TAG, including UL BWPs in two UL carriers of a serving cell, the timing advance command value is relative to the largest subcarrier spacing of the multiple active UL BWPs. The applicable  value for an UL BWP with lower subcarrier spacing may be rounded to align with the timing advance granularity for the UL BWP with the lower subcarrier spacing while satisfying the timing advance accuracy requirements in [10, TS38.133].

Adjustment of  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 uplink slot , the corresponding adjustment of the uplink transmission timing applies from the beginning of uplink slot  where ,  is a time duration of  symbols corresponding to a PDSCH reception time for PDSCH processing capability 1 when additional PDSCH DM-RS is configured,  is a time duration of  symbols corresponding to a PUSCH preparation time for PUSCH processing capability 1 [6, TS 38.214],  is the maximum timing advance value that can be provided by the TA command field of 12 bits,  is a number of slots per subframe, and  is the subframe duration of 1 msec.  and  are determined with respect to the minimum subcarrier spacing among the subcarrier spacings of all configured UL BWPs for all uplink carriers in a TAG and of their corresponding configured DL BWPs as described in Subclause 12. Slot  and  are determined with respect to the minimum subcarrier spacing among the subcarrier spacings of all configured UL BWPs for all uplink carriers in the TAG.  is determined with respect to the minimum subcarrier spacing among the subcarrier spacings of all configured UL BWPs for all uplink carriers in the TAG and of the initial UL BWP provided by higher layer parameter *initialuplinkBWP*.

If a UE changes an active UL BWP between a time of a timing advance command reception and a time of applying a corresponding adjustment of uplink transmission timing, the UE determines the timing advance command value based on the subcarrier spacing of the new active UL BWP. If the UE changes an active UL BWP after applying an adjustment of uplink transmission timing, the UE assumes a same absolute timing advance command value before and after the active UL BWP change.

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  accordingly.

If two adjacent slots overlap due to a TA command, the latter slot is reduced in duration relative to the former slot.

## 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 [11, TS 38.321] 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 [10, TS 38.133], 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 is 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-TimersAndConstants* is provided by the higher layers and is not set to release, the downlink radio link quality of the PSCell of the SCG is monitored by the 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, as described in Subclause 12, on the PSCell.

A UE can be configured for each DL BWP of a SpCell [11, TS 38.321] with a set of resource indexes, through a corresponding set of higher layer parameters *RadioLinkMonitoringRS*, for radio link monitoring by higher layer parameter *failureDetectionResources*. The UE is provided by higher layer parameter *RadioLinkMonitoringRS*, with either a CSI-RS resource configuration index, by higher layer parameter *csi-RS-Index*, or a SS/PBCH block index, by higher layer parameter *ssb-Index*. The UE can be configured with up to  *RadioLinkMonitoringRS* for link recovery procedures, as decribed in Subclause 6, and radio link monitoring. From the  *RadioLinkMonitoringRS*, up to  *RadioLinkMonitoringRS* can be used for radio link monitoring depending on a maximum number  of candidate SS/PBCH blocks per half frame as described in Subclause 4.1, and up to two *RadioLinkMonitoringRS* can be used for link recovery procedures.

If the UE is not provided higher layer parameter *RadioLinkMonitoringRS* and the UE is provided by higher layer parameter *TCI-state* for PDCCH one or more RSs that include one or more of a CSI-RS and/or a SS/PBCH block

- the UE uses for radio link monitoring the RS provided for the active TCI state for PDCCH if the active TCI state for PDCCH includes only one RS

- if the active TCI state for PDCCH includes two RS, the UE expects that one RS has QCL-TypeD and the UE uses the one RS for radio link monitoring; the UE does not expect both RS to have QCL-TypeD

- the UE is not required to use for radio link monitoring an aperiodic RS

A UE does not expect to use more than  *RadioLinkMonitoringRS* for radio link monitoring when the UE is not provided higher layer parameter *RadioLinkMonitoringRS*.

Values of  and  for different values of  are given in Table 5-1.

Table 5-1:  and  as a function of maximum number  of SS/PBCH blocks per half frame

|  |  |  |
| --- | --- | --- |
|  |  |  |
| 4 | 2 | 2 |
| 8 | 6 | 4 |
| 64 | 8 | 8 |

For a CSI-RS resource configuration, the higher layer parameter *powerControlOffsetSS*is not applicable and a UE expects to be provided only 'No CDM' from higher layer parameter *cdm-Type,* only '1' and '3' from higher layer parameter *density*, and only '1 port' from higher layer parameter *nrofPorts* [6, TS 38.214].

In non-DRX mode operation, the physical layer in the UE assesses once per indication period the radio link quality, evaluated over the previous time period defined in [10, TS 38.133] against thresholds (Qout and Qin) configured by higher layer parameter *rlmInSyncOutOfSyncThreshold*. The UE determines the indication period as the maximum between the shortest periodicity for radio link monitoring resources and 10 msec.

In DRX mode operation, the physical layer in the UE assesses once per indication period the radio link quality, evaluated over the previous time period defined in [10, TS 38.133], against thresholds (Qout and Qin) provided by higher layer parameter *rlmInSyncOutOfSyncThreshold*. The UE determines the indication period as the maximum between the shortest periodicity for radio link monitoring resources and the DRX period.

The physical layer in the UE indicates, in frames where the radio link quality is assessed, out-of-sync to higher layers when the radio link quality is worse than the threshold Qout for all resources in the set of resources for radio link monitoring. When the radio link quality is better than the threshold Qin for any resource in the set of resources for radio link monitoring, the physical layer in the UE indicates, in frames where the radio link quality is assessed, in-sync to higher layers.

# 6 Link recovery procedures

A UE can be provided, for a serving cell, with a set  of periodic CSI-RS resource configuration indexes by higher layer parameter *failureDetectionResources* and with a set  of periodic CSI-RS resource configuration indexes and/or SS/PBCH block indexes by higher layer parameter *candidateBeamRSList* for radio link quality measurements on the serving cell. If the UE is not provided with higher layer parameter *failureDetectionResources*, the UE determines the set  to include SS/PBCH block indexes and periodic CSI-RS resource configuration indexes with same values as the RS indexes in the RS sets indicated by the TCI states for respective control resource sets that the UE uses for monitoring PDCCH. The UE expects the set  to include up to two RS indexes and, if there are two RS indexes, the set  includes only RS indexes with QCL-TypeD configuration for the corresponding TCI states. The UE expects single port RS in the set .

The threshold Qout,LR corresponds to the default value of higher layer parameter *rlmInSyncOutOfSyncThreshold* and to the value provided by higher layer parameter *rsrp-ThresholdSSB*, respectively..

The physical layer in the UE assesses the radio link quality according to the set  of resource configurations against the threshold Qout,LR [10, TS 38.133]. For the set , the UE assesses 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 monitored by the UE. The UE applies the Qin,LR threshold to the L1-RSRP measurement obtained from a SS/PBCH block. The UE applies the Qin,LR threshold to the L1-RSRP measurement obtained for a CSI-RS resource after scaling a respective CSI-RS reception power with a value provided by higher layer parameter *powerControlOffsetSS*.

The physical layer in the UE provides an indication to higher layers when the radio link quality for all corresponding resource configurations in the set  that the UE uses to assess the radio link quality is worse than the threshold Qout,LR. The physical layer informs the higher layers when the radio link quality is worse than the threshold Qout,LR with a periodicity determined by the maximum between the shortest periodicity of periodic CSI-RS configurations or SS/PBCH blocks in the set  that the UE uses to assess the radio link quality and 2 msec.

Upon request from higher layers, the UE provides to higher layers the periodic CSI-RS configuration indexes and/or SS/PBCH block indexes from the set  and the corresponding L1-RSRP measurements that are larger than or equal to the corresponding thresholds.

A UE may be provided with a control resource set through a link to a search space set provided by higher layer parameter *recoverySearchSpaceId,* as described in Subclause 10.1, for monitoring PDCCH in the control resource set. If the UE is provided higher layer parameter *recoverySearchSpaceId*, the UE does not expect to be provided another search space set for monitoring PDCCH in the control resource set associated with the search space set provided by *recoverySearchSpaceId*.

The UE may receive by higher layer parameter *PRACH-ResourceDedicatedBFR*, a configuration for PRACH transmission as described in Subclause 8.1. For PRACH transmission in slot  and according to antenna port quasi co-location parameters associated with periodic CSI-RS configuration or SS/PBCH block with index  provided by higher layers [11, TS 38.321], the UE monitors PDCCH in a search space provided by higher layer parameter *recoverySearchSpaceId* for detection of a DCI format with CRC scrambled by C-RNTI starting from slot  within a window configured by higher layer parameter *BeamFailureRecoveryConfig*. For the PDCCH monitoring and for the corresponding PDSCH reception, the UE assumes the same antenna port quasi-collocation parameters with index  until the UE receives by higher layers an activation for a TCI state or any of the parameters *TCI-StatesPDCCH-ToAddlist* and/or *TCI-StatesPDCCH-ToReleaseList*. After the UE detects a DCI format with CRC scrambled by C-RNTI in the search space provided by *recoverySearchSpaceId*, the UE monitors PDCCH candidates in the search space provided by *recoverySearchSpaceId* until the UE receives a MAC CE activation command for a TCI state or higher layer parameters *TCI-StatesPDCCH-ToAddlist* and/or *TCI-StatesPDCCH-ToReleaseList.*

If the UE is not provided a control resource set for a search space set provided *recoverySearchSpaceId* or if the UE is not provided *recoverySearchSpaceId*, the UE does not expect to receive a PDCCH order triggering a PRACH transmission.

# 7 Uplink Power control

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

A PUSCH/PUCCH/SRS/PRACH transmission occasion  is defined by a slot index  within a frame with system frame number , a first symbol  within the slot, and a number of consecutive symbols .

## 7.1 Physical uplink shared channel

For PUSCH, a UE first scales a linear value  of the transmit power  on UL BWP , as described in Subclause 12, of carrier  of serving cell , 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. The UL BWP  is the active UL BWP.

### 7.1.1 UE behaviour

If a UE transmits a PUSCH on UL BWP  of carrier  of serving cell  using parameter set configuration with index  and PUSCH power control adjustment state with index , the UE determines the PUSCH transmission power  in PUSCH transmission occasion  as

 [dBm]

where,

- is the configured UE transmit power defined in [8-1, TS 38.101-1] and [8-2, TS38.101-2] for carrier  of serving cell  in PUSCH transmission occasion .

-  is a parameter composed of the sum of a component  and a component  where .

- If a UE is not provided with higher layer parameter *P0-PUSCH-AlphaSet* or for a Msg3 PUSCH transmission as described in Subclause 8.3, , , and  , where the parameter *preambleReceivedTargetPower* [11, TS 38.321] (for ) and *msg3-DeltaPreamble* (for ) are provided by higher layers for carrier  of serving cell .

- For a PUSCH (re)transmission configured by higher layer parameter *ConfiguredGrantConfig*, ,  is provided by higher layer parameter *p0-NominalWithoutGrant*, and  is provided by higher layer parameter *p0* obtained from *p0-PUSCH-Alpha* in *ConfiguredGrantConfig* that provides an index *P0-PUSCH-AlphaSetId* to a set of higher layer parameters *P0-PUSCH-AlphaSet* for UL BWP  of carrier  of serving cell .

- For, a  value, applicable for all , is provided by higher layer parameter *p0-NominalWithGrant* for each carrier  of serving cell  and a set of  values are provided by a set of higher layer parameters *p0* in *P0-PUSCH-AlphaSet* indicated by a respective set of higher layer parameters *p0-PUSCH-AlphaSetId* for UL BWP  of carrier  of serving cell .

- If the UE is provided by higher layer parameter *SRI-PUSCH-PowerControl* more than one values of *p0-PUSCH-AlphaSetId* and if DCI format 0\_1 includes a SRI field, the UE obtains a mapping from higher layer parameter *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for the SRI field in DCI format 0\_1 [5, TS 38.212] and a set of indexes provided by higher layer parameter *p0-PUSCH-AlphaSetId* that map to a set of *P0-PUSCH-AlphaSet* values. If the PUSCH transmission is scheduled by a DCI format 0\_1, the UE determines the values of  from the *p0alphasetindex* value that is mapped to the SRI field value.

- If the PUSCH transmission is scheduled by a DCI format 0\_0 or by a DCI format 0\_1 that does not include a SRI field, or if a higher layer parameter *SRI-P0AlphaSetIndex-Mapping* is not provided to the UE, , and the UE determines  from the first *p0-pusch-alpha-set* in *p0-pusch-alpha-setconfig*.

- For 

- For ,  is a value of higher layer parameter *msg3-Alpha*, when provided; otherwise, .

- For ,  is provided by higher layer parameter *alpha* obtained from *p0-PUSCH-Alpha* in *ConfiguredGrantConfig* providing an index *P0-PUSCH-AlphaSetId* to a set of higher layer parameters *P0-PUSCH-AlphaSet* for UL BWP  of carrier  of serving cell .

- For , a set of  values are provided by a set of higher layer parameters *alpha* in *P0-PUSCH-AlphaSet* indicated by a respective set of higher layer parameters *p0-PUSCH-AlphaSetId* for UL BWP  of carrier  of serving cell .

- If the UE is provided a higher layer parameter *SRI-PUSCH-PowerControl* and more than one values of *p0-PUSCH-AlphaSetId*, DCI format 0\_1 includes a SRI field and the UE obtains a mapping from higher layer parameter *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for the SRI field in DCI format 0\_1 [5, TS 38.212] and a set of indexes provided by higher layer parameter *p0-PUSCH-AlphaSetId* that map to a set of *P0-PUSCH-AlphaSet* values. If the PUSCH transmission is scheduled by a DCI format 0\_1, the UE determines the values of  from the *p0alphasetindex* value that is mapped to the SRI field value.

- If the PUSCH transmission is scheduled by a DCI format 0\_0 or by a DCI format 0\_1 that does not include a SRI field, or if a higher layer parameter *SRI-P0AlphaSetIndex-Mapping* is not provided to the UE, , and the UE determines from the first *p0-pusch-alpha-set* in *p0-pusch-alpha-setconfig*.

- is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks for PUSCH transmission occasion on UL BWP  of carrier  of serving cell and  is defined in [4, TS 38.211].

- is a downlink path-loss estimate in dB calculated by the UE using reference signal (RS) index  for a DL BWP that is linked with UL BWP  of carrier  of serving cell .

- If the UE is not provided higher layer parameter *PUSCH-PathlossReferenceRS* and before the UE is provided dedicated higher layer parameters, the UE calculates  using a RS resourcefrom the SS/PBCH block index that the UE obtains higher layer parameter *MasterInformationBlock*.

- If the UE is configured with a number of RS resource indexes up to the value of higher layer parameter *maxNrofPUSCH-PathlossReferenceRSs* and a respective set of RS configurations for the number of RS resource indexes by higher layer parameter *PUSCH-PathlossReferenceRS*. The set of RS resource indexes can include one or both of a set of SS/PBCH block indexes, each provided by higher layer parameter *ssb-Index* when a value of a corresponding higher layer parameter pusch-*PathlossReferenceRS-Id* maps to a SS/PBCH block index, and a set of CSI-RS resource indexes, each provided by higher layer parameter *csi-RS-Index* when a value of a corresponding higher layer parameter *pusch-PathlossReferenceRS-Id* maps to a CSI-RS resource index. The UE identifies a RS resource index in the set of RS resource indexes to correspond either to a SS/PBCH block index or to a CSI-RS resource index as provided by higher layer parameter *pusch-PathlossReferenceRS-Id* in *PUSCH-PathlossReferenceRS*.

- If the PUSCH is an Msg3 PUSCH, the UE uses the same RS resource index as for a corresponding PRACH transmission.

- If the UE is provided a higher layer parameter *SRI-PUSCH-PowerControl* and more than one values of *PUSCH-PathlossReferenceRS-Id*, the UE obtains a mapping from higher layer parameter *sri-PUSCH-PowerControlId* in *SRI-PUSCH-PowerControl* between a set of values for the SRI field in DCI format 0\_1 and a set of *PUSCH-PathlossReferenceRS-Id* values. If the PUSCH transmission is scheduled by a DCI format 0\_1, DCI format 0\_1 includes a SRI field and the UE determines the RS resource  from the value of *pusch-pathlossreference-index* that is mapped to the SRI field value.

- If the PUSCH transmission is in response to a DCI format 0\_0 detection, and if the UE is provided a spatial setting by higher layer parameter PUCCH-Spatialrelationinfo for a PUCCH resource with a lowest index for UL BWP  of each carrier  and serving cell , as described in Subclause 9.2.2, the UE uses the same RS resource index as for a PUCCH transmission.

- If the PUSCH transmission is scheduled by a DCI format 0\_0 and if the UE is not provided a spatial setting for a PUCCH transmission, or by a DCI format 0\_1 that does not include a SRI field, or if a higher layer parameter *SRI-PathlossReferenceIndex-Mapping* is not provided to the UE, the UE determines a RS resource with a respective higher layer parameter *pusch-pathlossreference-index* value being equal to zero.

- For a PUSCH transmission configured by higher layer parameter *ConfiguredGrantConfig,* if higher layer parameter *rrc-ConfiguredUplinkGrant* is included in *ConfiguredGrantConfig* , a RS resource index  is provided by a value of higher layer parameter *pathlossReferenceIndex* included in *rrc-ConfiguredUplinkGrant*.

- For a PUSCH transmission configured by higher layer parameter *ConfiguredGrantConfig* is not included in *ConfiguredGrantConfig* does not include higher layer parameter *pathlossReferenceIndex*, the UE determines the RS resource  from the value of *PUSCH-PathlossReferenceRS-Id* that is mapped to the SRI field value in the DCI format activating the PUSCH transmission. If the DCI format activating the PUSCH transmission does not include a SRI field, the UE determines a RS resource with a respective higher layer parameter *PUSCH-PathlossReferenceRS-Id* value being equal to zero.

= *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 , *referenceSignalPower* is provided by higher layer parameter *ss-PBCH-BlockPower*. For , *referenceSignalPower* is configured by either higher layer parameter *ss-PBCH-BlockPower* or, when periodic CSI-RS transmission is configured, by higher layer parameter *powerControlOffsetSS* providing an offset of the CSI-RS transmission power relative to the SS/PBCH block transmission power [6, TS 38.214].

-  for  and  for  where  is provided by higher layer parameter *deltaMCS* provided for each UL BWP  of each carrier  and serving cell . If the PUSCH transmission is over more than one layer [6, TS 38.214], .  and , for each UL BWP  of each carrier  and each serving cell , are computed as below.

-  for PUSCH with UL-SCH data and for CSI transmission in a PUSCH without UL-SCH data, where

-  is the number of code blocks,  is the size for code block ,  is the number of CSI part 1 bits including CRC bits, and  is the number of resource elements determined as , where  is the number of symbols for PUSCH transmission occasion on UL BWP  of carrier  of serving cell,  is a number of subcarriers excluding DM-RS subcarriers in PUSCH symbol , , and ,  are defined in [5, TS 38.212].

-  when the PUSCH includes UL-SCH data and , 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 UL BWP  of carrier  of serving cell  in PUSCH transmission occasion 

-  is a correction value, also referred to as a TPC command, and is included in a DCI format 0\_0 or DCI format 0\_1 that schedules the PUSCH transmission occasion , after a last PUSCH transmission occasion , on UL BWP  of carrier  of serving cell  or jointly coded with other TPC commands in a DCI format 2\_2 having CRC parity bits scrambled by TPC-PUSCH-RNTI, as described in Subclause 11.3;

-  if the UE is configured with higher layer parameter *twoPUSCH-PC-AdjustmentStates*, and  if the UE is not configured with higher layer parameter *twoPUSCH-PC-AdjustmentStates* or if the PUSCH is a Msg3 PUSCH.

- For a PUSCH (re)transmission configured by higher layer parameter *ConfiguredGrantConfig*, the value of  is provided to the UE by higher layer parameter *powerControlLoopToUse*

- If the UE is provided a higher layer parameter *SRI-PUSCH-PowerControl*, the UE obtains a mapping between a set of values for the SRI field in DCI format 0\_1 and the  value(s) provided by higher layer parameter *sri-PUSCH-ClosedLoopIndex*. If the PUSCH transmission is scheduled by a DCI format 0\_1 and if DCI format 0\_1 includes a SRI field, the UE determines the  value that is mapped to the SRI field value

- If the PUSCH transmission is scheduled by a DCI format 0\_0 or by a DCI format 0\_1 that does not include a SRI field, or if a higher layer parameter *SRI-PUSCH-PowerControl* is not provided to the UE, 

-  dB if the UE does not detect, after a last PUSCH transmission occasion , a DCI format providing a TPC command for PUSCH transmissions on UL BWP  of carrier  of serving cell .

- If the PUSCH transmission is in response to a PDCCH decoding with DCI format 0\_0 or DCI format 0\_1, or the TPC command is provided by DCI format 2\_2 having CRC parity bits scrambled by TPC-PUSCH-RNTI, the respective  accumulated values are given in Table 7.1.1-1.

- If the PUSCH transmission is in response to a detection by the UE of a DCI format 0\_0 or DCI format 0\_1,  is a number of symbols for UL BWP  of carrier  of serving cell  after a last symbol of a corresponding PDCCH and before a first symbol of the PUSCH transmission

- If the PUSCH transmission is configured by higher layer parameter *ConfiguredGrantConfig*,  is a number of  symbols equal to the product of a number of symbols per slot, , and the minimum of the values provided by higher layer parameter *k2* and for UL BWP  of carrier  of serving cell 

- If accumulation of TPC commands is enabled by higher layer parameter *tpc-Accumulation*, for accumulation of a TPC commands that the UE receives by DCI formats 2\_2 with CRC scrambled by a TPC-PUSCH-RNTI between a PUSCH transmission occasion  and a PUSCH transmission occasion ,

  
where

-  is a PUSCH transmission occasion immediately prior to PUSCH transmission occasion 

- if the PUSCH transmission occasions  and  on UL BWP  of carrier  of serving cell  are in response to detection by the UE of DCI format(s) 0\_0 or DCI format(s) 0\_1,  is a number of DCI formats 2\_2 with CRC scrambled by a TPC-PUSCH-RNTI that the UE receives corresponding PDCCHs

- after a last symbol of a corresponding PDCCH for PUSCH transmission occasion , and

- before a last symbol of a corresponding PDCCH for PUSCH transmission occasion 

- if the PUSCH transmission occasion  on UL BWP  of carrier  of serving cell  is in response to detection by the UE of DCI format 0\_0 or DCI format 0\_1 and the PUSCH transmission occasion  on UL BWP  of carrier  of serving cell  is configured by higher layer parameter *ConfiguredGrantConfig*,  is a number of DCI formats 2\_2 with CRC scrambled by a TPC-PUSCH-RNTI that the UE receives corresponding PDCCHs

- after a number of  symbols before a first symbol for PUSCH transmission at occasion , where  is equal to the product of a number of symbols per slot, , and the minimum of the values provided by higher layer parameter *k2* and for UL BWP  of carrier  of serving cell , and

- before a last symbol of a corresponding PDCCH for PUSCH transmission occasion 

- if the PUSCH transmission occasion  on UL BWP  of carrier  of serving cell  is configured by higher layer parameter *ConfiguredGrantConfig* and the PUSCH transmission occasion  on UL BWP  of carrier  of serving cell  is in response to detection by the UE of DCI format 0\_0 or DCI format 0\_1,  is a number of DCI formats 2\_2 with CRC scrambled by a TPC-PUSCH-RNTI that the UE receives corresponding PDCCHs

- after a last symbol of a corresponding PDCCH for PUSCH transmission occasion , and

- at or before a number of  symbols before a first symbol for PUSCH transmission occasion 

- if the PUSCH transmission occasions  and  on UL BWP  of carrier  of serving cell  are configured by higher layer parameter *ConfiguredGrantConfig*,  is a number of DCI formats 2\_2 with CRC scrambled by a TPC-PUSCH-RNTI that the UE receives corresponding PDCCHs

- after a number of  symbols before a first symbol for PUSCH transmission occasion , and

- at or before a number of  symbols before a first symbol for PUSCH transmission occasion 

-  is the PUSCH power control adjustment state for UL BWP  of carrier  of serving cell  and PUSCH transmission occasion  if accumulation is enabled based on higher layer parameter *tpc-Accumulation*, where

- If the UE has reached  for UL BWP  of carrier  of serving cell , the UE does not accumulate positive TPC commands for UL BWP  of carrier  of serving cell .

- If UE has reached minimum power, , for UL BWP  of carrier  of serving cell , the UE does not accumulate negative TPC commands for UL BWP  of carrier  of serving cell .

- A UE resets accumulation for UL BWP  of carrier  of serving cell 

- When  value is provided by higher layers;

- When  value is provided by higher layers and serving cell  is a secondary cell;

- When  value is provided by higher layers;

- If , the PUSCH transmission is scheduled by a DCI format 0\_1 that includes a SRI field, and the UE is provided higher layer parameter *SRI-PUSCH-PowerControl*, the UE determines the value of  from the value of  based on an indication by the SRI field for a *sri-PUSCH-PowerControlId* value associated with the *sri-P0-PUSCH-AlphaSetId* value corresponding to  and with the *sri-PUSCH-ClosedLoopIndex* value corresponding to 

- If  and the PUSCH transmission is scheduled by a DCI format 0\_0 or by a DCI format 0\_1 that does not include a SRI field or the UE is not provided higher layer parameter *SRI-PUSCH-PowerControl*, 

- If ,  is provided by the value of higher layer parameter *powerControlLoopToUse*

- is the first value after reset of accumulation.



- is the PUSCH power control adjustment state for UL BWP  of carrier  of serving cell  and PUSCH transmission occasion  if accumulation is not enabled based on higher layer parameter *tpc-Accumulation*, where

- If the PUSCH transmission is in response to a PDCCH decoding with DCI format 0\_0 or DCI format 0\_1, or the TPC command is provided by DCI format 2\_2 having CRC parity bits scrambled by TPC-PUSCH-RNTI, the respective  absolute values are given in Table 7.1.1-1.

- for a PUSCH transmission occasion , where the UE does not detect a DCI format 0\_0 or DCI format 0\_1, or DCI format 2\_2 having CRC parity bits scrambled by TPC-PUSCH-RNTI, after an immediately previous PUSCH transmission occasion  on UL BWP  of for carrier  of serving cell .

- If the UE receives the random access response message for UL BWP  of carrier  of serving cell 

- , where  and

-  is the TPC command indicated in the random access response grant of the random access response message corresponding to the random access preamble transmitted on UL BWP  of carrier  in the serving cell , and

-  and  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  in the serving cell ,  is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks for the first PUSCH transmission on UL BWP  of carrier  of serving cell, and  is the power adjustment of first PUSCH transmission on UL BWP  of carrier  of serving cell .

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

|  |  |  |
| --- | --- | --- |
| TPC Command Field | Accumulated or [dB] | Absolute or [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 active UL BWP  of carrier  in the primary cell  using PUCCH power control adjustment state with index , the UE determines the PUCCH transmission power  in PUCCH transmission occasion  as

 [dBm]

where

- is the configured UE transmit power defined in [8-1, TS 38.101-1] and [8-2, TS38.101-2] for carrier  of serving cell  in PUCCH transmission occasion .

-  is a parameter composed of the sum of a component , provided by higher layer parameter *p0-nominal* for carrier  of primary cell , and a component  provided by higher layer parameter *p0-PUCCH-Value* in *P0-PUCCH* for UL BWP  of carrier  of primary cell , where .  is a size for a set of  values provided by higher layer parameter *maxNrofPUCCH-P0-PerSet*. The set of  values is provided by higher layer parameter *p0-Set*.

- If the UE is provided higher layer parameter *PUCCH-SpatialRelationInfo*, the UE obtains a mapping, by an index provided by higher layer parameter *p0-PUCCH-Id*, between a set of *pucch-SpatialRelationInfoId* values and a set of *p0-PUCCH-Value* values. If the UE is provided more than one values for *pucch-SpatialRelationInfoId* and the UE receives an activation command [11, TS 38.321] indicating a value of *pucch-SpatialRelationInfoId*, the UE determines the *p0-PUCCH-Value* value through the link to a corresponding *p0-PUCCH-Id* index. The UE applies the activation command 3 msec after a slot where the UE transmits HARQ-ACK information for the PDSCH providing the activation command.

- If the UE is not provided higher layer parameter *PUCCH-SpatialRelationInfo*, the UE obtains the *p0-PUCCH-Value* value from the *P0-PUCCH* with *p0-PUCCH-Id* index 0 in *p0-Set* .

- is the bandwidth of the PUCCH resource assignment expressed in number of resource blocks for PUCCH transmission occasion on UL BWP  of carrier  of serving cell and  is defined in [4, TS 38.211].

- is a downlink path-loss estimate in dB calculated by the UE using reference signal (RS) index  for a DL BWP that is linked with UL BWP  of carrier  of the primary cell .

- If the UE is not provided higher layer parameter *pathlossReferenceRSs* and before the UE is provided dedicated higher layer parameters, the UE calculates  using a RS resource obtained from the SS/PBCH block index that the UE obtains higher layer parameter *MasterInformationBlock*.

- If the UE is provided a number of RS resource indexes, the UE calculates  using RS resource , where .  is a size for a set of RS resources provided by higher layer parameter *maxNrofPUCCH-PathlossReferenceRSs*. The set of RS resources is provided by higher layer parameter *pathlossReferenceRSs*. The set of RS resources can include one or both of a set of SS/PBCH block indexes, each provided by higher layer parameter *ssb-Index* in *PUCCH-PathlossReferenceRS* when a value of a corresponding higher layer parameter pucch-*PathlossReferenceRS-Id* maps to a SS/PBCH block index, and a set of CSI-RS resource indexes, each provided by higher layer parameter *csi-RS-Index* when a value of a corresponding higher layer parameter *pucch-PathlossReferenceRS-Id* maps to a CSI-RS resource index. The UE identifies a RS resource in the set of RS resources to correspond either to a SS/PBCH block index or to a CSI-RS resource index as provided by higher layer parameter *pucch-PathlossReferenceRS-Id* in *PUCCH-PathlossReferenceRS*.

- If the UE is provided higher layer parameter *PUCCH-SpatialRelationInfo*, the UE obtains a mapping, by indexes provided by corresponding higher layer parameters *pucch-PathlossReferenceRS-Id*, between a set of *pucch-SpatialRelationInfoId* values and a set of *referencesignal* values provided by higher layer parameter *PUCCH-PathlossReferenceRS*. If the UE is provided more than one values for *pucch-SpatialRelationInfoId* and the UE receives an activation command [11, TS 38.321] indicating a value of *pucch-SpatialRelationInfoId*, the UE determines the *referencesignal* value in *PUCCH-PathlossReferenceRS* through the link to a corresponding *pucch-PathlossReferenceRS-Id* index. The UE applies the activation command 3 msec after a slot where the UE transmits HARQ-ACK information for the PDSCH providing the activation command.

- If higher layer parameter *pucch-SpatialRelationInfo* includes higher layer parameters *cell* and *bwp-Id*, the UE receives the RS with index  on the DL BWP provided by *bwp-Id* of the serving cell provided by *cell*.

- If the UE is not provided higher layer parameter *PUCCH-SpatialRelationInfo*, the UE obtains the *referencesignal* value in *PUCCH-PathlossReferenceRS* from the *pucch-PathlossReferenceRS-Id* with index 0 in *PUCCH-PathlossReferenceRSs*.

- The parameter  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.

-  is a PUCCH transmission power adjustment component for UL BWP  of carrier  of primary cell .

- For a PUCCH transmission using PUCCH format 0 or PUCCH format 1,  where

-  is the number of PUCCH format 0 symbols or PUCCH format 1 symbols, provided by higher layer parameter *nrofSymbols* in *PUCCH-format0* or in *PUCCH-format1*, respectively

-  for PUCCH format 0

-  for PUCCH format 1

- For a PUCCH transmission using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 and for a number of UCI bits smaller than or equal to 11, , where

- 

-  is a number of HARQ-ACK information bits that the UE determines as described in Subclause 9.1.2.1 for Type-1 HARQ-ACK codebook and as described in Subclause 9.1.3.1 for Type-2 HARQ-ACK codebook. If the UE is not provided with higher layer parameter *pdsch-HARQ-ACK-Codebook*,  if the UE includes a HARQ-ACK information bit in the PUCCH transmission; otherwise, ;

-  is a number of SR information bits that the UE determines as described in Subclause 9.2.5.1;

-  is a number of CSI information bits that the UE determines as described in Subclause 9.2.5.2;

-  is a number of resource elements determined as  , where  is a number of subcarriers per resource block excluding subcarriers used for DM-RS transmission, and  is a number of symbols excluding symbols used for DM-RS transmission, as defined in Subclause 9.2.5.2, for PUCCH transmission occasion on UL BWP  of carrier  of serving cell.

- For a PUCCH transmission using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 and for a number of UCI bits larger than 11, , where

- 

- ;

-  is a number of HARQ-ACK information bits that the UE determines as described in Subclause 9.1.2.1 for Type-1 HARQ-ACK codebook and as described in Subclause 9.1.3.1 for Type-2 HARQ-ACK codebook. If the UE is not provided with higher layer parameter *pdsch-HARQ-ACK-Codebook*,  if the UE includes a HARQ-ACK information bit in the PUCCH transmission; otherwise, ;

-  is a number of SR information bits that the UE determines as described in Subclause 9.2.5.1;

-  is a number of CSI information bits that the UE determines as described in Subclause 9.2.5.2;

-  is a number of resource elements that the UE determines as , where  is a number of subcarriers per resource block excluding subcarriers used for DM-RS transmission, and  is a number of symbols excluding symbols used for DM-RS transmission, as defined in Subclause 9.2.5.2, for PUCCH transmission occasion on UL BWP  of carrier  of serving cell.

- For the PUCCH power control adjustment state for UL BWP  of carrier  of primary cell  and PUCCH transmission occasion 

-  is a correction value, also referred to as a TPC command, and is included in a DCI format 1\_0 or DCI format 1\_1 for UL BWP  of carrier  of the primary cell  that the UE detects for PUCCH transmission occasion , after a last PUCCH transmission occasion , or jointly coded with other TPC commands in a DCI format 2\_2 having CRC parity bits scrambled by TPC-PUCCH-RNTI [5, TS 36.212], as described in Subclause 11.3, where  if the UE is provided higher layer parameter *twoPUCCH-PC-AdjustmentStates* and  if the UE is not provided higher layer parameter *twoPUCCH-PC-AdjustmentStates* or *PUCCH-SpatialRelationInfo;*

- If the UE is provided higher layer parameter *PUCCH-SpatialRelationInfo*, the UE obtains a mapping, by an index provided by higher layer parameter *p0-PUCCH-Id*, between a set of *pucch-SpatialRelationInfoId* values and a set of values for higher layer parameter *closedLoopIndex* that provide the  value(s). If the UE receives an activation command indicating a value of *pucch-SpatialRelationInfoId*, the UE determines the value *closedLoopIndex* that provides the value of  through the link to a corresponding *p0-PUCCH-Id* index;

- If the PUCCH transmission is in response to a detection by the UE of a DCI format 1\_0 or DCI format 1\_1,  is a number of symbols for UL BWP  of carrier  of serving cell  after a last symbol of a corresponding PDCCH and before a first symbol of the PUCCH transmission;

- If the PUCCH transmission is not in response to a detection by the UE of a DCI format 1\_0 or DCI format 1\_1,  is a number of  symbols equal to the product of a number of symbols per slot, , and the minimum of the values provided by higher layer parameter *k2* and for UL BWP  of carrier  of serving cell  .

- The  dB values signalled 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.

-  dB if the UE does not detect after a last PUCCH transmission occasion  a DCI format providing a TPC command for PUCCH transmission occasion  on UL BWP  of carrier  of the primary cell .

- If accumulation of TPC commands is enabled by higher layer parameter *tpc-Accumulation*, for accumulation of a TPC commands that the UE receives by DCI formats 2\_2 with CRC scrambled by a TPC-PUCCH-RNTI between a PUCCH transmission occasion  and a PUCCH transmission occasion ,



where

-  is a PUCCH transmission occasion immediately prior to PUCCH transmission occasion 

- if the PUCCH transmission occasions  and  on UL BWP  of carrier  of serving cell  are in response to detection by the UE of DCI format(s) 1\_0 or DCI format(s) 1\_1,  is a number of DCI formats 2\_2 with CRC scrambled by a TPC-PUCCH-RNTI that the UE receives corresponding PDCCHs

- after a last symbol of a corresponding PDCCH for PUCCH transmission occasion , and

- before a last symbol of a corresponding PDCCH for PUCCH transmission occasion 

- if the PUCCH transmission occasion  on UL BWP  of carrier  of serving cell  is in response to detection by the UE of DCI format 1\_0 or DCI format 1\_1 and the PUCCH transmission occasion  on UL BWP  of carrier  of serving cell  is not in response to detection by the UE of DCI format 1\_0 or DCI format 1\_1,  is a number of DCI formats 2\_2 with CRC scrambled by a TPC-PUCCH-RNTI that the UE receives corresponding PDCCHs

- after a number of  symbols before a first symbol for PUCCH transmission occasion , where  is equal to the product of a number of symbols per slot, , and the minimum of the values provided by higher layer parameter *k2* and for UL BWP  of carrier  of serving cell , and

- before a last symbol of a corresponding PDCCH for PUCCH transmission occasion 

- if the PUCCH transmission occasion  on UL BWP  of carrier  of serving cell  is not in response to detection by the UE of DCI format 1\_0 or DCI format 1\_1 and the PUCCH transmission occasion  on UL BWP  of carrier  of serving cell  is in response to a detection by the UE of DCI format 1\_0 or DCI format 1\_1,  is a number of DCI formats 2\_2 with CRC scrambled by a TPC-PUCCH-RNTI that the UE receives corresponding PDCCHs

- after a last symbol of a corresponding PDCCH for PUCCH transmission occasion , and

- at or before a number of  symbols before a first symbol for PUCCH transmission occasion 

- if the PUCCH transmission occasions  and  on UL BWP  of carrier  of serving cell  are not in response to detection by the UE of DCI format 1\_0 or DCI format 1\_1,  is a number of DCI formats 2\_2 with CRC scrambled by a TPC-PUCCH-RNTI that the UE receives corresponding PDCCHs

- after a number of  symbols before a first symbol for PUCCH transmission occasion , and

- at or before a number of  symbols before a first symbol for PUCCH transmission occasion 

-  is the current PUCCH power control adjustment state and  is the first value after reset

- If  value is provided by higher layers,

- 

If the UE is provided higher layer parameter *PUCCH-SpatialRelationInfo*, the UE determines the value of  from the value of  based on a *pucch-SpatialRelationInfoId* value associated with the *p0-PUCCH-Id* value corresponding to  and with the *closedLoopIndex* value corresponding to ; otherwise, .

- Else,

- , where

 is the TPC command indicated in the random access response grant corresponding to the random access preamble transmitted on UL BWP  of carrier  in the serving cell , and,

if the UE transmits PUCCH,



;

otherwise,

 and  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 UL BWP  of carrier  of primary cell , and  corresponds to PUCCH format 0 or PUCCH format 1.

- If the UE has reached  for UL BWP  of carrier  of primary cell , the UE does not accumulate positive TPC commands for UL BWP  of carrier  of primary cell .

- If the UE has reached minimum power for UL BWP  of carrier  of primary cell , the UE does not accumulate negative TPC commands for UL BWP  of carrier  of primary cell .

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  values

|  |  |
| --- | --- |
| TPC Command Field | Accumulated [dB] |
| 0 | -1 |
| 1 | 0 |
| 2 | 1 |
| 3 | 3 |

## 7.3 Sounding reference signals

For SRS, the linear value  of the transmit power  on UL BWP  of carrier  of serving cell  is split equally across the configured antenna ports for SRS. The UL BWP  is the active UL BWP.

### 7.3.1 UE behaviour

If a UE transmits SRS on UL BWP  of carrier  of serving cell  using SRS power control adjustment state with index , the UE determines the SRS transmission power  in SRS transmission occasion  as

 [dBm]

where,

- is the configured UE transmit power defined in [8, TS 38.101-1] and [8-2, TS38.101-2] for carrier  of serving cell  in SRS transmission occasion .

-  is provided by higher layer parameter *p0* for UL BWP  of carrier  of serving cell  and SRS resource set  provided by higher layer parameters *SRS-ResourceSet* and *SRS-ResourceSetId*.

-  is the SRS bandwidth expressed in number of resource blocks for SRS transmission occasion on UL BWP  of carrier  of serving cell and  is defined in [4, TS 38.211].

- is provided by higher layer parameter *alpha* for UL BWP  of carrier  of serving cell  and SRS resource set .

- is a downlink path-loss estimate in dB calculated by the UE using reference signal (RS) index  for a DL BWP that is linked with UL BWP  of carrier  of serving cell  and SRS resource set  [6, TS 38.214]. The RS index  is provided by higher layer parameter *pathlossReferenceRS* associated with the SRS resource set  and is either a higher layer parameter *ssb-Index* providing a SS/PBCH block index or a higher layer parameter *csi-RS-Index* providing a CSI-RS resource index.

- If the UE is not provided higher layer parameter *pathlossReferenceRSs* and before the UE is provided dedicated higher layer parameters, the UE calculates  using a RS resource obtained from the SS/PBCH block index that the UE obtains higher layer parameter *MasterInformationBlock.*

- For the SRS power control adjustment state for UL BWP  of carrier  of serving cell  and SRS transmission occasion 

- , where  is the current PUSCH power control adjustment state as described in Subclause 7.1.1, if higher layer parameter *srs-PowerControlAdjustmentStates* indicates a same power control adjustment state for SRS transmissions and PUSCH transmissions; or

-  if the UE is not configured for PUSCH transmissions on UL BWP  of carrier  of serving cell , or if higher layer parameter *srs-PowerControlAdjustmentStates* indicates a separate power control adjustment state between SRS transmissions and PUSCH transmissions, and if accumulation is enabled based on the parameter *tpc-Accumulation* provided by higher layers, where  is jointly coded with other TPC commands in a PDCCH with DCI format 2\_3, as described in Subclause 11.4, that is last received by the UE prior to the SRS transmission and accumulative values of  are provided in Table 7.1.1-1, where

-  is a SRS transmission occasion immediately prior to SRS transmission occasion 

- if the SRS transmission is aperiodic,  is a number of symbols for UL BWP  of carrier  of serving cell  after a last symbol of a corresponding PDCCH and before a first symbol of the SRS transmission

- if the SRS transmission is semi-persistent or periodic,  is a number of  symbols equal to the product of a number of symbols per slot, , and the minimum of the values provided by higher layer parameter *k2* and for UL BWP  of carrier  of serving cell 

- for accumulation of a TPC commands that the UE receives by DCI formats 2\_3 between an aperiodic, semi-persistent, or periodic SRS transmission occasion  and an aperiodic, semi-persistent, or periodic SRS transmission occasion ,



where

-  is a number of DCI formats 2\_3 the UE receives corresponding PDCCHs

- after a number of  symbols before a first symbol of SRS transmission occasion , and

- at or before a number of  symbols before a first symbol of SRS transmission occasion 

- dB if the UE does not detect after a last SRS transmission a DCI format providing a TPC command for SRS transmissions on UL BWP  of carrier  of serving cell .

- If the UE has reached  for UL BWP  of carrier  of serving cell , the UE does not accumulate corresponding positive TPC commands.

- If UE has reached minimum power for UL BWP  of carrier  of serving cell , the UE does not accumulate corresponding negative TPC commands.

- A UE resets accumulation for UL BWP  of carrier  of serving cell 

- When  value is provided by higher layers;

- When  value is provided by higher layers.

-  is the first value after reset of accumulation.

- If  value is provided by higher layers,

- 

- Else,

- , where

 is the TPC command indicated in the random access response grant corresponding to the random access preamble transmitted on UL BWP  of carrier  of the serving cell , and

;

and  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 UL BWP  of carrier  of serving cell .

-  if the UE is not configured for PUSCH transmissions on UL BWP  of carrier  of serving cell , or if higher layer parameter *srs-PowerControlAdjustmentStates* indicates a separate power control adjustment state between SRS transmissions and PUSCH transmissions, and if accumulation is not enabled based on the higher layer parameter *tpc-Accumulation*, and the UE detects a DCI format 2\_3 for a SRS transmission occasion  that follows SRS transmission occasion , where absolute values of  are provided in Table 7.1.1-1.

-  for a SRS transmission occasion  where the UE does not detect a DCI format 2\_3 after an immediately previous SRS transmission occasion  for UL BWP  of carrier  of serving cell .

- if higher layer parameter *srs-PowerControlAdjustmentStates* indicates a same power control adjustment state for SRS transmissions and PUSCH transmissions, the update of the power control adjustment state for SRS transmission occasion  occurs at the beginning of each SRS resource in the SRS resource set ; otherwise, the update of the power control adjustment state SRS transmission occasion  occurs at the beginning of the first transmitted SRS resource in the SRS resource set .

## 7.4 Physical random access channel

A UE determines a transmission power for a physical random access channel (PRACH), , on active UL BWP  of carrier  based on a current SS/PBCH block determination for serving cell  in transmission occasion  as

 [dBm],

where  is the configured UE transmission power defined in [8-1, TS 38.101-1] and [8-2, TS38.101-2] for carrier  of serving cell  within transmission occasion ,  is the PRACH preamble target reception power *PREAMBLE\_RECEIVED\_TARGET\_POWER* provided by higher layers [11, TS 38.321] for the UL BWP  of carrier  of serving cell , and  is a pathloss for the UL BWP  of carrier  for the current SS/PBCH block of serving cell  calculated by the UE in dB as *referenceSignalPower* – higher layer filtered RSRP, where RSRP is defined in [7, TS 38.215] and the higher layer filter configuration is defined in [12, TS 38.331].

If the PRACH transmission from the UE is not in response to a detection of a PDCCH order by the UE, or is in response to a detection of a PDCCH order by the UE that triggers a contention based random access procedure, *referenceSignalPower* is provided by *ss-PBCH-BlockPower*.

If the PRACH transmission from the UE is in response to a detection of a PDCCH order by the UE that triggers a non-contention based random access procedure and depending the DL RS that the DM-RS of the PDCCH order is quasi-collocated with as described in Subclause 10.1, *referenceSignalPower* is provided by *ss-PBCH-BlockPower* or, when the UE is configured resources for a periodic CSI-RS reception, *referenceSignalPower* is obtained by higher layer parameters *ss-PBCH-BlockPower* and *powerControlOffsetSS* where *powerControlOffsetSS* provides an offset of CSI-RS transmission power relative to SS/PBCH block transmission power [6, TS 38.214]. If *powerControlOffsetSS* is not provided to the UE, the UE assumes an offset of 0 dB.

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 determines a transmission power for a subsequent PRACH transmission, if any, as described in [11, TS 38.321].

If prior to a PRACH retransmission, a UE changes the spatial domain transmission filter, Layer 1 notifies higher layers to suspend the power ramping counter as described in [11, TS 38.321].

## 7.5 Prioritizations for transmission power reductions

For single cell operation with two uplink carriers or for operation with carrier aggregation, if a total UE transmit power for a PUSCH or PUCCH or PRACH or SRS transmission in a respective transmission occasion  would exceed , where  is the linear value of  in transmission occasion  as defined in [8-1, TS 38.101-1] and [8-2, TS38.101-2], 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 to  in every symbol of transmission occasion . When determining a total transmit power in a symbol of transmission occasion , the UE does not include power for transmissions starting after the symbol of transmission occasion . The total UE transmit power is defined as the sum of the linear values of UE transmit powers for PUSCH, PUCCH, PRACH, and SRS.

- PRACH transmission on the PCell

- PUCCH transmission with HARQ-ACK information and/or SR or PUSCH transmission with HARQ-ACK information

- PUCCH transmission with CSI or PUSCH transmission with CSI

- PUSCH transmission without HARQ-ACK information or CSI

- SRS transmission, with aperiodic SRS having higher priority than semi-persistent and/or periodic SRS, or PRACH transmission on a serving cell other than the PCell

In case of same priority order and for operation with carrier aggregation, the UE prioritizes power allocation for transmissions on the primary cell of the MCG or the SCG over transmissions on a secondary cell and prioritizes power allocation for transmissions on the PCell over transmissions on the PSCell. In case of same priority order and for operation with two uplink carriers, the UE prioritizes power allocation for transmissions on the carrier where the UE is configured to transmit PUCCH.

## 7.6 Dual connectivity

### 7.6.1 EN-DC

If a UE is configured with a MCG using E-UTRA radio access and with a SCG using NR radio access, the UE is configured a maximum power  for transmissions on the MCG by higher layer parameter *p-MaxEUTRA* and a maximum power  for transmissions on the SCG by higher layer parameter *p-NR*. The UE determines a transmission power for the MCG as described in [13, TS 36.213] using  as the maximum transmission power. The UE determines transmission power for the SCG as described Subclauses 7.1 through 7.5 using  as the maximum transmission power for .

If a UE is configured with , where  is the linear value of ,  is the linear value of , and  is the linear value of a configured maximum transmission power for EN-DC operation as defined in [8-3, TS 38.101-3] for frequency range 1, the UE determines a transmission power on the SCG as follows.

- If the UE is configured with reference TDD configuration for EUTRA (by higher layer parameter *tdm-PatternConfig-r15* in [13, TS 36.213])

- If the UE does not indicate a capability for dynamic power sharing between EUTRA and NR, the UE is not expected to transmit in a slot on the SCG when a corresponding subframe on the MCG is an UL subframe in the reference TDD configuration.

- If the UE indicates a capability for dynamic power sharing between EUTRA and NR and

- if the UE is not configured for operation with shortened TTI and processing time on the MCG [13, TS 36.213], and

- if the UE transmission(s) in subframe  of the MCG overlap in time with UE transmission(s) in slot  of the SCG, and

- if  in any portion of slot  of the SCG,

the UE reduces transmission power in any portion of slot  of the SCG so that  in any portion of slot , where  and  are the linear values of the total UE transmission powers in subframe  of the MCG and in slot  of the SCG, respectively.

- If the UE does not indicate a capability for dynamic power sharing between EUTRA and NR, the UE is expected to be configured with reference TDD configuration for EUTRA (by higher layer parameter *tdm-PatternConfig-r15* in [13, TS 36.213]).

## 7.7 Power headroom report

The types of UE power headroom reports are the following. A Type 1 UE power headroom  that is valid for PUSCH transmission occasion  on UL BWP  of carrier  of serving cell . A Type 3 UE power headroom that is valid for SRS transmission occasion  on UL BWP  of carrier  of serving cell .

A UE determines whether a power headroom report for an activated serving cell [11, TS38.321] is based on an actual transmission or a reference format by considering the downlink control information the UE received until and including the PDCCH monitoring occasion where the UE detects the first DCI format 0\_0 or DCI format 0\_1 scheduling an initial transmission of a transport block, as determined by the new data indicator field in DCI format 0\_0 or DCI format 0\_1, since a power headroom report was triggered.

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 Type 1 PH Report

If a UE determines that a Type 1 power headroom report for an activated serving cell is based on an actual PUSCH transmission then, for PUSCH transmission occasion  on active UL BWP  of carrier  of serving cell , the UE computes the Type 1 power headroom report as

 [dB]

where , , , , ,  and  are defined in Subclause 7.1.1.

If a UE is configured with multiple cells for PUSCH transmissions, where a subcarrier spacing configuration  on active UL BWP  of carrier  of serving cell  is smaller than a subcarrier spacing configuration  on active UL BWP  of carrier  of serving cell , and if the UE provides a Type 1 power headroom report in a PUSCH transmission in a slot on UL BWP  that overlaps with multiple slots on UL BWP , the UE provides a Type 1 power headroom report for the first slot of the multiple slots on UL BWP  that fully overlaps with the slot on UL BWP .

If a UE is configured with multiple cells for PUSCH transmissions, the UE does not consider for computation of a Type 1 power headroom report in a first PUSCH transmission that includes an initial transmission of transport block on active UL BWP  of carrier  of serving cell , a second PUSCH transmission on active UL BWP  of carrier  of serving cell  that overlaps with the first PUSCH transmission if

- the second PUSCH transmission is in response to detection of a DCI format 0\_0 or a DCI format 0\_1 in a PDCCH received in a second PDCCH monitoring occasion, and

- the second PDCCH monitoring occasion is after a first PDCCH monitoring occasion where the UE detects a first DCI format 0\_0 or DCI format 0\_1 scheduling the first PUSCH transmission

If the UE determines that a Type 1 power headroom report for an activated serving cell is based on a reference PUSCH transmission then, for PUSCH transmission occasion  on UL BWP  of carrier  of serving cell , the UE computes the Type 1 power headroom report as

 [dB]

where  is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB. TC =0dB. MPR, A-MPR, P-MPR and TC are defined in [8-1, TS 38.101-1] and [8-2, TS38.101-2]. The remaining parameters are defined in Subclause 7.1.1where  and  are provided from *p0-PUSCH-AlphaSetId* *= 0* for the UL BWP  of carrier  of serving cell ,  is obtained using *PathlossReferenceRS-Id = 0*, and .

If a UE is configured with two UL carriers for a serving cell and the UE determines a Type 1 power headroom report for the serving cell based on a reference PUSCH transmission, the UE computes a Type 1 power headroom report for the serving cell assuming a reference PUSCH transmission on the UL carrier provided by higher layer parameter *pusch-Config*. If the UE is provided higher layer parameter *pusch-Config* for both UL carriers, the UE computes a Type 1 power headroom report for the serving cell assuming a reference PUSCH transmission on the UL carrier provided by higher layer parameter *pucch-Config*. If *pucch-Config* is not configured, the UE computes a Type 1 power headroom report for the serving cell assuming a reference PUSCH transmission on the non-supplementary UL carrier.

### 7.7.2 Type 2 PH report

This subclause is reserved.

### 7.7.3 Type 3 PH Report

If a UE determines that a Type 3 power headroom report for an activated serving cell is based on an actual SRS transmission then, for SRS transmission occasion  on active UL BWP  of carrier  of serving cell  and if the UE is not configured for PUSCH transmissions on carrier  of serving cell , the UE computes a Type 3 power headroom report as

 [dB]

where , , , ,  and  are defined in Subclause 7.3.1.

If the UE determines that a Type 3 power headroom report for an activated serving cell is based on a reference SRS transmission then, for SRS transmission occasion  on UL BWP  of carrier  of serving cell , and if the UE is not configured for PUSCH transmissions on UL BWP  of carrier  of serving cell , the UE computes a Type 3 power headroom report as

 [dB]

where  is a SRS resource set corresponding to *SRS-ResourceSetId = 0* and ,,  and  are defined in Subclause 7.3.1 with corresponding values obtained from *SRS-ResourceSetId = 0*.  is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and TC =0dB. MPR, A-MPR, P-MPR and TC are defined in [8-1, TS 38.101-1] and [8-2, TS38.101-2]..

# 8 Random access procedure

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

Prior to initiation of the physical random access procedure, Layer 1 receives 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 (), 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) message with a PDCCH/PDSCH (Msg2), and when applicable, the transmission of Msg3 PUSCH, and PDSCH for contention resolution.

If 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.

## 8.1 Random access preamble

Physical random access procedure is triggered upon request of a PRACH transmission by higher layers or by a PDCCH order. 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, , a corresponding RA-RNTI, and a PRACH resource.

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

A UE is provided a number  of SS/PBCH blocks associated with one PRACH occasion and a number  of contention based preambles per SS/PBCH block by higher layer parameter *ssb-perRACH-OccasionAndCB-PreamblesPerSSB*. If , one SS/PBCH block is mapped to  consecutive PRACH occasions. If ,  contention based preambles with consecutive indexes associated with SS/PBCH block , , per PRACH occasion start from preamble index . SS/PBCH block indexes are mapped to PRACH occasions in the following order where the parameters are described in [4, TS 38.211].

- First, in increasing order of preamble indexes within a single PRACH occasion.

- Second, in increasing order of frequency resource indexes for frequency multiplexed PRACH occasions.

- Third, in increasing order of time resource indexes for time multiplexed PRACH occasions within a PRACH slot.

- Fourth, in increasing order of indexes for PRACH slots.

An association period, starting from frame 0, for mapping SS/PBCH blocks to PRACH occasions is the smallest value in the set determined by the PRACH configuration period according Table 8.1-1 such that  SS/PBCH blocks are mapped at least once to the PRACH occasions within the association period, where a UE obtains  from the value of higher layer parameter *ssb-PositionsInBurst* in *SystemInformationBlockType1* and/or in *ServingCellConfigCommon*. If after an integer number of SS/PBCH blocks to PRACH occasions mapping cycles within the association period there is a set of PRACH occasions that are not mapped to SS/PBCH blocks, no SS/PBCH blocks are mapped to the set of PRACH occasions. An association pattern period consists of one or more association periods and is determined so that a pattern between PRACH occasions and SS/PBCH blocks repeats at most every 160 msec. PRACH occasions not associated with SS/PBCH blocks after an integer number of association periods, if any, are not used for PRACH transmissions.

For a PRACH transmission triggered by a PDCCH order, the PRACH mask index field [5, TS 38.212], if the value of the Random Access Preamble index field is not zero, indicates the PRACH occasion for the PRACH transmission where the PRACH occasions are associated with the SS/PBCH index provided by the SS/PBCH index field of the PDCCH order. For the indicated preamble index, the ordering of the PRACH occasions is

- First, in increasing order of frequency resource indexes for frequency multiplexed PRACH occasions

- Second, in increasing order of time resource indexes for time multiplexed PRACH occasions within a PRACH slot

- Third, in increasing order of indexes for PRACH slots

Table 8.1-1: Mapping between PRACH configuration period and SS/PBCH block to PRACH occasion association period

|  |  |
| --- | --- |
| PRACH configuration period (msec) | Association period (number of PRACH configuration periods) |
| 10 | {1, 2, 4, 8, 16} |
| 20 | {1, 2, 4, 8} |
| 40 | {1, 2, 4} |
| 80 | {1, 2} |
| 160 | {1} |

If a UE is provided higher layer parameter *tdd-UL-DL-ConfigurationCommon*, or is also provided higher layer parameter *tdd-UL-DL-ConfigurationCommon2*, a PRACH occasion in a PRACH slot is valid if

- it is within UL symbols, or

- it does not precede a SS/PBCH block in the PRACH slot and starts at least symbols after a last downlink symbol and at least symbols after a last SS/PBCH block transmission symbol, where  is provided in Table 8.2-2.

For preamble format B4 [4, TS 38.211], .

Table 8.1-2:  values for different preamble subcarrier spacing configurations 

|  |  |
| --- | --- |
| Preamble subcarrier spacing |  |
| 1.25 kHz or 5 kHz | 0 |
| 15 kHz or 30 kHz or 60 kHz or 120 kHz | 2 |

If a random access procedure is initiated by a PDCCH order, the UE, if requested by higher layers, transmits a PRACH in the first available PRACH occasion for which a time between the last symbol of the PDCCH order reception and the first symbol of the PRACH transmission is larger than or equal to  msec, where  is a time duration of  symbols corresponding to a PUSCH preparation time for PUSCH processing capability 1 [6, TS 38.214],  if the active UL BWP does not change and  is defined in [10, TS 38.133] otherwise, and  msec for FR1 and  msec for FR2. For a PRACH transmission using 1.25 kHz or 5 kHz subcarrier spacing, the UE determines  assuming subcarrier spacing configuration .

For single cell operation or for operation with carrier aggregation in a same frequency band, a UE does not transmit PRACH and PUSCH/PUCCH/SRS in a same slot or when a gap between the first/last symbol of a PRACH transmission in a first slot is separated by less than  symbols from the last/first symbol of a PUSCH/PUCCH/SRS transmission in a second slot where  for  or ,  for  or , and  is the subcarrier spacing configuration for the active UL BWP..

## 8.2 Random access response

In response to a PRACH transmission, a UE attempts to detect a DCI format 1\_0 with a CRC scrambled by 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 at least  symbols after the last symbol of the preamble sequence transmission, where  is defined in [10, TS 38.133] and  is the subcarrier spacing configuration for Type1-PDCCH common search space. The length of the window in number of slots, based on the subcarrier spacing for Type1-PDCCH common search space as defined in Subclause 10.1, is provided by higher layer parameter *ra-ResponseWindow*.

If a UE detects the DCI format 1\_0 with the CRC scrambled by the corresponding RA-RNTI and a corresponding PDSCH that includes a 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. If the higher layers identify the RAPID in RAR message(s) of the DL-SCH transport block, the higher layers indicate an uplink grant to the physical layer. This is referred to as random access response (RAR) UL grant in the physical layer.

If the UE does not detect the DCI format 1\_0 with the CRC scrambled by the corresponding RA-RNTI within the window, or if the UE does not correctly receive the DL-SCH transport block in the PDSCH within the window, or if the higher layers do not identify the RAPID associated with the PRACH transmission, the higher layers can indicate to the physical layer to transmit a PRACH. If requested by higher layers, the UE shall be ready to transmit a PRACH no later than  msec after the last symbol of the window, or the last symbol of the PDSCH reception, where  is a time duration of  symbols corresponding to a PDSCH reception time for PDSCH processing capability 1 when additional PDSCH DM-RS is configured.

If a UE detects a DCI format 1\_0 with the CRC scrambled by the corresponding RA-RNTI and receives the corresponding PDSCH that includes the DL-SCH transport block, the UE may assume same DM-RS antenna port quasi co-location properties, as described in [6, 38.214], as for a SS/PBCH block or a CSI-RS resource the UE used for PRACH association as described in Subclause 8.1. If the UE attempts to detect the DCI format 1\_0 with CRC scrambled by the corresponding RA-RNTI in response to a PRACH transmission initiated by a PDCCH order that triggers non-contention based random access procedure, the UE may assume that the PDCCH and the PDCCH order have same DM-RS antenna port quasi co-location properties.

A RAR UL grant schedules a PUSCH transmission from the UE (Msg3 PUSCH). The contents of the RAR UL grant, starting with the MSB and ending with the LSB, are given in Table 8.2-1.

If the value of the frequency hopping flag is 0, the UE transmits Msg3 PUSCH without frequency hopping; otherwise, the UE transmits Msg3 PUSCH with frequency hopping.

The Msg3 PUSCH frequency resource allocation is for uplink resource allocation type 1 [6, 38.214]. In case of Msg3 PUSCH transmission with frequency hopping, the first one or two bits,  bits, of the Msg3 PUSCH frequency resource allocation field are used as hopping information bits as described in Table 8.3-1.

If higher layer parameter *pusch-AllocationList* is provided by *pusch-ConfigCommon*, a value of the Msg3 PUSCH time resource allocation field indicates an entry to a table provided by *pusch-AllocationList*; otherwise a value of the Msg3 PUSCH time resource allocation field indicates an entry to default time resource allocation table [6, 38.214].

The MCS is determined from the first sixteen indices of the applicable MCS index table for PUSCH as described in [6, 38.214].

The TPC command  is used for setting the power of the Msg3 PUSCH, as described in Subclause 7.1.1, and is interpreted according to Table 8.2-2.

In non-contention based random access procedure, the CSI request field is interpreted to determine whether an aperiodic CSI report is included in the corresponding PUSCH transmission according to [6, TS 38.214]. In contention based random access procedure, the CSI request field is reserved.

Table 8.2-1: Random Access Response Grant Content field size

|  |  |
| --- | --- |
| RAR grant field | Number of bits |
| Frequency hopping flag | 1 |
| Msg3 PUSCH frequency resource allocation | 14 |
| Msg3 PUSCH time resource allocation | 4 |
| MCS | 4 |
| TPC command for Msg3 PUSCH | 3 |
| CSI request | 1 |
|  |  |

Table 8.2-2: TPC Command  for Msg3 PUSCH

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

Unless a UE is configured a subcarrier spacing, the UE receives subsequent PDSCH using same subcarrier spacing as for the PDSCH reception providing the RAR message.

If a UE does not detect the DCI format with CRC scrambled by a corresponding RA-RNTI or does not correctly receive 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-transformPrecoding* 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.

If the UE applies transform precoding to an Msg3 PUSCH transmission with frequency hopping, the frequency offset for the second hop [6, TS38.214] is given in Table 8.3-1.

Table 8.3-1: Frequency offset for second hop for Msg3 PUSCH transmission with frequency hopping

|  |  |  |
| --- | --- | --- |
| Number of PRBs in initial active UL BWP | Value of  Hopping Bits | Frequency offset for 2nd hop |
|  | 0 |  |
| 1 |  |
|  | 00 |  |
| 01 |  |
| 10 |  |
| 11 | Reserved |

The subcarrier spacing for Msg3 PUSCH transmission is provided by higher layer parameter *SubcarrierSpacing* in *BWP-UplinkCommon*. A UE transmits PRACH and Msg3 PUSCH on a same uplink carrier of the same serving cell.

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

A UE transmits an UL-SCH in an Msg3 PUSCH scheduled by a RAR grant in a corresponding RAR message using redundancy version number 0. Retransmissions, if any, of the UL-SCH in an Msg3 PUSCH are scheduled by a DCI format 0\_0 with CRC scrambled by a TC-RNTI provided in the corresponding RAR message [11, TS 38.321].

If in slot  a UE receives a PDSCH with a RAR message for a corresponding preamble transmission from the UE, the UE transmits a Msg3 PUSCH in slot , where  is provided in [6, TS 38.214]. The UE may assume a minimum time between the last symbol of a PDSCH reception conveying a RAR and the first symbol of a corresponding Msg3 PUSCH transmission scheduled by the RAR in the PDSCH for a UE is equal to  msec.  is a time duration of  symbols corresponding to a PDSCH reception time for PDSCH processing capability 1 when additional PDSCH DM-RS is configured and,  is a time duration of  symbols corresponding to a PUSCH preparation time for PUSCH processing capability 1 [6, TS 38.214].

## 8.4 PDSCH with UE contention resolution identity

In response to an Msg3 PUSCH transmission when a UE has not been provided with a C-RNTI, the UE attempts to detect a DCI format 1\_0 with CRC scrambled by a corresponding TC-RNTI scheduling a PDSCH that includes a UE contention resolution identity [11, TS 38.321]. In response to the PDSCH reception with the UE contention resolution identity, the UE transmits HARQ-ACK information in a PUCCH. The PUCCH transmission is within a same initial active UL BWP as the Msg3 PUSCH transmission. A minimum time between the last symbol of the PDSCH reception and the first symbol of the corresponding HARQ-ACK information transmission is equal to  msec.  is a time duration of  symbols corresponding to a PDSCH reception time for PDSCH processing capability 1 when additional PDSCH DM-RS is configured.

# 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 multiplex UCI in a PUCCH transmission that overlaps with a PUSCH transmission, and the PUSCH and PUCCH transmissions fulfill the conditions in Subclause 9.2.5 for UCI multiplexing, the UE multiplexes the UCI in the PUSCH transmission and does not transmit the PUCCH.

If a UE multiplexes aperiodic CSI in a PUSCH and the UE would multiplex UCI in a PUCCH that overlaps with the PUSCH, the UE multiplexes the UCI in the PUSCH.

If a UE transmits multiple PUSCHs in a slot on respective serving cells that include first PUSCHs that are in response to detection by the UE of DCI format(s) 0\_0 or DCI format(s) 0\_1 and second PUSCHs configured by respective higher layer parameters *ConfiguredGrantConfig*, and the UE would multiplex UCI in one of the multiple PUSCHs, and the multiple PUSCHs fulfil the conditions in Subclause 9.2.5 for UCI multiplexing, the UE multiplexes the UCI in a PUSCH from the first PUSCHs.

If a UE transmits multiple PUSCHs in a slot in response to detection by the UE of DCI format(s) 0\_0 or DCI format(s) 0\_1 on respective serving cells and the UE would multiplex UCI in one of the multiple PUSCHs and the UE does not multiplex aperiodic CSI in any of the multiple PUSCHs, the UE multiplexes the UCI in a PUSCH of the serving cell with the smallest *ServCellIndex* subject to the conditions in Subclause 9.2.5 for UCI multiplexing being fulfilled. If the UE transmits more than one PUSCHs in the slot on the serving cell with the smallest *ServCellIndex* that fulfil the conditions in Subclause 9.2.5 for UCI multiplexing, the UE multiplexes the UCI in the PUSCH that the UE transmits first in the slot.

A HARQ-ACK information bit value of 0 represents a negative acknowledgement (NACK) while a HARQ-ACK information bit value of 1 represents a positive acknowledgement (ACK).

## 9.1 HARQ-ACK codebook determination

If a UE receives a PDSCH without receiving a corresponding PDCCH, or if the UE receives a PDCCH indicating a SPS PDSCH release, the UE generates one corresponding HARQ-ACK information bit.

If a UE is not provided higher layer parameter *PDSCH-CodeBlockGroupTransmission*, the UE generates one HARQ-ACK information bit per transport block.

A UE is not expected to be indicated to transmit HARQ-ACK information for more than two SPS PDSCH receptions in a same PUCCH.

In the following, the CRC for DCI format 1\_0 is scrambled with a C-RNTI or a CS-RNTI and the CRC for DCI format 1\_1 is scrambled with a C-RNTI.

### 9.1.1 CBG-based HARQ-ACK codebook determination

If a UE is provided higher layer parameter *PDSCH-CodeBlockGroupTransmission* for a serving cell, the UE receives PDSCHs that include code block groups (CBGs) of a transport block and the UE is provided higher layer parameter *maxCodeBlockGroupsPerTransportBlock* indicating a maximum number  of CBGs for generating respective HARQ-ACK information bits for a transport block reception for the serving cell.

For a number of  code blocks (CBs) in a transport block, the UE determines a number of CBGs as . Each of the first  CBGs includes  CBs, where CBG , includes CBs , and each of the last  CBGs includes  CBs, where CBG , includes CBs . The UE generates  HARQ-ACK information bits through a one-to-one mapping with the  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. The UE generates an ACK for the HARQ-ACK information bit of a CBG if the UE correctly received all code blocks of the CBG and generates a NACK for the HARQ-ACK information bit of a CBG if the UE incorrectly received at least one code block of the CBG.

The HARQ-ACK codebook includes the  HARQ-ACK information bits and, if  for a transport block, the UE generates a NACK value for the last  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  CBGs and does not correctly detect the transport block for the  CBGs, the UE generates a NACK value for each of the  CBGs.

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

If a UE receives a PDSCH that is scheduled by a PDCCH with DCI format 1\_0, or a SPS PDSCH, or the UE detects a SPS PDSCH release, and if the UE is configured with higher layer parameter *pdsch-HARQ-ACK-Codebook = semi-static*, the UE repeats  times the HARQ-ACK information for the transport block in the PDSCH or for the SPS PDSCH release, respectively, for generating  HARQ-ACK information bits as described in Subclause 9.1.2.

### 9.1.2 Type-1 HARQ-ACK codebook determination

This subclause applies if the UE is configured with *pdsch-HARQ-ACK-Codebook = semi-static*.

A UE reports HARQ-ACK information for a corresponding PDSCH reception or SPS PDSCH release only in a HARQ-ACK codebook that the UE transmits in a slot indicated by a value of a PDSCH-to-HARQ\_feedback timing indicator field in a corresponding DCI format 1\_0 or DCI format 1\_1. The UE reports NACK value(s) for HARQ-ACK information bit(s) in a HARQ-ACK codebook that the UE transmits in a slot not indicated by a value of a PDSCH-to-HARQ\_feedback timing indicator field in a corresponding DCI format 1\_0 or DCI format 1\_1.

If the UE is provided higher layer parameter *pdsch-AggregationFactor*,  is a value of *pdsch-AggregationFactor*; otherwise, . The UE reports HARQ-ACK information only for a last slot of the  slots.

If a UE reports HARQ-ACK information in a PUSCH or a PUCCH only for a SPS PDSCH release or only for a PDSCH reception within the occasions for candidate PDSCH receptions, as determined in Subclause 9.1.2.1, that is scheduled by DCI format 1\_0 with a counter downlink assignment indicator (DAI) field value of 1 on the PCell, the UE determines a HARQ-ACK codebook only for the SPS PDSCH release or only the PDSCH reception; otherwise, the following procedures for a HARQ-ACK codebook determination apply.

#### 9.1.2.1 Type-1 HARQ-ACK codebook in physical uplink control channel

For a serving cell  and the active DL BWP and the active UL BWP, as described in Subclause 12, the UE determines a set of  occasions for candidate PDSCH receptions for which the UE can transmit corresponding HARQ-ACK information in a PUCCH in slot . The determination is based:

a) on a set of slot timing values  associated with the active UL BWP

a) If the UE is configured to monitor PDCCH for DCI format 1\_0 and is not configured to monitor PDCCH for DCI format 1\_1 on serving cell ,  is provided by the slot timing values {1, 2, 3, 4, 5, 6, 7, 8} for DCI format 1\_0;

b) If the UE is configured to monitor PDCCH for DCI format 1\_1 on serving cell ,  is provided by higher layer parameter *dl-DataToUL-ACK* for DCI format 1\_1.

b) when provided, on a set of row indexes of a table provided by higher layer parameter *PDSCH-TimeDomainResourceAllocation* associated with the active DL BWP and defining respective sets of slot offsets , start and length indicators *SLIV*, and PDSCH mapping types for PDSCH reception as described in [6, TS 38.214]; and

c) when provided, on higher layer parameter *tdd-UL-DL-ConfigurationCommon*, higher layer parameter *tdd-UL-DL- ConfigurationCommon2*, and higher layer parameter *tdd-UL-DL-ConfigDedicated* as described in Subclause 11.1.

For the set of slot timing values, the UE determines  occasions for candidate PDSCH receptions or SPS PDSCH releases according to the following pseudo-code.

Set  - index of occasion for candidate PDSCH reception or SPS PDSCH release

Set 

Set 

Set  to the cardinality of set 

Set *k* =0 – index of slot timing values  in set  for serving cell 

while 

Set  to the set of rows provided by *PDSCH-TimeDomainResourceAllocation*

Set  to the cardinality of ,

Set  – index of row provided by *PDSCH-TimeDomainResourceAllocation*

if slot  is after a slot for an active DL BWP change on serving cell  or an active UL BWP change on the PCell and slot  is before the slot for the active DL BWP change on serving cell  or the active UL BWP change on the PCell

;

else

while 

if the UE is provided higher layer parameter *tdd-UL-DL-ConfigurationCommon*, or higher layer parameter *tdd-UL-DL- ConfigurationCommon2*, or higher layer parameter *tdd-UL-DL-ConfigDedicated* and, for each slot from slot to slot , at least one OFDM symbol of the PDSCH time resource derived by row  is configured as ULwhere  is the *k*-th slot timing value in set ,

;

end if

;

end while

If the UE does not indicate a capability to receive more than one unicast PDSCH per slot and,



The UE does not expect to receive SPS PDSCH release and unicast PDSCH in a same slot;

else

Set  to the cardinality of 

Set  to the smallest last OFDM symbol index, as determined by the *SLIV*, among all rows of 

while 

Set 

while 

if  for start OFDM symbol index  for row 

; - index of occasion for candidate PDSCH reception or SPS PDSCH release associated with row 

;



end if

;

end while



;

Set  to the smallest last OFDM symbol index among all rows of ;

end while

end if

;

end if

end while

For rows of *PDSCH-TimeDomainResourceAllocation* associated with a same value of , where , the UE is not expected to receive more than one PDSCH in a same slot.

If a UE is provided higher layer parameter *dl-DataToUL-ACK*, the UE does not expect to be indicated by DCI format 1\_0 a slot timing value for transmission of HARQ-ACK information that does not belong to the intersection of the set of slot timing values {1, 2, 3, 4, 5, 6, 7, 8} and the set of slot timing values provided by higher layer parameter *dl-DataToUL-ACK* for the active DL BWP of a corresponding serving cell.

If an occasion for a candidate PDSCH reception can be in response to a PDCCH with DCI format 1\_1 and if higher layer parameter *maxNrofCodeWordsScheduledByDCI* indicates reception of two transport blocks, when the UE receives a PDSCH with one transport block, the HARQ-ACK information is associated with the first transport block and the UE generates a NACK for the second transport block if higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is not provided and generates HARQ-ACK information with value of ACK for the second transport block if higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is provided.

A UE determines  HARQ-ACK information bits, for a total number of  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. The cardinality of the set  defines a total number  of occasions for PDSCH reception or SPS PDSCH release for serving cell .

Set  – serving cell index: lower indices correspond to lower RRC indices of corresponding cell

Set - HARQ-ACK information bit index

Set  to the number of serving cells configured by higher layers for the UE

while 

Set  – index of occasion for candidate PDSCH reception or SPS PDSCH release

while 

if higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is not provided, higher layer parameter *PDSCH-CodeBlockGroupTransmission* is not provided, and the UE is configured by higher layer parameter *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for the active DL BWP of serving cell ,

 = HARQ-ACK information bit corresponding to a first transport block of this cell;

;

 = HARQ-ACK information bit corresponding to a second transport block of this cell;

;

elseif higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is provided, and the UE is configured by higher layer parameter *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for the active DL BWP of serving cell ,

 = binary AND operation of the HARQ-ACK information 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;

;

elseif higher layer parameter *PDSCH-CodeBlockGroupTransmission* is provided, and  CBGs are indicated by higher layer parameter *maxCodeBlockGroupsPerTransportBlock* for serving cell ,

Set - CBG index

while 

 = HARQ-ACK information bit corresponding to CBG  of the first transport block;

if the UE is configured by higher layer parameter *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for the active DL BWP of serving cell 

 = HARQ-ACK information bit corresponding to CBG  of the second transport block;

end if

;

end while

, where  is the value of higher layer parameter *maxNrofCodeWordsScheduledByDCI* for the active DL BWP of serving cell ;

else

 = HARQ-ACK information bit of this cell

;

end if

;

end while

;

end while

If , the UE determines a number of HARQ-ACK information bits  for obtaining a transmission power for a PUCCH, as described in Subclause 7.2.1, as  where

-  is the number of transport blocks the UE receives in PDSCH reception occasion  for serving cell  if higher layer parameters *harq-ACK-SpatialBundlingPUCCH* and *PDSCH-CodeBlockGroupTransmission* are not provided, or the number of transport blocks the UE receives in PDSCH reception occasion  for serving cell  if higher layer parameter *PDSCH-CodeBlockGroupTransmission* is provided and the PDSCH reception is in response to a DCI format 1\_0 detection, or the number of PDSCH receptions if higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is provided or SPS PDSCH release in PDSCH reception occasion  for serving cell  and the UE reports corresponding HARQ-ACK information in the PUCCH.

-  is the number of CBGs the UE receives in a PDSCH reception occasion  for serving cell  if higher layer parameter *PDSCH-CodeBlockGroupTransmission* is provided and the PDSCH reception is in response to a DCI format 1\_1 detection and the UE reports corresponding HARQ-ACK information in the PUCCH.

#### 9.1.2.2 Type-1 HARQ-ACK codebook in physical uplink shared channel

If a UE multiplexes HARQ-ACK information in a PUSCH transmission that is not scheduled by a DCI format or is scheduled by DCI format 0\_0, then

- if the UE has not received any PDSCH or SPS PDSCH release that the UE transmits corresponding HARQ-ACK information in the PUSCH, based on a value of a respective PDSCH-to-HARQ feedback timing field in a DCI format scheduling the PDSCH reception or the SPS PDSCH release, in any of the  occasions for PDSCH reception by DCI format 1\_0 or DCI format 1\_1 or SPS PDSCH on any serving cell , as described in Subclause 9.1.2.1, the UE does not multiplex HARQ-ACK information in the PUSCH transmission;

- else the UE generates the HARQ-ACK codebook as described in Subclause 9.1.2.1 except that *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*.

A UE sets to NACK value in the HARQ-ACK codebook any HARQ-ACK information corresponding to PDSCH reception or SPS PDSCH release scheduled by DCI format 1\_0 or DCI format 1\_1 that the UE detects in a PDCCH monitoring occasion that is after a PDCCH monitoring occasion where the UE detects a DCI format 0\_0 or a DCI format 0\_1 scheduling the PUSCH transmission.

If a UE multiplexes HARQ-ACK information in a PUSCH transmission that is scheduled by DCI format 0\_1, the UE generates the HARQ-ACK codebook as described in Subclause 9.1.2.1 when a value of the DAI field in DCI format 0\_1 is  except that *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*. The UE does not generate a HARQ-ACK codebook for multiplexing in the PUSCH transmission when .

### 9.1.3 Type-2 HARQ-ACK codebook determination

This subclause applies if the UE is configured with *pdsch-HARQ-ACK-Codebook = dynamic*.

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

A UE determines monitoring occasions for PDCCH with DCI format 1\_0 or DCI format 1\_1 for scheduling PDSCH receptions or SPS PDSCH release on an active DL BWP of a serving cell  and for which the UE transmits HARQ-ACK information in a same PUCCH in slot  based on

- maximum and minimum PDSCH-to-HARQ\_feedback timing values provided by union of the set of slot timing values {1, 2, 3, 4, 5, 6, 7, 8} for DCI format 1\_0 and the set of slot timing values provided by higher layer parameter *dl-DataToUL-ACK* for DCI format 1\_1

- a set of slot offsets  [6, TS 38.214] determined by higher layer parameter *PDSCH-TimeDomainResourceAllocation*, when provided, and by higher layer parameter *pdsch-AggregationFactor*, when provided.

The set of PDCCH monitoring occasions is defined as the union of PDCCH monitoring occasions across active DL BWPs of configured serving cells, ordered in ascending order of start time of the search space set associated with a PDCCH monitoring occasion. The cardinality of the set of PDCCH monitoring occasions defines a total number  of PDCCH monitoring occasions.

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 , where .

The value of the total DAI, when present [5, TS 38.212], in DCI format 1\_1 denotes the total number of {serving cell, PDCCH monitoring occasion}-pair(s) in which PDSCH reception(s) or SPS PDSCH release associated with DCI format 1\_0 or DCI format 1\_1 is present, up to the current PDCCH monitoring occasion and is updated from PDCCH monitoring occasion to PDCCH monitoring occasion.

Denote  as the value of the counter DAI in DCI format 1\_0 or DCI format 1\_1 for scheduling on serving cell  in PDCCH monitoring occasion  according to Table 9.1.3-1. Denote as the value of the total DAI in DCI format 1\_1 in PDCCH monitoring occasion  according to Table 9.1.3-1. The UE assumes a same value of total DAI in all DCI formats 1\_1 in PDCCH monitoring occasion .

If the UE transmits HARQ-ACK information in a PUCCH in slot  and for any PUCCH format, the UE determines the , for a total number of  HARQ-ACK information bits, according to the following pseudo-code:

Set  – serving cell index: lower indices correspond to lower RRC indices of corresponding cell

Set  – 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 

Set 

Set 

Set 

Set  to the number of serving cells configured by higher layers for the UE

Set  to the number of PDCCH monitoring occasion(s)

while 

while 

if PDCCH monitoring occasion  is before an active DL BWP change on serving cell  or an active UL BWP change on the PCell and an active DL BWP change is not triggered by a DCI format 1\_1 in PDCCH monitoring occasion 

;

else

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

if 



end if



if 



else



end if

if the higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is not provided and  is a monitoring occasion for PDCCH with DCI format 1\_0 or DCI format 1\_1 and the UE is configured by higher layer parameter *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for at least one configured DL BWP of at least one serving cell,

 = HARQ-ACK information bit corresponding to the first transport block of this cell

 = HARQ-ACK information bit corresponding to the second transport block of this cell



elseif the higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is provided and  is a monitoring occasion for PDCCH with DCI format 1\_1 and the UE is configured by higher layer parameter *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks in at least one configured DL BWP of a serving cell,

 = binary AND operation of the HARQ-ACK information bits corresponding to the first and second transport blocks of this cell



else

 = HARQ-ACK information bit of this cell



end if

end if



end if

end while



end while

if 



end if

if the higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is not provided and the UE is configured by higher layer parameter *maxNrofCodeWordsScheduledByDCI* with reception of two transport blocks for at least one configured DL BWP of a serving cell,



else



end if

 for any 

Set 

while 

if SPS PDSCH transmission is activated for a UE and the UE is configured to receive SPS PDSCH in a slot  for serving cell , where  is the PDSCH-to-HARQ-feedback timing value for SPS PDSCH on serving cell 



= HARQ-ACK information bit associated with the SPS PDSCH reception

end if

;

end while

For a PDCCH monitoring occasion with DCI format 1\_0 or DCI format 1\_1 in the active DL BWP of a serving cell, when a UE receives a PDSCH with one transport block and the value of higher layer parameter *maxNrofCodeWordsScheduledByDCI* is 2, the HARQ-ACK information is associated with the first transport block and the UE generates a NACK for the second transport block if higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is not provided and generates HARQ-ACK information with value of ACK for the second transport block if spatial bundling is applied.

If a UE is not provided higher layer parameter *PDSCH-CodeBlockGroupTransmission* for each of the  serving cells, or for PDSCH receptions scheduled by DCI format 1\_0, or for SPS PDSCH receptions, or for SPS PDSCH release, and if , the UE determines a number of HARQ-ACK information bits  for obtaining a transmission power for a PUCCH, as described in Subclause 7.2.1, as



where

- if ,  is the value of the counter DAI in the last DCI format 1\_0 or DCI format 1\_1 scheduling PDSCH reception or indicating SPS PDSCH release for any serving cell  that the UE detects within the  PDCCH monitoring occasions.

- if 

- if the UE does not detect any DCI format 1\_1 in a last PDCCH monitoring occasion within the  PDCCH monitoring occasions where the UE detects at least one DCI format scheduling PDSCH reception or indicating SPS PDSCH release for any serving cell ,  is the value of the counter DAI in a last DCI format 1\_0 the UE detects in the last PDCCH monitoring occasion

- if the UE detects at least one DCI format 1\_1 in a last PDCCH monitoring occasion within the  PDCCH monitoring occasions where the UE detects at least one DCI format scheduling PDSCH reception or indicating SPS PDSCH release for any serving cell ,  is the value of the total DAI in the least one DCI format 1\_1

-  if the UE does not detect any DCI format 1\_0 or DCI format 1\_1 scheduling PDSCH reception or indicating downlink SPS release for any serving cell  in any of the  PDCCH monitoring occasions.

-  is the total number of DCI format 1\_0 and DCI format 1\_1 scheduling PDSCH receptions or indicating downlink SPS release that the UE detects within the  PDCCH monitoring occasions for serving cell .  if the UE does not detect any DCI format 1\_0 or DCI format 1\_1 scheduling PDSCH reception or indicating downlink SPS release for serving cell  in any of the  PDCCH monitoring occasions.

-  if the value of higher layer parameter *maxNrofCodeWordsScheduledByDCI* is 2 for any serving cell  and higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is not provided; otherwise, .

-  is the number of transport blocks the UE receives in a PDSCH scheduled by DCI format 1\_0 or DCI format 1\_1 that the UE detects in PDCCH monitoring occasion  for serving cell  if higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is not provided, or the number of PDSCH scheduled by DCI format 1\_0 and DCI format 1\_1 that the UE detects in PDCCH monitoring occasion  for serving cell  if higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is provided, or the number of DCI format 1\_0 that the UE detects and indicate SPS PDSCH release in PDCCH monitoring occasion  for serving cell .

-  is the number of SPS PDSCH receptions by the UE on serving cell  for which the UE transmits corresponding HARQ-ACK information in the same PUCCH as for HARQ-ACK information corresponding to PDSCH receptions or SPS PDSCH release scheduled by DCI format 1\_0 within the  PDCCH monitoring occasions.

If a UE transmits HARQ-ACK information and the UE

- is provided higher layer parameter *PDSCH-CodeBlockGroupTransmission* for  serving cells; and

- is not provided higher layer parameter *PDSCH-CodeBlockGroupTransmission*, for  serving cells where 

the UE determines the  according to the previous pseudo-code with the following modifications

-  is used for the determination of a first HARQ-ACK sub-codebook for SPS PDSCH releases, SPS PDSCH receptions, and for TB-based PDSCH receptions scheduled by DCI formats 1\_0 on the  serving cells and by DCI formats 1\_0 and DCI formats 1\_1 on the  serving cells;

-  is replaced by  for the determination of a second HARQ-ACK sub-codebook corresponding to the  serving cells for CBG-based PDSCH receptions scheduled by DCI format 1\_1, and

- Instead of generating one HARQ-ACK information bit per transport block for a serving cell from the  serving cells, the UE generates  HARQ-ACK information bits, where  is the maximum value of  across all  serving cells and  is the value of higher layer parameter *maxNrofCodeWordsScheduledByDCI* for serving cell . If for a serving cell  it is , the UE generates NACK for the last  HARQ-ACK information bits for serving cell ;

- The pseudo-code operation when higher layer parameter *harq-ACK-SpatialBundlingPUCCH* is provided is not applicable;

- The counter DAI value and the total DAI value apply separately for each HARQ-ACK sub-codebook;

- The UE generates the HARQ-ACK codebook by appending the second HARQ-ACK sub-codebook to the first HARQ-ACK sub-codebook.

If , the UE also determines  for obtaining a PUCCH transmission power, as described in Subclause 7.2.1, with



where

- if ,  is the value of the counter DAI in the last DCI format 1\_1 scheduling CBG-based PDSCH reception for any serving cell  that the UE detects within the  PDCCH monitoring occasions.

- if ,  is the value of the total DAI in the last DCI format 1\_1 scheduling CBG-based PDSCH reception for any serving cell  that the UE detects within the  PDCCH monitoring occasions

-  if the UE does not detect any DCI format 1\_1 scheduling CBG-based PDSCH reception for any serving cell  in any of the  PDCCH monitoring occasions.

-  is the total number of DCI format 1\_1 scheduling CBG-based PDSCH receptions that the UE detects within the  PDCCH monitoring occasions for serving cell .  if the UE does not detect any DCI format 1\_1 scheduling CBG-based PDSCH reception for serving cell  in any of the  PDCCH monitoring occasions.

-  is the number of CBGs the UE receives in a PDSCH scheduled by DCI format 1\_1 that the UE detects in PDCCH monitoring occasion  for serving cell  and the UE reports corresponding HARQ-ACK information in the PUCCH.

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

|  |  |  |
| --- | --- | --- |
| DAI MSB, LSB | or | 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  and |
| 0,0 | 1 |  |
| 0,1 | 2 |  |
| 1,0 | 3 |  |
| 1,1 | 4 |  |

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

If a UE multiplexes HARQ-ACK information in a PUSCH transmission that is not scheduled by a DCI format or is scheduled by DCI format 0\_0, then

- if the UE has not received any PDCCH within the monitoring occasions for DCI format 1\_0 or DCI format 1\_1 for scheduling PDSCH receptions or DL SPS PDSCH release on any serving cell  and the UE does not have HARQ-ACK information in response to SPS PDSCH reception(s) to multiplex in the PUSCH, as described in Subclause 9.1.3.1, the UE does not multiplex HARQ-ACK information in the PUSCH transmission;

- else, the UE generates the HARQ-ACK codebook as described in Subclause 9.1.3.1, except that *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*.

If a UE multiplexes HARQ-ACK information in a PUSCH transmission that is scheduled by DCI format 0\_1, the UE generates the HARQ-ACK codebook as described in Subclause 9.1.3.1, with the following modifications:

- For ,  and for ,  is replaced by  where  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-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*.

A UE does not multiplex in a PUSCH transmission HARQ-ACK information that is in response to PDSCH reception or SPS PDSCH release scheduled by DCI format 1\_0 or DCI format 1\_1 that the UE detects in a PDCCH monitoring occasion that is after a PDCCH monitoring occasion where the UE detects a DCI format 0\_0 or a DCI format 0\_1 scheduling the PUSCH transmission.

If a UE is scheduled for a PUSCH transmission by DCI format 0\_1 with  and the UE has not received any PDCCH within the monitoring occasions for PDCCH with DCI format 1\_0 or DCI format 1\_1 for scheduling PDSCH receptions or DL SPS release on any serving cell  and the UE does not have HARQ-ACK information in response to SPS PDSCH reception(s) to multiplex in the PUSCH, as described in Subclause 9.1.3.1, the UE does not multiplex HARQ-ACK information in the PUSCH transmission.

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

|  |  |  |
| --- | --- | --- |
| DAI MSB, LSB |  | 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  and |
| 0,0 | 1 |  |
| 0,1 | 2 |  |
| 1,0 | 3 |  |
| 1,1 | 4 |  |

## 9.2 UCI reporting in physical uplink control channel

UCI types reported in a PUCCH include HARQ-ACK information, SR, and CSI. UCI bits include HARQ-ACK information bits, if any, SR information bit, if any, and CSI bits, if any. The HARQ-ACK information bits correspond to a HARQ-ACK codebook as described in Subclause 9.1.

A UE may transmit one or two PUCCHs on a serving cell in different symbols within a slot of  symbols as defined in [4, TS 38.211]. When the UE transmits two PUCCHs in a slot, at least one of the two PUCCHs uses PUCCH format 0 or PUCCH format 2.

### 9.2.1 PUCCH Resource Sets

If a UE does not have dedicated PUCCH resource configuration, provided by higher layer parameter *PUCCH-ResourceSet* in *PUCCH-Config*, a PUCCH resource set is provided by higher layer parameter *pucch-ResourceCommon* in *SystemInformationBlockType1* through an index to a row of Table 9.2.1-1 for transmission of HARQ-ACK information on PUCCH in an initial active UL BWP of  PRBs provided by *SystemInformationBlockType1*. The PUCCH resource set is provided by higher layer parameter *PUCCH-Resource-Common* and includes sixteen resources, each corresponding to a PUCCH format, a first symbol, a duration, a PRB offset ****, and a cyclic shift index set for a PUCCH transmission. The UE transmits a PUCCH using frequency hopping. The UE transmits the PUCCH using the same spatial domain transmission filter as for the Msg3 PUSCH transmission.

The UE is not expected to generate more than one HARQ-ACK information bit.

If the UE provides HARQ-ACK information in a PUCCH transmission in response to detecting a DCI format 1\_0 or DCI format 1\_1, the UE determines a PUCCH resource with index , , as , where  is a number of CCEs in a control resource set of a PDCCH reception conveying the DCI format 1\_0, as described in Subclause 10.1,  is the index of a first CCE for the PDCCH reception, and  is a value of the PUCCH resource indicator field in the DCI format 1\_0 or DCI format 1\_1.

If 

- the UE determines the PRB index of the PUCCH transmission in the first hop as  and the PRB index of the PUCCH transmission in the second hop as , where  is the total number of cyclic shift indexes in the cyclic shift index set

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as ****

If 

- the UE determines the PRB index of the PUCCH transmission in the first hop as  and the PRB index of the PUCCH transmission in the second hop as 

- the UE determines the initial cyclic shift index in the set of initial cyclic shift indexes as ****

Table 9.2.1-1: PUCCH resource sets before dedicated PUCCH resource configuration

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Index | **PUCCH format** | **First symbol** | **Number of symbols** | **PRB offset** | **Set of initial CS indexes** |
| 0 | 0 | 12 | 2 | 0 | {0, 3} |
| 1 | 0 | 12 | 2 | 0 | {0, 4, 8} |
| 2 | 0 | 12 | 2 | 3 | {0, 4, 8} |
| 3 | 1 | 10 | 4 | 0 | {0, 6} |
| 4 | 1 | 10 | 4 | 0 | {0, 3, 6, 9} |
| 5 | 1 | 10 | 4 | 2 | {0, 3, 6, 9} |
| 6 | 1 | 10 | 4 | 4 | {0, 3, 6, 9} |
| 7 | 1 | 4 | 10 | 0 | {0, 6} |
| 8 | 1 | 4 | 10 | 0 | {0, 3, 6, 9} |
| 9 | 1 | 4 | 10 | 2 | {0, 3, 6, 9} |
| 10 | 1 | 4 | 10 | 4 | {0, 3, 6, 9} |
| 11 | 1 | 0 | 14 | 0 | {0, 6} |
| 12 | 1 | 0 | 14 | 0 | {0, 3, 6, 9} |
| 13 | 1 | 0 | 14 | 2 | {0, 3, 6, 9} |
| 14 | 1 | 0 | 14 | 4 | {0, 3, 6, 9} |
| 15 | 1 | 0 | 14 |  | {0, 3, 6, 9} |

If a UE has dedicated PUCCH resource configuration, the UE is provided by higher layers with one or more PUCCH resources.

A PUCCH resource includes the following parameters:

- a PUCCH resource index provided by higher layer parameter *pucch-ResourceId*

- an index of the first PRB prior to frequency hopping or for no frequency hopping by higher layer parameter *startingPRB*

- an index of the first PRB after frequency hopping by higher layer parameter *secondHopPRB*;

- an indication for intra-slot frequency hopping by higher layer parameter *intraSlotFrequencyHopping*

- a configuration for a PUCCH format, from PUCCH format 0 through PUCCH format 4, provided by higher layer parameter *format*

If the higher layer parameter *format* indicates *PUCCH-format0*,the PUCCH format configured for a PUCCH resource is PUCCH format 0, where the PUCCH resource also includes an index for an initial cyclic shift provided by higher layer parameter *initialCyclicShift*, a number of symbols for a PUCCH transmission provided by higher layer parameter *nrofSymbols*, a first symbol for the PUCCH transmission provided by higher layer parameter *startingSymbolIndex*.

If the higher layer parameter *format* indicates *PUCCH-format1*,the PUCCH format configured for a PUCCH resource is PUCCH format 1, where the PUCCH resource also includes an index for an initial cyclic shift provided by higher layer parameter *initialCyclicShift*, a number of symbols for a PUCCH transmission provided by higher layer parameter *nrofSymbols*, a first symbol for the PUCCH transmission provided by higher layer parameter *startingSymbolIndex*, and an index for an orthogonal cover code by higher layer parameter *timeDomainOCC*.

If the higher layer parameter *format* indicates *PUCCH-format2* or *PUCCH-format3*,the PUCCH format configured for a PUCCH resource is PUCCH format 2 or PUCCH format 3, respectively, where the PUCCH resource also includes a number of PRBs provided by higher layer parameter *nrofPRBs*, a number of symbols for a PUCCH transmission provided by higher layer parameter *nrofSymbols*, and a first symbol for the PUCCH transmission provided by higher layer parameter *startingSymbolIndex*.

If the higher layer parameter *format* indicates *PUCCH-format4*, the PUCCH format configured for a PUCCH resource is PUCCH format 4, where the PUCCH resource also includes a number of symbols for a PUCCH transmission provided by higher layer parameter *nrofSymbols*, a length for an orthogonal cover code by higher layer parameter *occ-Length*, an index for an orthogonal cover code by higher layer parameter *occ-Index*, and a first symbol for the PUCCH transmission provided by higher layer parameter *startingSymbolIndex*.

A UE can be configured up to four sets of PUCCH resources by higher layer parameter *PUCCH-ResourceSet*. A PUCCH resource set is associated with a PUCCH resource set index provided by higher layer parameter *pucch-ResourceSetId*, with a set of PUCCH resource indexes provided by higher layer parameter *resourceList* that provides a set of *pucch-ResourceId* used in the PUCCH resource set, and with a maximum number of UCI information bits the UE can transmit using a PUCCH resource in the PUCCH resource set provided by higher layer parameter *maxPayloadMinus1*. For the first PUCCH resource set, the maximum number of UCI information bits is fixed to two. For the PUCCH resource set with the largest index, other than the first one, the maximum number of UCI information bits is 1706. A maximum number of PUCCH resource indexes for a set of PUCCH resources is provided by higher layer parameter *maxNrofPUCCH-ResourcesPerSet*. The maximum number of PUCCH resources in the first PUCCH resource set is 32 and the maximum number of PUCCH resources in the other sets of PUCCH resources is 8.

If the UE transmits  UCI information bits, that include HARQ-ACK information bits, the UE determines a PUCCH resource set to be

- a first set of PUCCH resources with *pucch-ResourceSetId = 0* if  including 1 or 2 HARQ-ACK information bits and a positive or negative SR on one SR transmission occasion if transmission of HARQ-ACK information and SR occurs simultaneously, or

- a second set of PUCCH resources with *pucch-ResourceSetId = 1*, if provided by higher layers, if  where  is provided by higher layer parameter *maxPayloadMinus1* for the PUCCH resource set with *pucch-ResourceSetId = 1*, or

- a third set of PUCCH resources with *pucch-ResourceSetId = 2*, if provided by higher layers, if  where  is provided by higher layer parameter *maxPayloadMinus1* for the PUCCH resource set with *pucch-ResourceSetId = 2*, or

- a fourth set of PUCCH resources with *pucch-ResourceSetId = 3*, if provided by higher layers, if .

### 9.2.2 PUCCH Formats for UCI transmission

If a UE is not transmitting PUSCH, and the UE is transmitting UCI, the UE transmits UCI in a PUCCH using

- PUCCH format 0 if

- the transmission is over 1 symbol or 2 symbols,

- the number of HARQ-ACK information bits with positive or negative SR (HARQ-ACK/SR bits) is 1 or 2

- PUCCH format 1 if

- the transmission is over 4 or more symbols,

- the number of HARQ-ACK/SR bits is 1 or 2

- PUCCH format 2 if

- the transmission is over 1 symbol or 2 symbols,

- the number of UCI bits is more than 2

- PUCCH format 3 if

- the transmission is over 4 or more symbols,

- the number of UCI bits is more than 2

- 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

A spatial setting for a PUCCH transmission is provided by higher layer parameter *PUCCH-Spatialrelationinfo* if the UE is configured with a single value for higher layer parameter *pucch-SpatialrelationinfoId*; otherwise, the spatial setting is provided by higher layer parameter *PUCCH-SpatialRelationInfo* from a set of multiple values provided by respective higher layer parameters *pucch-SpatialRelationInfoId* [11, TS 38.321]. The UE applies corresponding actions in [10, TS 38.321] and a corresponding setting for a spatial domain filter to transmit PUCCH 3 msec after the slot where the UE transmits HARQ-ACK information corresponding to a PDSCH reception providing the *PUCCH-SpatialRelationInfo*.

- If *PUCCH-Spatialrelationinfo* provides higher layer parameter *ssb-Index*, the UE transmits the PUCCH using a same spatial domain filter as for a reception of a SS/PBCH block with index provided by *ssb-Index*; else if *PUCCH-Spatialrelationinfo* provides higher layer parameter *csi-RS-Index*, the UE transmits the PUCCH using a same spatial domain filter as for a reception of a CSI-RS with resource index provided by *csi-RS-Index*; else *PUCCH-Spatialrelationinfo* provides higher layer parameter *srs*, and the UE transmits the PUCCH with a same spatial domain filter used as for a transmission of a SRS with resource index provided by *srs*.

A number of DMRS symbols for a PUCCH transmission using PUCCH format 3 or 4 is provided by higher layer parameter *additionalDMRS*.

Use of /2-PBSK, instead of QPSK, for a PUCCH transmission using PUCCH format 3 or 4 is indicated by higher layer parameter *pi2BPSK*.

### 9.2.3 UE procedure for reporting HARQ-ACK

A UE does not expect to transmit more than one PUCCH with HARQ-ACK information in a slot.

For DCI format 1\_0, the PDSCH-to-HARQ-timing-indicator field values map to {1, 2, 3, 4, 5, 6, 7, 8}. For DCI format 1\_1, if present, the PDSCH-to-HARQ-timing-indicator field values map to values for a set of number of slots provided by higher layer parameter *dl-DataToUL-ACK* as defined in Table 9.2.3-1.

For a SPS PDSCH reception in slot , the UE transmits the PUCCH in slot where  is provided by the PDSCH-to-HARQ-timing-indicator field in DCI format 1\_0 or, if present, in DCI format 1\_1 activating the SPS PDSCH reception.

If the UE detects a DCI format 1\_1 that does not include a PDSCH-to-HARQ-timing-indicator field and schedules a PDSCH reception or activates a SPS PDSCH reception in slot , the UE provides corresponding HARQ-ACK information in a PUCCH transmission within slot  where  is provided by higher layer parameter *dl-DataToUL-ACK*.

With reference to slots for PUCCH transmissions, if the UE detects a DCI format 1\_0 or a DCI format 1\_1 scheduling a PDSCH reception in slot  or if the UE detects a DCI format 1\_0 indicating a SPS PDSCH release through a PDCCH reception in slot , the UE provides corresponding HARQ-ACK information in a PUCCH transmission within slot , where  is a number of slots and is indicated by the PDSCH-to-HARQ-timing-indicator field in the DCI format, if present, or provided by higher layer parameter *dl-DataToUL-ACK*. If the PDSCH subcarrier spacing is equal to or larger than the PUCCH subcarrier spacing,  corresponds to the slot of the PUCCH transmission that overlaps with the slot of the PDSCH transmission. If the PDSCH subcarrier spacing is smaller than the PUCCH subcarrier spacing,  corresponds to the slot of the PUCCH transmission that ends at a same time as the slot of the PDSCH reception or of the PDCCH reception in case of SPS PDSCH release.

HARQ-ACK information transmission in a PUCCH is subject to the limitations for UE transmissions described in Subclause 11.1 and Subclause 11.1.1.

Table 9.2.3-1: Mapping of PDSCH-to-HARQ\_feedback timing indicator field values to numbers of slots

|  |  |
| --- | --- |
| PDSCH-to-HARQ\_feedback timing indicator | Number of slots |
| '000' | 1st value provided by *dl-DataToUL-ACK* |
| '001' | 2nd value provided by *dl-DataToUL-ACK* |
| '010' | 3rd value provided by *dl-DataToUL-ACK* |
| '011' | 4th value provided by *dl-DataToUL-ACK* |
| '100' | 5th value provided by *dl-DataToUL-ACK* |
| '101' | 6th value provided by *dl-DataToUL-ACK* |
| '110' | 7th value provided by *dl-DataToUL-ACK* |
| '111' | 8th value provided by *dl-DataToUL-ACK* |

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 for  HARQ-ACK information bits, 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, among the DCI formats 1\_0 or DCI formats 1\_1 that have a value of a PDSCH-to-HARQ\_feedback timing indicator field indicating a same slot for the PUCCH transmission, that the UE detects and for which the UE transmits corresponding HARQ-ACK information in the PUCCH where, for PUCCH resource determination, detected DCI formats are first indexed in a descending order across serving cells indexes and are then in an ascending order across PDCCH monitoring occasion indexes.

The PUCCH resource indicator field values map to values of a set of PUCCH resource indexes, as defined in Table 9.2.3-2, provided by higher layer parameter *ResourceList* for PUCCH resources from a set of PUCCH resources provided by higher layer parameter *PUCCH-ResourceSet* with a maximum of eight PUCCH resources.

For the first set of PUCCH resources and when the size  of higher layer parameter *resourceList* is larger than eight, when a UE provides HARQ-ACK information in a PUCCH transmission in response to detecting a last DCI format 1\_0 or DCI format 1\_1, the UE determines a PUCCH resource with index , , as



where  is a number of CCEs in control resource set  of a corresponding PDCCH reception for the DCI format 1\_0 or DCI format 1\_1 as described in Subclause 10.1,  is the index of a first CCE for the PDCCH reception, and  is a value of the PUCCH resource indicator field in the DCI format 1\_0 or DCI format 1\_1.

Table 9.2.3-2: Mapping of PUCCH resource indication field values to a PUCCH resource in a PUCCH resource set with maximum 8 PUCCH resources

|  |  |
| --- | --- |
| PUCCH resource indicator | PUCCH resource |
| '000' | 1st PUCCH resource provided by *pucch-ResourceId* obtained from the 1st value of *resourceList* |
| '001' | 2nd PUCCH resource provided by *pucch-ResourceId* obtained from the 2nd value of *resourceList* |
| '010' | 3rd PUCCH resource provided by *pucch-ResourceId* obtained from the 3rd value of *resourceList* |
| '011' | 4th PUCCH resource provided by *pucch-ResourceId* obtained from the 4th value of *resourceList* |
| '100' | 5th PUCCH resource provided by *pucch-ResourceId* obtained from the 5th value of *resourceList* |
| '101' | 6th PUCCH resource provided by *pucch-ResourceId* obtained from the 6th value of *resourceList* |
| '110' | 7th PUCCH resource provided by *pucch-ResourceId* obtained from the 7th value of *resourceList* |
| '111' | 8th PUCCH resource provided by *pucch-ResourceId* obtained from the 8th value of *resourceList* |

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

If a UE transmits HARQ-ACK information using PUCCH format 0, the UE determines values  and  for computing a value of cyclic shift  [4, TS 38.211] where is provided by higher layer parameter *initialCyclicShift* of *PUCCH-format0*, and  is determined from the value of one HARQ-ACK information bit or from the values of two HARQ-ACK information bits as in Table 9.2.3-3 and Table 9.2.3-4, respectively.

Table 9.2.3-3: Mapping of values for one HARQ-ACK information bit to sequences for PUCCH format 0

|  |  |  |
| --- | --- | --- |
| HARQ-ACK Value | 0 | 1 |
| **Sequence cyclic shift** |  |  |

Table 9.2.3-4: Mapping of values for two HARQ-ACK information bits to sequences for PUCCH format 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| HARQ-ACK Value | {0, 0} | {0, 1} | {1, 1} | {1, 0} |
| **Sequence cyclic shift** |  |  |  |  |

If a UE transmits HARQ-ACK information using PUCCH format 1, the UE is provided a value for  by higher layer parameter *initialCyclicShift* of *PUCCH-format1*.

If a UE transmits HARQ-ACK information bits and  bits using PUCCH format 2 or PUCCH format 3 in a PUCCH resource that includes  PRBs, the UE determines a number of PRBs  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 *nrofPRBs* of *PUCCH-format2* or *nrofPRBs* of *PUCCH-format3* and starts from the first PRB from the number of PRBs, that results to  and, if , , where , , , and  are defined in Subclause 9.2.5.2. If , the UE transmits the PUCCH over  PRBs.

### 9.2.4 UE procedure for reporting SR

A UE is configured by higher layer paremater *SchedulingRequestResourceConfig* a set of configurations for SR transmission in a PUCCH using either PUCCH format 0 or PUCCH format 1.

The UE is configured a PUCCH resource by higher layer parameter *SchedulingRequestResourceId* providing a PUCCH format 0 resource or a PUCCH format 1 resource as described in Subclause 9.2.1. The UE is also configured a periodicity  in symbols or slots and an offset  in slots by higher layer parameter *periodicityAndOffset* for a PUCCH transmission conveying SR. If  is larger than one slot, the UE determines a SR transmission occasion in a PUCCH to be in a slot with number  [4, TS 38.211] in a frame with number  if .

If  is one slot, the UE expects that =0 and every slot is a SR transmission occasion in a PUCCH.

If  is smaller than one slot, the UE determines a SR transmission occasion in a PUCCH to start in a symbol with index  [4, TS 38.211] if  where  is the value of higher layer parameter *startingSymbolIndex*.

If the UE determines that, for an occasion of a SR transmission in a PUCCH, the number of symbols available for the PUCCH transmission in a slot is smaller than the value provided by higher layer parameter *nrofSymbols*, the UE does not transmit the PUCCH in the slot.

SR transmission occasions in a PUCCH are subject to the limitations for UE transmissions described in Subclause 11.1 and Subclause 11.1.1.

The UE transmits a PUCCH in the PUCCH resource for the corresponding SR configuration only when the UE transmits a positive SR. For a positive SR transmission using PUCCH format 0, the UE transmits the PUCCH as described in [4, TS 38.211] by obtaining  as described for HARQ-ACK information transmission in Subclause 9.2.3 and by setting . For a positive SR transmission using PUCCH format 1, the UE transmits the PUCCH as described in [4, TS 38.211] by setting .

### 9.2.5 UE procedure for reporting multiple UCI types

A UE multiplexes HARQ-ACK/SR and periodic/semi-persistent CSI in a same PUCCH if the UE is provided higher layer parameter *simultaneousHARQ-ACK-CSI*; otherwise, the UE drops the periodic/semi-persistent CSI report(s) and includes only HARQ-ACK/SR in the PUCCH.

If a UE is configured with multiple PUCCH resources in a slot to transmit only semi-persistent or periodic CSI reports

- if the UE is not provided higher layer parameter *multi-CSI-PUCCH-ResourceList*, the UE determines a first resource corresponding to a CSI report with the highest priority [6, TS38.214]. If the first resource includes PUCCH format 2, and if there are remaining resources that do not overlap with the first resource, the UE determines a CSI report with the highest priority, among the CSI reports with corresponding resources from the remaining resources, and a corresponding second resource as an additional resource for CSI reporting

- if the UE is provided higher layer parameter *multi-CSI-PUCCH-ResourceList*, the UE multiplexes CSI reports with overlapping resources in a resource from the resources provided by *multi-CSI-PUCCH-ResourceList*, as described in Subclause 9.2.5.2

If a UE would transmit multiple overlapping PUCCHs without repetitions in a slot or overlapping PUCCH(s) without repetitions and PUSCH(s) in a slot and, when applicable as described in Subclauses 9.2.5.1 and 9.2.5.2, the UE is configured to multiplex different UCI types in one PUCCH, and one of the multiple overlapping PUCCHs or PUSCHs is in response to a DCI format detection by the UE, the UE multiplexes all corresponding UCI types if the following conditions are met.

If one of the PUCCHs or PUSCHs is in response to a DCI format detection by the UE, the UE expects that the first symbol of the earliest PUCCH or PUSCH, among the overlapping PUCCHs and PUSCHs in the slot, is not before symbol  after a last symbol of any corresponding PDSCH or SPS PDSCH release and is not before symbol  after a last symbol of any corresponding PDCCH where  is obtained by adding one symbol to a number of symbols  corresponding to a PDSCH reception time for the UE PDSCH processing capability, is obtained by adding one symbol to a number of symbols  corresponding to a PUSCH preparation time for the UE PUSCH processing capability, where , , , , and  are defined in [6, TS 38.214]. A UE does not expect a PUCCH or a PUSCH that is in response to a DCI format detection to overlap with any other PUCCH or PUSCH that does not satisfy the above  and  timing conditions.

If a UE would transmit multiple PUCCHs in a slot that include HARQ-ACK/SR and CSI and PUCCHs with HARQ-ACK satisfies the above  and  timing conditions and does not overlap with any other PUCCH or PUSCH that does not satisfy the above  and  timing conditions, the UE multiplexes HARQ-ACK/SR and CSI and determines corresponding PUCCH(s) for transmission in the slot according to the following pseudo-code.

Set  to the set of resources for transmission of corresponding PUCCHs in a slot where

- a resource with an earlier first symbol is placed before a resource with later first symbol

- for two resources with same first symbol, the resource with longer duration is placed before the resource with shorter duration

- for two resources with same first symbol and same duration, the placement is arbitrary

- the above three steps for the set  are according to a subsequent pseudo-code for a function 

- if the UE is not provided higher layer parameter *simultaneousHARQ-ACK-CSI* and resources for transmission of HARQ-ACK information include PUCCH format 0 or PUCCH format 2, resources that include PUCCH format 2, or PUCCH format 3, or PUCCH format 4 for transmission of CSI reports are excluded from the set  if they overlap with any resource from the resources for transmission of HARQ-ACK information

- if the UE is not provided higher layer parameter *simultaneousHARQ-ACK-CSI* and at least one of the resources for transmission of HARQ-ACK information includes PUCCH format 1, PUCCH format 3, or PUCCH format 4

- resources that include PUCCH format 3 or PUCCH format 4 for transmission of CSI reports are excluded from the set 

- resources that include PUCCH format 2 for transmission of CSI reports are excluded from the set  if they overlap with any resource from the resources for transmission of HARQ-ACK information

Set  to the cardinality of 

Set to be the first symbol of resource  in the slot

Set  to be the number of symbols of resource  in the slot

Set  - index of first resource in set 

Set  - counter of overlapped resources

while 

if any of resources  overlaps with resource 





else

if 

multiplex UCI for resources  in a single resource as described in Subclauses 9.2.5.1 and 9.2.5.2

set the index of the single resource to 



 % start from the beginning after reordering unmerged resources at next step



 % function that re-orders resources in current set 

else



end if

end if

end while

The function  performs the following pseudo-code

{



while  % the next two while loops are to re-order the unmerged resources



while 

if  OR 







end if



end while



end while

}

For each PUCCH resource in the set  that satisfies the aforementioned  and  timing conditions

- the UE transmits a PUCCH using the resource if the resource does not overlap with a PUSCH, or if the resource is associated with repetitions of a PUCCH over multiple slots

- the UE multiplexes HARQ-ACK information and/or CSI in a PUSCH if the resource overlaps with the PUSCH, as described in Subclause 9.3, and does not transmit SR. In case the resource overlaps with multiple PUSCHs, the PUSCH for multiplexing HARQ-ACK information and/or CSI is selected as described in Subclause 9.

Subclauses 9.2.5.1 and 9.2.5.2 assume the following

- resources for transmissions of UCI types, prior to multiplexing or dropping, overlap in a slot

- multiplexing conditions of corresponding UCI types in a single PUCCH are satisfied, and

- the UE does not transmit any overlapping PUSCH in the slot

#### 9.2.5.1 UE procedure for multiplexing HARQ-ACK or CSI and SR in a PUCCH

In the following, a UE is configured to transmit  PUCCHs for respective  SRs in a slot, as determined by a set of higher layer parameters *schedulingRequestResourceId*, with transmission occasions that would overlap with a transmission of HARQ-ACK information from the UE in the slot or with periodic/semi persistent CSI transmission from the UE in the slot.

If a UE would transmit positive SR and at most two HARQ-ACK information bits in a resource using PUCCH format 0, the UE transmits a PUCCH in the resource using PUCCH format 0 in PRB(s) for HARQ-ACK information as described in Subclause 9.2.3. The UE determines a value of  and  for computing a value of cyclic shift  [4, TS 38.211] where  is provided by higher layer parameter *initialcyclicshift* of *PUCCH-format0*, and  is determined from the value of one HARQ-ACK information bit or from the values of two HARQ-ACK information bits as in Table 9.2.5-1 and Table 9.2.5-2, respectively.

If the UE would transmit negative SR and at most two HARQ-ACK information bits in a resource using PUCCH format 0, the UE transmits a PUCCH in the resource using PUCCH format 0 for HARQ-ACK information as described in Subclause 9.2.3.

Table 9.2.5-1: Mapping of values for one HARQ-ACK information bit and positive SR to sequences for PUCCH format 0

|  |  |  |
| --- | --- | --- |
| HARQ-ACK Value | 0 | 1 |
| **Sequence cyclic shift** |  |  |

Table 9.2.5-2: Mapping of values for two HARQ-ACK information bits and positive SR to sequences for PUCCH format 0

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| HARQ-ACK Value | {0, 0} | {0, 1} | {1, 1} | {1, 0} |
| **Sequence cyclic shift** |  |  |  |  |

If a UE would transmit positive or negative SR in a resource using PUCCH format 0 and HARQ-ACK information bits in a resource using PUCCH format 1, the UE transmits only the HARQ-ACK information bits in the resource using PUCCH format 1.

If the UE would transmit positive SR in a resource using PUCCH format 1 and at most two HARQ-ACK information bits in a resource using PUCCH format 1 in a slot, the UE transmits a PUCCH in the PUCCH resource using PUCCH format 1 for SR transmission as described in Subclause 9.2.4. If a UE would transmit negative SR in a resource using PUCCH format 1 and at most two HARQ-ACK information bits in a resource using PUCCH format 1 in a slot, the UE transmits a PUCCH in the resource using PUCCH format 1 for HARQ-ACK information as described in Subclause 9.2.3.

If a UE would transmit HARQ-ACK information bits in a resource using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 in a slot, as described in Subclause 9.2.3,  bits representing a negative or positive SR, in ascending order of the values of *schedulingRequestResourceId*, are appended to the HARQ-ACK information bits and the UE transmits the combined UCI bits in a PUCCH using a resource with PUCCH format 2 or PUCCH format 3 or PUCCH format 4 for transmission of HARQ-ACK information bits. An all-zero value for the  bits represents a negative SR value across all  SRs.

If a UE would transmit periodic/semi-persistent CSI in a resource using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 in a slot ,  bits representing corresponding negative or positive SR, in ascending order of the values of *schedulingRequestResourceId* , are prepended to the periodic/semi-persistent CSI information bits as described in Subclause 9.2.5.2 and the UE transmits a PUCCH with the combined UCI bits in a resource using the PUCCH format 2 or PUCCH format 3 or PUCCH format 4 resource for CSI reporting. An all-zero value for the  bits represents a negative SR value across all  SRs.

If a UE would transmit periodic/semi-persistent CSI in a resource using PUCCH format 2 or PUCCH format 3 or PUCCH format 4 in a slot,  bits representing corresponding negative or positive SR, in ascending order of the values of *schedulingRequestResourceId* , are prepended to the periodic/semi-persistent CSI information bits as described in Subclause 9.2.5.2 and the UE transmits a PUCCH with the combined UCI bits in a resource using PUCCH format 2 or PUCCH format 3 or PUCCH format 4. An all-zero value for the  bits represents a negative SR value across all  SRs.

If a UE transmits HARQ-ACK information bits,  SR bits, and  CRC bits using PUCCH format 2 or PUCCH format 3 in a PUCCH resource that includes  PRBs, the UE determines a number of PRBs  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 *nrofPRBs* in *PUCCH-format2* or *nrofPRBs* in *PUCCH-format3* and starts from the first PRB from the number of PRBs, that results to  and, if , , where , , , and  are defined in Subclause 9.2.5.2. If , the UE transmits the PUCCH over the  PRBs.

#### 9.2.5.2 UE procedure for multiplexing HARQ-ACK/SR and CSI in a PUCCH

For a single transmission occasion of periodic/semi-persistent CSI reports, a PUCCH resource is provided by higher layer parameter *pucch-CSI-ResourceList*. For multiple transmission occasions of periodic/semi-persistent CSI reports, corresponding PUCCH resources are provided by higher layer parameter *multi-CSI-PUCCH-ResourceList*.

If a UE is provided only one PUCCH resource set for transmission of HARQ-ACK information in response to PDSCH reception scheduled by a DCI format or in response to a SPS PDSCH release, the UE does not expect to be provided higher layer parameter *simultaneousHARQ-ACK-CSI*.

A UE is configured by higher layer parameter *maxCodeRate* a code rate for transmission of HARQ-ACK/SR and periodic/semi-persistent CSI report(s) in PUCCH format 2, PUCCH format 3, or PUCCH format 4.

If a UE transmits CSI reports using PUCCH format 2, the UE transmits only wideband CSI for each CSI report [6, TS 38.214]. In the following, a Part 1 CSI report refers either to a CSI report with only wideband CSI or to a Part 1 of a CSI report with wideband CSI and sub-band CSI.

If a UE transmits periodic/semi-persistent CSI reports that include Part 2 CSI reports, the UE determines a PUCCH resource and a number of PRBs in the PUCCH resource assuming that each of the periodic/semi-persistent CSI reports indicates rank 1. Let  be a total number of UCI bits and  be a total number of CRC bits a UE transmits in a PUCCH, where

-  is a total number of HARQ-ACK bits, if any

-  if there is no scheduling request bit; otherwise,  as described in Subclause 9.2.5.1

- ,  is a number of Part 1 CSI report bits for CSI report with priority level ,  is a number of Part 2 CSI report bits, if any, for CSI report with priority level  [6, TS 38.214], and  is a number of periodic/semi-persistent CSI reports

- ,  is a number of CRC bits, if any, for encoding HARQ-ACK/SR and Part 1 of a CSI report, and  is a number of CRC bits, if any, for encoding Part 2 of the CSI report

In the following

-  is a code rate given by higher layer parameter *maxCodeRate* as in Table 9.2.5.2-1.

-  is a number of PRBs for PUCCH format 2, or PUCCH format 3, or PUCCH format 4, respectively, where  is provided by higher layer parameter *nrofPRBs* in *PUCCH-format2* for PUCCH format 2 or by higher layer parameter *nrofPRBs* in *PUCCH-format3* for PUCCH format 3, and  for PUCCH format 4

-  for PUCCH format 2,  for PUCCH format 3, and  for PUCCH format 4, where  is a number of subcarriers per resource block [4, TS 38.211]

-  is equal to a number of PUCCH symbols  for PUCCH format 2 provided by higher layer parameter *nrofSymbols* in *PUCCH-format2*. For PUCCH format 3 or for PUCCH format 4,  is equal to a number of PUCCH symbols  for PUCCH format 3 or equal to a number of PUCCH symbols  for PUCCH format 4 provided by higher layer parameter *nrofSymbols* in *PUCCH-format3* or *nrofSymbols* in *PUCCH-format4*, respectively, 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]

-  if pi/2-BPSK is the modulation scheme and  if QPSK is the modulation scheme as indicated by higher layer parameter *pi2BPSK* for PUCCH format 3 or PUCCH format 4. For PUCCH format 2, 

If a UE has CSI reports and zero or more HARQ-ACK/SR information bits to transmit in a PUCCH where the HARQ-ACK, if any, is in response to a PDSCH reception without a corresponding PDCCH

- if the UE is provided by higher layer parameter *pucch-CSI-ResourceList* or by higher layer parameter *multi-CSI-PUCCH-ResourceList* with  PUCCH resources, for PUCCH format 2 and/or PUCCH format 3 and/or PUCCH format 4, as described in Subclause 9.2.1, where the resources are indexed according to an ascending order for the product of a number of corresponding REs, modulation order , and configured code rate ;

- if , the UE uses PUCCH format 2 resource , or the PUCCH format 3 resource , or the PUCCH format 4 resource ;

- else if  and , , the UE transmits a PUCCH conveying HARQ-ACK/SR and periodic/semi-persistent CSI report(s) in a respective PUCCH where the UE uses the PUCCH format 2 resource , or the PUCCH format 3 resource , or the PUCCH format 4 resource;

- else the UE uses the PUCCH format 2 resource , or the PUCCH format 3 resource , or the PUCCH format 4 resource  and the UE selects  CSI report(s) for transmission together with HARQ-ACK/SR, when any, in ascending priority order as described in [6, TS 38.214].

If a UE has HARQ-ACK/SR and wideband or sub-band CSI reports to transmit and the UE determines a PUCCH resource with PUCCH format 2, or the UE has HARQ-ACK/SR and wideband CSI reports [6, TS38.214] to transmit and the UE determines a PUCCH resource with PUCCH format 3 or PUCCH format 4, where

- the UE determines the PUCCH resource using the PUCCH resource indicator field [5, TS 38.212] in a last DCI format 1\_0 or DCI format 1\_1, from DCI formats 1\_0 or DCI formats 1\_1 that have a value of a PDSCH-to-HARQ\_feedback timing indicator field indicating a same slot for the PUCCH transmission, from a PUCCH resource set provided to the UE for HARQ-ACK transmission, and

- the UE determines the PUCCH resource set as described in Subclause 9.2.1 and Subclause 9.2.3 for  UCI bits

and

- if , the UE transmits the HARQ-ACK/SR and periodic/semi-persistent CSI reports bits by selecting the minimum number  of the  PRBs satisfying  as described in Subclauses 9.2.3 and 9.2.5.1;

- else, the UE selects  CSI report(s) for transmission together with HARQ-ACK/SR in ascending priority order, where the value of  satisfies  and , where  is a number of CRC bits corresponding to  UCI bits, and  is a number of CRC bits corresponding to  UCI bits.

If a UE has HARQ-ACK/SR and sub-band CSI reports to transmit and the UE determines a PUCCH resource with PUCCH format 3 or PUCCH format 4, where

- the UE determines the PUCCH resource using the PUCCH resource indicator field [5, TS 38.212] in a last DCI format 1\_0 or DCI format 1\_1, from DCI formats 1\_0 or DCI formats 1\_1 that have a value of a PDSCH-to-HARQ\_feedback timing indicator field indicating a same slot for the PUCCH transmission, from a PUCCH resource set provided to the UE for HARQ-ACK transmission, and

- the UE determines the PUCCH resource set as described in Subclause 9.2.1 and Subclause 9.2.3 for  UCI bits

and

- if , the UE transmits the HARQ-ACK/SR and the  periodic/semi-persistent CSI report bits by selecting the minimum number  of PRBs from the  PRBs satisfying  as described in Subclauses 9.2.3 and 9.2.5.1;

- else,

- if for  CSI part 2 report priority level(s), it is

 and

,

the UE selects the first  CSI part 2 report priority level(s), according to [6, TS 38.214], for transmission together with the HARQ-ACK/SR and  CSI part 1 reports , where  is the number of CSI part 1 report bits for the  CSI report and  is the number of CSI part 2 report bits for the  CSI report priority level, is a number of CRC bits corresponding to , and  is a number of CRC bits corresponding to ;

- else, the UE drops all CSI part 2 reports and selects  CSI part 1 report(s), in ascending priority order, for transmission together with the HARQ-ACK/SR bits where the value of  satisfies  and , where is a number of CRC bits corresponding to  UCI bits, and  is a number of CRC bits corresponding to  UCI bits.

Table 9.2.5.2-1: Code rate  corresponding to higher layer parameter *maxCodeRate*

|  |  |
| --- | --- |
| *maxCodeRate* | **Code rate** |
|
| 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, , for a PUCCH transmission by respective higher layer parameters *nrofSlots*.

For ,

- the UE repeats the UCI in the PUCCH transmission in the first slot of the  slots in the PUCCH transmission in each of the remaining  slots;

- a PUCCH transmission has the same number of consecutive symbols, as provided by higher layer parameter *nrofSymbols* in *PUCCH-format1*, *nrofSymbols* in *PUCCH-format3*, or *nrofSymbols* in *PUCCH-format4*, in each of the  slots;

- a PUCCH transmission has a same first symbol, as provided by higher layer parameter *startingSymbolIndex* in *PUCCH-format1*, *startingSymbolIndex* in *PUCCH-format3*, or *startingSymbolIndex* in *PUCCH-format4*, in each of the  slots;

- the UE is configured by higher layer parameter *interslotFrequencyHopping* whether or not to perform frequency hopping for PUCCH transmissions in different slots.

- If the UE is configured to perform frequency hopping for PUCCH transmissions in different slots,

- the UE performs frequency hopping per slot;

- the UE transmits the PUCCH starting from the first PRB in slots with even number and starting from the second PRB in slots with odd number. The slot indicated to the UE for the first PUCCH transmission has number 0 and each subsequent slot until the UE transmits the PUCCH in slots is counted regardless of whether or not the UE transmits the PUCCH in the slot;

- the UE is not expected to be configured to perform frequency hopping for a PUCCH transmission within a slot.

- If the UE is configured to perform frequency hopping for PUCCH transmissions within a slot, the frequency hopping pattern between the first PRB and the second PRB is same within each slot.

If the UE determines that, for a PUCCH transmission in a slot, the number of symbols available for the PUCCH transmission is smaller than the value provided by higher layer parameter *nrofSymbols* for the corresponding PUCCH format, the UE does not transmit the PUCCH in the slot.

If a UE is provided higher layer parameter *tdd-UL-DL-ConfigurationCommon*, or is additionally providedhigher layer parameter *tdd-UL-DL-ConfigurationCommon2*, or is additionally provided higher layer parameter *tdd-UL-DL-ConfigDedicated* for the slot format per slot over the number of slots, as described in Subclause 11.1, the UE determines the  slots for a PUCCH transmission starting from a slot indicated to the UE as described in Subclause 9.2.3 and having

- an UL symbol or flexible symbol provided by higher layer parameter *PUCCH-F1-F3-F4-starting-symbol* as a first symbol, and

- consecutive UL symbols or flexible symbols, starting from the first symbol, equal to or larger than a number of symbols provided by higher layer parameter *PUCCH-F1-F3-F4-number-of-symbols*.

If a UE is not provided higher layer parameter *tdd-UL-DL-ConfigurationCommon* or higher layer parameter *tdd-UL-DL-ConfigurationCommon2*, the UE determines the  slots for a PUCCH transmission as the  consecutive slots starting from a slot indicated to the UE as described in Subclause 9.2.3.

If the UE would transmit UCI in a PUCCH over a first number  of slots and the UE would transmit a PUSCH over a second number of slots, and the PUCCH transmission would overlap with the PUSCH transmission in one or more slots, and the conditions in Subclause 9.2.5 for multiplexing the UCI in the PUSCH are satisfied in the overlapping slots, the UE transmits the PUCCH and does not transmit the PUSCH in the overlapping slots.

## 9.3 UCI reporting in physical uplink shared channel

If a UE would have on a serving cell a PUSCH transmission without UL-SCH that overlaps with a PUCCH transmission on the serving cell that includes positive SR information, the UE does not transmit the PUSCH.

If a UE has a PUSCH transmission that overlaps with a PUCCH transmission that includes HARQ-ACK information and/or semi-persistent/periodic CSI and the conditions in Subclause 9.2.5 for multiplexing the UCI in the PUSCH are satisfied, the UE multiplexes the HARQ-ACK information and/or the semi-persistent/periodic CSI in the PUSCH.

Offset values are defined for a UE to determine a number of resources for multiplexing HARQ-ACK information 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.

If DCI format 0\_0, or DCI format 0\_1 that does not include a beta\_offset indicator field, schedules the PUSCH transmission from the UE, the UE applies the , , and  values that are configured by higher layers for the corresponding HARQ-ACK information and/or CSI part 1 and CSI part 2 payloads.

HARQ-ACK information offsets  is configured to values according to Table 9.3-1. The higher layer parameters *betaOffsetACK-Index1*, *betaOffsetACK-Index2*, and *betaOffsetACK-Index3* respectively provide indexes , , and  for the UE to use if the UE multiplexes up to 2 HARQ-ACK information bits, more than 2 and up to 11 HARQ-ACK information bits, and more than 11 bits in the PUSCH, respectively.

CSI part 1 and CSI part 2 offsets  and , respectively, is configured to values according to Table 9.3-2. Higher layer parameters *betaOffsetCSI-Part1-Index1* and *betaOffsetCSI-Part2-Index1* respectively provide indexes  and  for the UE to use if the UE multiplexes up to 11 bits for CSI part 1 or CSI part 2 in the PUSCH. Higher layer parameters *betaOffsetCSI-Part1-Index2* and *betaOffsetCSI-Part2-Index2* respectively provide indexes  or , respectively, for the UE to use if the UE multiplexes more than 11 bits for CSI part 1 or CSI part 2 in the PUSCH.

If a DCI format 0\_1 schedules the PUSCH transmission from the UE and if DCI format 0\_1 includes a beta\_offset indicator field, as configured by higher layer parameter *uci-OnPUSCH*, the UE is provided by each of higher layer parameters { *betaOffsetACK-Index1*, *betaOffsetACK-Index2*, *betaOffsetACK-Index3*} a set of four  indexes, by each of higher layer parameters { *betaOffsetCSI-Part1-Index1*, *betaOffsetCSI-Part1-Index2*} a set of four  indexes and by each of higher layer parameters { *betaOffsetCSI-Part2-Index1*, *betaOffsetCSI-Part2-Index2*} a set of four  indexes from Table 9.3-1 and 9.3-2, respectively, for multiplexing HARQ-ACK information, CSI part 1, and CSI part 2, respectively, in the PUSCH transmission. The beta\_offset indicator field indicates a  value, a  value and a  value from the respective sets of values, with the mapping defined in Table 9.3-3.

Table 9.3-1: Mapping of beta\_offset values for HARQ-ACK information and the index signalled by higher layers

|  |  |
| --- | --- |
| or  or |  |
| 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 beta\_offset values for CSI and the index signalled by higher layers

|  |  |
| --- | --- |
| or   or |  |
| 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 | 12.625 |
| 17 | 15.875 |
| 18 | 20.000 |
| 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 beta\_offset indicator values to offset indexes

|  |  |
| --- | --- |
| beta\_offset indicator | ( or  or ), ( or ), ( or ) |
| '00' | 1st offset index provided by higher layers |
| '01' | 2nd offset index provided by higher layers |
| '10' | 3rd offset index provided by higher layers |
| '11' | 4th offset index provided by higher layers |

# 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 monitors a set of PDCCH candidates in one or more control resource sets on the active DL BWP on each activated serving cell configured with PDCCH monitoring according to corresponding search space sets where monitoring implies decoding each PDCCH candidate according to the monitored DCI formats.

A UE can be configured by higher layer parameter *ssb-periodicityServingCell* a periodicity of half frames for reception of SS/PBCH blocks in a serving cell.

For monitoring of a PDCCH candidate in a slot

- If the UE has received *ssb-PositionsInBurst* in *SystemInformationBlockType1* and has not received *ssb-PositionsInBurst* in *ServingCellConfigCommon* for a serving cell and if the UE does not monitor PDCCH candidates in a Type0-PDCCH common search space and at least one RE for a PDCCH candidate overlaps with respective at least one RE corresponding to a SS/PBCH block index provided by *ssb-PositionsInBurst* in *SystemInformationBlockType1*, the UE is not required to monitor the PDCCH candidate.

- If a UE has received *ssb-PositionsInBurst* in *ServingCellConfigCommon* for a serving cell and if the UE does not monitor PDCCH candidates in a Type0-PDCCH common search space and at least one RE for a PDCCH candidate overlaps with respective at least one RE corresponding to a SS/PBCH block index provided by *ssb-PositionsInBurst* in *ServingCellConfigCommon*, the UE is not required to monitor the PDCCH candidate.

- If the UE monitors the PDCCH candidate for a Type0-PDCCH common search space on the serving cell according to the procedure described in Subclause 13, the UE may assume that no SS/PBCH block is transmitted in REs used for monitoring the PDCCH candidate on the serving cell.

- If at least one RE of a PDCCH candidate on the serving cell overlaps with at least one RE of *lte-CRS-ToMatchAround*, the UE is not required to monitor the PDCCH candidate.

If a UE indicates in *UE-NR-Capability* a carrier aggregation capability larger than 4 serving cells, 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 4 cells. When the UE is configured for carrier aggregation operation over more than 4 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 space sets. A search space set can be a common search space set or a UE-specific search space set. A UE monitors PDCCH candidates in one or more of the following search spaces sets

- a Type0-PDCCH common search space set configured by *searchSpaceZero* in *MasterInformationBlock* or by *searchSpaceSIB1* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a SI-RNTI on a primary cell;

- a Type0A-PDCCH common search space set configured by *searchSpace-OSI* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a SI-RNTI on a primary cell;

- a Type1-PDCCH common search space set configured by *ra-SearchSpace* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a RA-RNTI, or a TC-RNTI on a primary cell;

- a Type2-PDCCH common search space set configured by *pagingSearchSpace* in *PDCCH-ConfigCommon* for a DCI format with CRC scrambled by a P-RNTI on a primary cell;

- a Type3-PDCCH common search space set configured by *SearchSpace* in *PDCCH-Config* with *searchSpaceType* = *common* for DCI formats with CRC scrambled by INT-RNTI, or SFI-RNTI, or TPC-PUSCH-RNTI, or TPC-PUCCH-RNTI, or TPC-SRS-RNTI and, only for the primary cell, C-RNTI, or CS-RNTI(s); and

- a UE-specific search space set configured by *SearchSpace* in *PDCCH-Config* with *searchSpaceType* = *ue-Specific* for DCI formats with CRC scrambled by C-RNTI, or CS-RNTI(s).

If a UE is not provided higher layer parameter *searchSpace-SIB1* for Type0-PDCCH common search space set, , the UE determines a control resource set and PDCCH monitoring occasions for Type0-PDCCH common search space set as described in Subclause 13. The Type0-PDCCH common search space set is defined by the CCE aggregation levels and the number of PDCCH candidates per CCE aggregation level given in Table 10.1-1. The control resource set configured for Type0-PDCCH common search space set has control resource set index 0. The Type0-PDCCH common search space set has search space index 0.

If a UE is not provided by dedicated higher layer signaling a control resource set for Type0A-PDCCH common search space or for Type2-PDCCH common search space, the corresponding control resource set is same as the control resource set for Type0-PDCCH common search space. The CCE aggregation levels and the number of PDCCH candidates per CCE aggregation level for Type0A-PDCCH common search space or for Type2-PDCCH common search space are given in Table 10.1-1.

For Type1-PDCCH common search space, a UE can be provided a configuration for a control resource set by higher layer parameter *ra-ControlResourceSet* and a configuration for a search space by higher layer parameter *ra-SearchSpace*. If higher layer parameter *ra-ControlResourceSet* is not provided to the UE, the control resource set for Type1-PDCCH common search space is the same as for Type0-PDCCH common search space.

If a UE is not provided higher layer parameter *searchSpaceOtherSystemInformation* for Type0A-PDCCH common search space set, the association between PDCCH monitoring occasions for Type0A-PDCCH common search space set and the SS/PBCH block index are same as the association of PDCCH monitoring occasions for Type0-PDCCH common search space set as described in Subclause 13. The CCE aggregation levels and the number of PDCCH candidates per CCE aggregation level are given in Table 10.1-1.

If a UE is not provided higher layer parameter *pagingSearchSpace* for Type2-PDCCH common search space set, the association between PDCCH monitoring occasions for Type2-PDCCH common search space set and the SS/PBCH block index are same as the association of PDCCH monitoring occasions for Type0-PDCCH common search space set as described in Subclause 13. The CCE aggregation levels and the number of PDCCH candidates per CCE aggregation level are given in Table 10.1-1.

The UE may assume that the DM-RS antenna port associated with PDCCH receptions in the control resource set configured by *pdcch-ConfigSIB1* in *MasterInformationBlock* and for corresponding PDSCH receptions, and the corresponding SS/PBCH block are quasi co-located with respect to average gain, QCL-TypeA, and QCL-TypeD properties, when applicable [6, TS 38.214]. The value for the DM-RS scrambling sequence initialization is the cell ID. A subcarrier spacing is provided by higher layer parameter *subCarrierSpacingCommon* in *MasterInformationBlock*.

For single cell operation or for operation with carrier aggregation in a same frequency band, a UE is not expected to monitor a PDCCH for Type0/0A/2/3-PDCCH common search space if the SS/PBCH block or the CSI-RS the UE selects for PRACH association, as described in Subclause 8.1, does not have same QCL-TypeD [6, TS 38.214] with a DM-RS for monitoring the PDCCH for Type0/0A/2/3-PDCCH common search space.

If a UE is configured with one or more downlink bandwidth parts (BWPs), as described in Subclause 12, the UE can be configured with *PDCCH-ConfigCommon* and *PDCCH-Config* for each configured DL BWP on the primary cell, other than the initial active DL BWP, as described in Subclause 12.

If a UE is provided one or more search space sets by corresponding one or more higher layer parameters *searchSpaceZero, searchSpaceSIB1*, *searchSpaceOtherSystemInformation*, *pagingSearchSpace*, *ra-SearchSpace*, and the UE is provided with a C-RNTI or a CS-RNTI, the UE monitors PDCCH candidates for DCI format 0\_0 and DCI format 1\_0 with the C-RNTI or the CS-RNTI in the one or more search space sets.

Table 10.1-1: CCE aggregation levels and maximum number of PDCCH candidates per CCE aggregation level for common search space sets configured by *searchSpace-SIB1*

|  |  |
| --- | --- |
| CCE Aggregation Level | Number of Candidates |
| 4 | 4 |
| 8 | 2 |
| 16 | 1 |

For each DL BWP configured to a UE in a serving cell, a UE can be provided by higher layer signalling with  control resource sets. For each control resource set, the UE is provided the following by higher layer parameter *ControlResourceSet*:

- a control resource set index , , by higher layer parameter *controlResourceSetId*;

- a DM-RS scrambling sequence initialization value by higher layer parameter *pdcch-DMRS-ScramblingID*;

- a precoder granularity for a number of REGs in the frequency domain where the UE can assume use of a same DM-RS precoder by higher layer parameter *precoderGranularity*;

- a number of consecutive symbols provided by higher layer parameter *duration*;

- a set of resource blocks provided by higher layer parameter *frequencyDomainResources*;

- CCE-to-REG mapping parameters provided by higher layer parameter *cce-REG-MappingType*;

- 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\_1 transmitted by a PDCCH in control resource set , by higher layer parameter *TCI-PresentInDCI*.

When *precoderGranularity* = *allContiguousRBs*, a UE does not expect to be configured a set of resource blocks of a control resource set that includes more than four sub-sets of resource blocks that are not contiguous in frequency.

For each control resource set in a DL BWP of a serving cell, a respective higher layer parameter *frequencyDomainResources* 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  PRBs with starting position  where the first PRB of the first group of 6 PRBs has index . A group of 6 PRBs is allocated to a control resource set if a corresponding bit value in the bitmap is 1; else, if a corresponding bit value in the bitmap is 0, the group of 6 PRBs is not allocated to the control resource set.

If a UE has received initial configuration of more than one TCI states by higher layer parameter *TCI-StatesPDCCH* but has not received a MAC CE activation command for one of the TCI states, the UE assumes that the DM-RS antenna port associated with PDCCH reception is quasi co-located with the SS/PBCH block the UE identified during the initial access procedure.

If the UE has received a MAC CE activation command for one of the TCI states, the UE applies the activation command 3 msec after a slot where the UE transmits HARQ-ACK information for the PDSCH providing the activation command.

If a UE has received higher layer parameter *TCI-StatesPDCCH* containing a single TCI state, the UE assumes that the DM-RS antenna port associated with PDCCH reception is quasi co-located with the one or more DL RS configured by the TCI state.

For each DL BWP configured to a UE in a serving cell, the UE is provided by higher layers with  search space sets where, for each search space set from the  search space sets, the UE is provided the following by higher layer parameter *SearchSpace*:

- a search space set index , , by higher layer parameter *searchSpaceId*;

- an association between the search space set  and a control resource set  by higher layer parameter *controlResourceSetId*;

- a PDCCH monitoring periodicity of  slots and a PDCCH monitoring offset of  slots, by higher layer parameter *monitoringSlotPeriodicityAndOffset*;

- 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 *monitoringSymbolsWithinSlot*;

- a number of PDCCH candidates  per CCE aggregation level  by higher layer parameters *aggregationLevel1*, *aggregationLevel2*, *aggregationLevel4*, *aggregationLevel8*, and *aggregationLevel16*, for CCE aggregation level 1, CCE aggregation level 2, CCE aggregation level 4, CCE aggregation level 8, and CCE aggregation level 16, respectively;

- an indication that search space set  is either a common search space set or a UE-specific search space set by higher layer parameter *searchSpaceType*;

- if search space set  is a common search space set,

- an indication by higher layer parameter *dci-Format0-0-AndFormat1-0* to monitor PDCCH candidates for DCI format 0\_0 and DCI format 1\_0 with CRC scrambled by a C-RNTI or a CS-RNTI (if configured), RA-RNTI, TC-RNTI, P-RNTI, SI-RNTI;

- an indication by higher layer parameter *dci-Format2-0* to monitor one or two PDCCH candidates for DCI format 2\_0 and a corresponding CCE aggregation level;

- an indication by higher layer parameter *dci-Format2-1* to monitor PDCCH candidates for DCI format 2\_1;

- an indication by higher layer parameter *dci-Format2-2* to monitor PDCCH candidates for DCI format 2\_2;

- an indication by higher layer parameter *dci-Format2-3* to monitor PDCCH candidates for DCI format 2\_3;

- if search space set  is a UE-specific search space set, an indication by higher layer parameter *dci-Formats* to monitor PDCCH candidate either for DCI format 0\_0 and DCI format 1\_0, or for DCI format 0\_1 and DCI format 1\_1.

The UE may also be provided, by higher layer parameter *duration*, a duration of  slots indicating a number of slots that the search space set  exists.

If the higher layer parameter *monitoringSymbolsWithinSlot* indicates to a UE only one PDCCH monitoring occasion within a slot, the UE does not expect to be configured with a PDCCH subcarrier spacing other than 15 kHz for the corresponding search space set  if the control resource set  associated with the search space  includes at least one symbol after the third symbol of the slot.

A UE does not expect to be provided a first symbol and a number of consecutive symbols for a control resource set that results to a PDCCH candidate mapping to symbols of different slots.

A UE does not expect any two PDCCH monitoring occasions, for a same search space set or for different search space sets, in a same control resource set to be separated by a non-zero number of symbols that is smaller than the control resource set duration.

A UE determines a PDCCH monitoring occasion from the PDCCH monitoring periodicity, the PDCCH monitoring offset, and the PDCCH monitoring pattern within a slot. For search space set  in control resource set , the UE determines that a PDCCH monitoring occasion(s) exists in a slot with number  [4, TS 38.211] in a frame with number  if . If the UE is provided higher layer parameter *duration*, the UE monitors PDCCH for search space set  in control resource set  for  consecutive slots, starting from slot , and does not monitor PDCCH for search space set  in control resource set  for the next  consecutive slots.

A PDCCH UE-specific search space at CCE aggregation level  is defined by a set of PDCCH candidates for CCE aggregation level .

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 DL BWP of 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 monitors 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 monitors the PDCCH candidates with carrier indicator field.

A UE is not expected to monitor PDCCH candidates on a DL BWP of 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 DL BWP of a serving cell on which the UE monitors PDCCH candidates, the UE monitors PDCCH candidates at least for the same serving cell.

For a search space set  associated with control resource set , the CCE indexes for aggregation level  corresponding to PDCCH candidate  of the search space set in slot  for a serving cell corresponding to carrier indicator field value  are given by



where

for any common search space, ;

for a UE-specific search space, , ,  for ,  for ,  for , and ;

;

 is the number of CCEs, numbered from 0 to , in control resource set ;

 is the carrier indicator field value if the UE is configured with a carrier indicator field by higher layer parameter *CrossCarrierSchedulingConfig* for the serving cell on which PDCCH is monitored; otherwise, including for any common search space, ;

, where  is the number of PDCCH candidates the UE is configured to monitor for aggregation level  for a serving cell corresponding to  and a search space set ;

for any common search space, ;

for a UE-specific search space,  is the maximum of  over all configured  values for a CCE aggregation level  of search space set  in control resource set ;

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

A UE that is configured for operation with carrier aggregation, and indicates support of search space sharing through higher layer parameter *searchSpaceSharingCA-UL*, and has a PDCCH candidate with CCE aggregation level  in control resource set  for a DCI format 0\_1 having a first size and associated with serving cell , can receive a corresponding PDCCH through a PDCCH candidate with CCE aggregation level  in control resource set  for a DCI format 0\_1 having a second size and associated with serving cell  if the first size and the second size are same. A UE that is configured for operation with carrier aggregation, and indicates support of search space sharing through higher layer parameter *searchSpaceSharingCA-DL*, and has a PDCCH candidate with CCE aggregation level  in control resource set  for a DCI format 1\_1 having a first size and associated with serving cell , can receive a corresponding PDCCH through a PDCCH candidate with CCE aggregation level  in control resource set  for a DCI format 1\_1 having a second size and associated with serving cell  if the first size and the second size are same.

A PDCCH candidate with index  for a search space set  using a set of CCEs in a control resource set  for serving cell  is not counted as a monitored PDCCH candidate if there is a PDCCH candidate with index  for a search space set  in the control resource set  for serving cell  using a same set of CCEs, have identical scrambling, and the corresponding DCI formats for the PDCCH candidates have a same size; otherwise, the PDCCH candidate with index  is counted as a monitored PDCCH candidate.

Table 10.1-2 provides the maximum number of monitored PDCCH candidates, , for subcarrier spacing configuration  for a UE per slot for operation with a single serving cell.

Table 10.1-2: Maximum number  of monitored PDCCH candidates per slot for subcarrier spacing configuration  for a single serving cell

|  |  |
| --- | --- |
|  | Maximum number of monitored PDCCH candidates per slot and per serving cell |
| 0 | 44 |
| 1 | 36 |
| 2 | 22 |
| 3 | 20 |

Table 10.1-3 provides the maximum number of non-overlapped CCEs, , for subcarrier spacing configuration  that a UE is expected to monitor per slot for operation with a single serving cell.

CCEs are non-overlapped if they correspond to

- different control resource set indexes, or

- different first symbols for the reception of the respective PDCCH candidates.

Table 10.1-3: Maximum number  of non-overlapped CCEs per slot for subcarrier spacing configuration  for a single serving cell

|  |  |
| --- | --- |
|  | Maximum number of non-overlapped CCEs per slot and per serving cell |
| 0 | 56 |
| 1 | 56 |
| 2 | 48 |
| 3 | 32 |

If a UE is capable for operation with carrier aggregation with a maximum of 4 downlink cells and the UE is configured with  downlink cells for each corresponding subcarrier spacing configuration  where , and for scheduling on a same cell, the UE is expected to be capable to monitor  PDCCH candidates for DCI formats with different size and/or different corresponding DM-RS scrambling sequences, and  non-overlapped CCEs per slot per cell with subcarrier spacing configuration .

If a UE is capable for operation with carrier aggregation with more than 4 downlink cells, and the UE indicates through *pdcch-BlindDetectionCA* a capability to monitor PDCCH candidates for  downlink cells, and the UE is configured with  with subcarrier spacing configuration , and for scheduling on a same cell, the UE is expected to be able to monitor a total of  PDCCH candidates for DCI formats with different size and/or different corresponding DM-RS scrambling sequences per slot over the  cells with subcarrier spacing configuration , and a total of  non-overlapped CCEs per slot over the  cells with subcarrier spacing configuration . The maximum number of PDCCH candidates for DCI formats with different size and/or different corresponding DM-RS scrambling sequences and the maximum number of non-overlapped CCEs per slot and per cell of the  cells are  and , respectively.

If the UE is configured with a total of  downlink cells with same subcarrier spacing configuration  or if the UE indicates through *pdcch-BlindDetectionCA* a capability to monitor PDCCH candidates for  downlink cells then, for cross-carrier scheduling over the  downlink cells with same subcarrier spacing configuration , including the scheduling cell, the UE is expected to monitor  PDCCH candidates for DCI formats with different size per slot on the scheduling cell and  non-overlapped CCEs per slot on the scheduling cell.

A UE does not expect to be configured common search space sets that result to corresponding total numbers of monitored PDCCH candidates and non-overlapped CCEs per slot that exceed the corresponding maximum numbers per slot.

For same cell scheduling, a UE does not expect a number of PDCCH candidates for DCI formats with different size and/or different corresponding DM-RS scrambling sequences, and a number of corresponding non-overlapped CCEs per slot on a secondary cell to be larger than the corresponding numbers that the UE is capable of monitoring on the secondary cell per slot.

For all search space sets within a slot , denote by  a set of common search space sets in a corresponding set  of control resource sets with cardinality of  and by  a set of UE-specific search space sets in a corresponding set  of control resource sets with cardinality of . The location of UE-specific search space sets , , in  is according to an ascending order of the search space set index .

Denote by  a number of monitored PDCCH candidates, , from the  PDCCH candidates for common search space set  in corresponding control resource set  and by  a number of monitored PDCCH candidates, , from the  PDCCH candidates for UE-specific search space set  in corresponding control resource set .

The UE monitors  PDCCH candidates requiring for the common search space sets requiring a total of  non-overlapping CCEs in a slot.

The UE allocates monitored PDCCH candidates to UE-specific search space sets of the primary cell with subcarrier spacing configuration  in slot  according to the following pseudocode. A UE is not expected to monitor PDCCH in a UE-specific search space set without monitored PDCCH candidates.

Denote by  the set of non-overlapping CCEs for search space set  and by  the cardinality of  where the non-overlapping CCEs for search space set  are determined considering the monitored PDCCH candidates for the common search space sets and the monitored PDCCH candidates for all search space sets , .

Set 

Set 

Set 

while AND 

allocate  monitored PDCCH candidates to UE-specific search space set 

;

;

;

end while

A UE configured with a bandwidth part indicator in DCI formats 0\_1 or 1\_1 determines, in case of an active DL BWP or of an active UL BWP change, the DCI information applicable to the new active DL BWP or UL BWP, respectively, as described in Subclause 12.

For unpaired spectrum operation, if a UE is not configured for PUSCH/PUCCH transmission on serving cell , the UE is not expected to monitor PDCCH on serving cell  if the PDCCH overlaps in time with SRS transmission (including any interruption due to uplink or downlink RF retuning time [10, TS 38.133]) on serving cell  and if the UE is not capable of simultaneous reception and transmission on serving cell and serving cell .

If a UE is provided higher layer parameters *resourceblocks* and s*ymbolsInResourceBlock* in *RateMatchPattern*, or if the UE is additionally provided higher layer parameter *periodicityAndPattern* in *RateMatchPattern*, the UE can determine a set of RBs in symbols of a slot that are not available for PDSCH reception as described in [6, TS 38.214]. If a PDCCH candidate in a slot is mapped to one or more subcarriers that overlap with subcarriers of any RB in the set of RBs in symbols of the slot, the UE is not expected to monitor the PDCCH candidate.

## 10.2 PDCCH validation for DL SPS and UL grant Type 2

A UE validates, for scheduling activation or scheduling release, a DL SPS assignment PDCCH or configured UL grant Type 2 PDCCH if

- the CRC parity bits of a corresponding DCI format are scrambled with a CS-RNTI provided by higher layer parameter *cs-RNTI*, and

- the new data indicator field for the enabled transport block is set to '0'.

Validation of the DCI format is achieved if all fields for the DCI format are set according to Table 10.2-1 or Table 10.2-2.

If validation is achieved, the UE considers the information in the DCI format as a valid activation or valid release of DL SPS or configured UL grant Type 2. If validation is not achieved, the UE considers the DCI format as having been detected with a non-matching CRC.

Table 10.2-1: Special fields for DL SPS and UL grant Type 2 scheduling activation PDCCH validation

|  |  |  |  |
| --- | --- | --- | --- |
|  | DCI format 0\_0/0\_1 | DCI format 1\_0 | DCI format 1\_1 |
| HARQ process number | set to all '0's | set to all '0's | set to all '0's |
| Redundancy version | set to '00' | set to '00' | For the enabled transport block: set to '00' |

Table 10.2-2: Special fields for DL SPS and UL grant Type 2 scheduling release PDCCH validation

|  |  |  |
| --- | --- | --- |
|  | DCI format 0\_0 | DCI format 1\_0 |
| HARQ process number | set to all '0's | set to all '0's |
| Redundancy version | set to '00' | set to '00' |
| Modulation and coding scheme | set to all '1's | set to all '1's |
| Resource block assignment | set to all '1's | set to all '1's |

A UE with capability 1 [6, TS 36.214] is expected to be able to provide HARQ-ACK information in response to a DL SPS scheduling release after  symbols from the last symbol of a PDCCH providing the DL SPS scheduling release where, for the subcarrier spacing of the PDCCH reception,  for 15 kHz,  for 30 kHz,  for 60 kHz, and  for 120 kHz.

# 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 *tdd-UL-DL-ConfigurationCommon* and the UE is not provided higher layer parameter *tdd-UL-DL-ConfigurationCommon2*, the UE sets the slot format per slot over a number of slots as indicated by higher layer parameter *tdd-UL-DL-ConfigurationCommon*.

The higher layer parameter *tdd-UL-DL-ConfigurationCommon* provides

- A reference subcarrier spacing  by higher layer parameter *referenceSubcarrierSpacing*

- A slot configuration period of  msec by higher layer parameter *dl-UL-TransmissionPeriodicity*

- A number of slots  with only downlink symbols by higher layer parameter *nrofDownlinkSlots*

- A number of downlink symbols  by higher layer parameter *nrofDownlinkSymbols*

- A number of slots  with only uplink symbols by higher layer parameter *nrofUplinkSlots*

- A number of uplink symbols  by higher layer parameter *nrofUplinkSymbols*

A value  msec is valid only for . A value  msec is valid only for  or . A value  msec is valid only for , or , or .

A slot configuration period of  msec includes  slots with  subcarrier spacing. From the  slots, a first  slots include only downlink symbols and a last  slots include only uplink symbols. The  symbols after the first  slots are downlink symbols. The  symbols before the last  slots are uplink symbols. The remaining  are flexible symbols.

The first symbol every  periods is a first symbol in an even frame.

A UE expects that the reference subcarrier spacing  is smaller than or equal to the subcarrier spacing  for any of the configured DL BWP or UL BWP.

If the UE is provided higher layer parameters *tdd-UL-DL-ConfigurationCommon* and *tdd-UL-DL-ConfigurationCommon2*, the UE sets the slot format per slot over a first number of slots as indicated by higher layer parameter *tdd-UL-DL-ConfigurationCommon* and the UE sets the slot format per slot over a second number of slots as indicated by *tdd-UL-DL-ConfigurationCommon2*.

The higher layer parameter *tdd-UL-DL-ConfigurationCommon2* provides

- A reference subcarrier spacing  by higher layer parameter *referenceSubcarrierSpacing*;

- A slot configuration period of  msec by higher layer parameter *dl-UL-TransmissionPeriodicity*;

- A number of slots  with only downlink symbols by higher layer parameter *nrofDownlinkSlots*;

- A number of downlink symbols  by higher layer parameter *nrofDownlinkSymbols*;

- A number of slots  with only uplink symbols by higher layer parameter *nrofUplinkSlots*;

- A number of uplink symbols  by higher layer parameter *nrofUplinkSymbols*.

A UE expects .

A value  msec is valid only for . A value  msec is valid only for  or . A value  msec is valid only for , or , or .

A slot configuration period of  slots includes first  slots and second  slots. From the  slots, a first  slots include only downlink symbols and a last  include only uplink symbols. The  symbols after the first  slots are downlink symbols. The  symbols before the last  slots are uplink symbols. The remaining  are flexible symbols.

A UE expects that  divides 20 msec.

The first symbol every  periods is a first symbol in an even frame.

If the UE is additionally provided higher layer parameter *tdd-UL-DL-ConfigDedicated*, the parameter *tdd-UL-DL-ConfigDedicated* overrides only flexible symbols per slot over the number of slots as provided by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationCommon2*.

The higher layer parameter *tdd-UL-DL-ConfigDedicated* provides

- A set of slot configurations by higher layer parameter *slotSpecificConfigurationsToAddModList*;

- For each slot configuration from the set of slot configurations

- A slot index for a slot provided by higher layer parameter *slotIndex*;

- A set of symbols for a slot by higher layer parameter *symbols* where

- if *symbols* = *allDownlink*, all symbols in the slot are downlink;

- if *symbols* = *allUplink*, all symbols in the slot are uplink;

- if *symbols* = *explicit* and higher layer parameter *nrofDownlinkSymbols* provides a number of downlink first symbols in the slot and higher layer parameter *nrofUplinkSymbols* provides a number of uplink last symbols in the slot. If *nrofDownlinkSymbols* is not provided, there are no downlink first symbols in the slot and if *nrofUplinkSymbols* is not provided, there are no uplink last symbols in the slot. The remaining symbols in the slot are flexible.

For each slot having a corresponding index provided by higher layer parameter *slotIndex*, the UE applies a format provided by the corresponding higher layer parameter *symbols*. The UE does not expect *tdd-UL-DL-ConfigDedicated* to indicate as uplink or as downlink a symbol that *tdd-UL-DL-ConfigurationCommon* or, when provided, *tdd-UL-DL-ConfigurationCommon2* indicates as a downlink or as an uplink symbol, respectively.

For each slot configuration provided by *tdd-UL-DL-ConfigDedicated*, a reference subcarrier spacing is the reference subcarrier spacing  provided by *tdd-UL-DL-ConfigurationCommon*.

A slot configuration period and a number of downlink symbols, uplink symbols, and flexible symbols in each slot of the slot configuration period are determined from higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2* and *tdd-UL-DL-ConfigDedicated* and are common to each configured BWP.

A UE considers symbols in a slot indicated as downlink by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated* to be available for receptions and considers symbols in a slot indicated as uplink by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon*2, or by *tdd*-*UL-DL-ConfigDedicated* to be available for transmissions.

If a UE is not configured to monitor PDCCH for DCI format 2-0, for a set of symbols of a slot that are indicated as flexible by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, or *tdd*-*UL-DL-ConfigDedicated*, when provided to a UE, or when *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, and *tdd*-*UL-DL-ConfigDedicated* are not provided to the UE.

- The UE receives PDSCH or CSI-RS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format 1\_0, DCI format 1\_1, or DCI format 0\_1.

- The UE transmits PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3.

- If the UE is configured by higher layers to receive a PDCCH, or a PDSCH, or a CSI-RS in the set of symbols of the slot, the UE receives the PDCCH, the PDSCH, or the CSI-RS if

- the UE does not detect a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3 that indicates to the UE to transmit a PUSCH, a PUCCH, a PRACH, or a SRS in the set of symbols of the slot, or

- the UE detects a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3 that indicates to the UE to transmit a PUSCH, a PUCCH, a PRACH, or a SRS in the set of symbols of the slot and a number of symbols between a last symbol of a control resource set where the UE detects the DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3 and a first symbol in the set of symbols is smaller than the PUSCH preparation time N2 for the corresponding PUSCH timing capability [6, TS 38.214].

Otherwise, the UE does not receive the PDCCH, or the PDSCH, or the CSI-RS in the set of symbols of the slot.

- If the UE is configured by higher layers to transmit a periodic SRS, or a PUCCH, or a PUSCH, or a PRACH in the set of symbols in the slot, the UE transmits the periodic SRS, or the PUCCH, or the PUSCH, or the PRACH in the set of symbols of the slot if

- the UE does not detect a DCI format 1\_0, DCI format 1\_1, or DCI format 0\_1 that indicates to the UE to receive PDSCH or CSI-RS in the set of symbols in the slot, or

- the UE detects a DCI format 1\_0, DCI format 1\_1, or DCI format 0\_1 that indicates to the UE to receive PDSCH or CSI-RS in the set of symbols in the slot and a number of symbols between a last symbol of a control resource set where the UE detects the DCI format 1\_0 or DCI format 1\_1 and a first symbol in the set of symbols is smaller than the PUSCH preparation time N2 for the corresponding PUSCH timing capability.

Otherwise, the UE does not transmit the periodic SRS, or the PUCCH, or the PUSCH, or the PRACH in the set of symbols of the slot.

A PUSCH preparation time N2 throughout Subclause 11.1 is defined with respect to the subcarrier spacing of the PDCCH providing the corresponding DCI format.

For a set of symbols of a slot that are indicated to a UE as uplink by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated*, when provided to the UE, the UE does not 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 to a UE as downlink by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated*, when provided to the UE, the UE does not 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 to a UE as flexible by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated*, when provided to the UE, the UE does not expect to receive both dedicated higher layer parameters configuring transmission from the UE in the set of symbols of the slot and dedicated higher layer parameters configuring reception by the UE in the set of symbols of the slot.

For a set of symbols of a slot that are indicated to a UE by higher layer parameter *ssb-PositionsInBurst* in *SystemInformationBlockType1* or *ssb-PositionsInBurst* in *ServingCellConfigCommon*, when provided to the UE, for reception of SS/PBCH blocks, the UE does not transmit PUSCH, PUCCH, PRACH in the slot if a transmission would overlap with any symbol from the set of symbols and the UE does not transmit SRS in the set of symbols of the slot. The UE does not expect the set of symbols of the slot to be indicated as uplink by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated*, when provided to the UE.

For a set of symbols of a slot corresponding to a valid PRACH occasion and  symbols before the valid PRACH occasion, as described in Sublcause 8.1, the UE does not receive PDCCH for Type1-PDCCH common search space, PDSCH, or CSI-RS in the slot if a reception would overlap with any symbol from the set of symbols. The UE does not expect the set of symbols of the slot to be indicated as downlink by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated*.

For a set of symbols of a slot indicated to a UE by higher layer parameters *pdcch-ConfigSIB1* in *MasterInformationBlock* for a control resource set for Type0-PDCCH common search space, the UE does not expect the set of symbols to be indicated as uplink by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL- ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated*.

If a UE is scheduled by a DCI format 1\_1 to receive PDSCH over multiple slots, and if higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated*, when provided to the UE, indicate that, for a slot from the multiple slots, at least one symbol from a set of symbols where the UE is scheduled PDSCH reception in the slot is an uplink symbol, the UE does not receive the PDSCH in the slot.

If a UE is scheduled by a DCI format 0\_1 to transmit PUSCH over multiple slots, and if higher layer parameter *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-Configuration-Common2*, or *tdd-UL-DL-ConfigDedicated*, when provided to a UE, indicates that, for a slot from the multiple slots, at least one symbol from a set of symbols where the UE is scheduled PUSCH transmission in the slot is a downlink symbol, the UE does not transmit the PUSCH in the slot.

### 11.1.1 UE procedure for determining slot format

This subclause applies for a serving cell that is included in a set of serving cells configured to a UE by higher layer parameters *slotFormatCombToAddModList* and *slotFormatCombToReleaseList*.

If a UE is configured by higher layers with parameter *SlotFormatIndicator*, the UE is provided with a SFI-RNTI by higher layer parameter *sfi-RNTI* and with a payload size of DCI format 2\_0 by higher layer parameter *dci-PayloadSize*. The UE is also provided in one or more serving cells with a configuration for a search space set and a corresponding control resource set  for monitoring  PDCCH candidates for DCI format 2\_0 with a CCE aggregation level of  CCEs as described in Subclause 10.1. The  PDCCH candidates are the first  PDCCH candidates for CCE aggregation level  for search space set  in control resource set .

For each serving cell in the set of serving cells, the UE can be provided:

- an identity of the serving cell by higher layer parameter *servingCellId*

- a location of a SFI-index field in DCI format 2\_0 by higher layer parameter *positionInDCI*

- a set of slot format combinations by higher layer parameter *slotFormatCombinations*, where each slot format combination in the set of slot format combinations includes

- one or more slot formats indicated by a respective higher layer parameter *slotFormats* for the slot format combination, and

- a mapping for the slot format combination provided by *slotFormats* to a corresponding SFI-index field value in DCI format 2\_0 provided by higher layer parameter *slotFormatCombinationId*

- for unpaired spectrum operation, a reference subcarrier spacing  by higher layer parameter *subcarrierSpacing* and, when a supplementary UL carrier is configured for the serving cell, a reference subcarrier spacing  by higher layer parameter *subcarrierSpacing2* for the supplementary UL carrier

- for paired spectrum operation, a reference subcarrier spacing  for a DL BWP by higher layer parameter *subcarrierSpacing* and a reference subcarrier spacing  for an UL BWP by higher layer parameter *subcarrierSpacing2*

A SFI-index field value in a DCI format 2\_0 indicates to a UE a slot format for each slot in a number of slots for each DL BWP or each UL BWP starting from a slot where the UE detects the DCI format 2\_0. The number of slots is equal to or larger than a PDCCH monitoring periodicity for DCI format 2\_0. The SFI-index field includes  bits where maxSFIindex is the maximum value of the values provided by corresponding higher layer parameters *slotFormatCombinationId*. A slot format is identified by a corresponding format index as provided in Table 11.1.1-1 where 'D' denotes a downlink symbol, 'U' denotes an uplink symbol, and 'F' denotes a flexible symbol.

If a PDCCH monitoring periodicity for DCI format 2\_0, provided to a UE for the search space set  by higher layer parameter *monitoringSlotPeriodicityAndOffset*,is smaller than a duration of a slot format combination the UE obtains at a PDCCH monitoring occasion for DCI format 2\_0 by a corresponding SFI-index field value, and the UE detects more than one DCI formats 2\_0 indicating a slot format for a slot, the UE expects each of the more than one DCI formats 2\_0 to indicate a same format for the slot.

A UE does not expect to be configured to monitor PDCCH for DCI format 2\_0 on a second serving cell that uses larger subcarrier spacing than the serving cell.

Table 11.1.1-1: Slot formats for normal cyclic prefix

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Format** | **Symbol number in a slot** | | | | | | | | | | | | | |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
| 0 | D | D | D | D | D | D | D | D | D | D | D | D | D | D |
| 1 | U | U | U | U | U | U | U | U | U | U | U | U | U | U |
| 2 | F | F | F | F | F | F | F | F | F | F | F | F | F | F |
| 3 | D | D | D | D | D | D | D | D | D | D | D | D | D | F |
| 4 | D | D | D | D | D | D | D | D | D | D | D | D | F | F |
| 5 | D | D | D | D | D | D | D | D | D | D | D | F | F | F |
| 6 | D | D | D | D | D | D | D | D | D | D | F | F | F | F |
| 7 | D | D | D | D | D | D | D | D | D | F | F | F | F | F |
| 8 | F | F | F | F | F | F | F | F | F | F | F | F | F | U |
| 9 | F | F | F | F | F | F | F | F | F | F | F | F | U | U |
| 10 | F | U | U | U | U | U | U | U | U | U | U | U | U | U |
| 11 | F | F | U | U | U | U | U | U | U | U | U | U | U | U |
| 12 | F | F | F | U | U | U | U | U | U | U | U | U | U | U |
| 13 | F | F | F | F | U | U | U | U | U | U | U | U | U | U |
| 14 | F | F | F | F | F | U | U | U | U | U | U | U | U | U |
| 15 | F | F | F | F | F | F | U | U | U | U | U | U | U | U |
| 16 | D | F | F | F | F | F | F | F | F | F | F | F | F | F |
| 17 | D | D | F | F | F | F | F | F | F | F | F | F | F | F |
| 18 | D | D | D | F | F | F | F | F | F | F | F | F | F | F |
| 19 | D | F | F | F | F | F | F | F | F | F | F | F | F | U |
| 20 | D | D | F | F | F | F | F | F | F | F | F | F | F | U |
| 21 | D | D | D | F | F | F | F | F | F | F | F | F | F | U |
| 22 | D | F | F | F | F | F | F | F | F | F | F | F | U | U |
| 23 | D | D | F | F | F | F | F | F | F | F | F | F | U | U |
| 24 | D | D | D | F | F | F | F | F | F | F | F | F | U | U |
| 25 | D | F | F | F | F | F | F | F | F | F | F | U | U | U |
| 26 | D | D | F | F | F | F | F | F | F | F | F | U | U | U |
| 27 | D | D | D | F | F | F | F | F | F | F | F | U | U | U |
| 28 | D | D | D | D | D | D | D | D | D | D | D | D | F | U |
| 29 | D | D | D | D | D | D | D | D | D | D | D | F | F | U |
| 30 | D | D | D | D | D | D | D | D | D | D | F | F | F | U |
| 31 | D | D | D | D | D | D | D | D | D | D | D | F | U | U |
| 32 | D | D | D | D | D | D | D | D | D | D | F | F | U | U |
| 33 | D | D | D | D | D | D | D | D | D | F | F | F | U | U |
| 34 | D | F | U | U | U | U | U | U | U | U | U | U | U | U |
| 35 | D | D | F | U | U | U | U | U | U | U | U | U | U | U |
| 36 | D | D | D | F | U | U | U | U | U | U | U | U | U | U |
| 37 | D | F | F | U | U | U | U | U | U | U | U | U | U | U |
| 38 | D | D | F | F | U | U | U | U | U | U | U | U | U | U |
| 39 | D | D | D | F | F | U | U | U | U | U | U | U | U | U |
| 40 | D | F | F | F | U | U | U | U | U | U | U | U | U | U |
| 41 | D | D | F | F | F | U | U | U | U | U | U | U | U | U |
| 42 | D | D | D | F | F | F | U | U | U | U | U | U | U | U |
| 43 | D | D | D | D | D | D | D | D | D | F | F | F | F | U |
| 44 | D | D | D | D | D | D | F | F | F | F | F | F | U | U |
| 45 | D | D | D | D | D | D | F | F | U | U | U | U | U | U |
| 46 | D | D | D | D | D | F | U | D | D | D | D | D | F | U |
| 47 | D | D | F | U | U | U | U | D | D | F | U | U | U | U |
| 48 | D | F | U | U | U | U | U | D | F | U | U | U | U | U |
| 49 | D | D | D | D | F | F | U | D | D | D | D | F | F | U |
| 50 | D | D | F | F | U | U | U | D | D | F | F | U | U | U |
| 51 | D | F | F | U | U | U | U | D | F | F | U | U | U | U |
| 52 | D | F | F | F | F | F | U | D | F | F | F | F | F | U |
| 53 | D | D | F | F | F | F | U | D | D | F | F | F | F | U |
| 54 | F | F | F | F | F | F | F | D | D | D | D | D | D | D |
| 55 | D | D | F | F | F | U | U | U | D | D | D | D | D | D |
| 56 – 254 | Reserved | | | | | | | | | | | | | |
| 255 | UE determines the slot format for the slot based on *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated* and, if any, on detected DCI formats | | | | | | | | | | | | | |

For unpaired spectrum operation for a UE on a serving cell, the UE is provided by higher layer parameter *subcarrierSpacing* a reference subcarrier spacing configuration of  for each slot format in a combination of slot formats indicated by a SFI-index field value in DCI format 2\_0. The UE expects that for a reference subcarrier spacing configuration of  and for an active DL BWP and UL BWP pair with subcarrier spacing configuration of , it is . Each slot format in the combination of slot formats indicated by the SFI-index field value in DCI format 2\_0 is applicable to  consecutive slots in the active DL BWP and UL BWP pair where the first slot starts at a same time as a first slot for the reference subcarrier spacing configuration of  and each downlink or flexible or uplink symbol for the reference subcarrier spacing configuration of  corresponds to  consecutive downlink or flexible or uplink symbols for the subcarrier spacing configuration .

For paired spectrum operation for a UE on a serving cell, the SFI-index field in DCI format 2\_0 indicates a combination of slot formats that includes a combination of slot formats for a reference DL BWP and a combination of slot formats for a reference UL BWP of the serving cell. The UE is provided by higher layer parameter *subcarrierSpacing* a reference subcarrier spacing configuration of  for the combination of slot formats indicated by the SFI-index field value in DCI format 2\_0 for the reference DL BWP of the serving cell. The UE is provided by higher layer parameter *subcarrierSpacing2* a reference subcarrier spacing configuration of  for the combination of slot formats indicated by the SFI-index field value in DCI format 2\_0 for the reference UL BWP of the serving cell. If  and for each  values provided by a value of higher layer parameter *slotFormats*, where the value of *slotFormats* is determined by a value of *slotFormatCombinationId* in *slotFormatCombination* and the value of *slotFormatCombinationId* is set by the value of the SFI-index field value in DCI format 2\_0, the first  values for the combination of slot formats are applicable to the reference DL BWP and the next value is applicable to the reference UL BWP. If  and for each  values provided by higher layer parameter *slotFormats*, the first value for the combination of slot formats is applicable to the reference DL BWP and the next  values are applicable to the reference UL BWP.

The UE is provided with a reference subcarrier spacing configuration of  so that for an active DL BWP with subcarrier spacing configuration of , it is . The UE is provided with a reference subcarrier spacing configuration of  so that for an active UL BWP with subcarrier spacing configuration of , it is . Each slot format for a combination of slot formats indicated by the SFI-index field value in DCI format 2\_0 for the reference DL BWP, by indicating a value for *slotFormatCombinationId* that is mapped to a value of *slotFormats* in *slotFormatCombination*, is applicable to  consecutive slots for the active DL BWP where the first slot starts at a same time as a first slot in the reference DL BWP and each downlink or flexible symbol for the reference subcarrier spacing configuration of  corresponds to  consecutive downlink or flexible symbols for the subcarrier spacing configuration . Each slot format for the combination of slot formats for the reference UL BWP is applicable to  consecutive slots for the active UL BWP where the first slot starts at a same time as a first slot in the reference UL BWP and each uplink or flexible symbol for the reference subcarrier spacing configuration of  corresponds to  consecutive uplink or flexible symbols for the subcarrier spacing configuration .

For unpaired spectrum operation with a second UL carrier for a UE on a serving cell, the SFI-index field value in DCI format 2\_0 indicates a combination of slot formats that includes a combination of slot formats for a reference first UL carrier of the serving cell and a combination of slot formats for a reference second UL carrier of the serving cell. The UE is provided by higher layer parameter *subcarrierSpacing* a reference subcarrier spacing configuration of  for the combination of slot formats indicated by the SFI-index field in DCI format 2\_0 for the reference first UL carrier of the serving cell. The UE is provided by higher layer parameter *subcarrierSpacing2* a reference subcarrier spacing configuration of  for the combination of slot formats indicated by the SFI-index field value in DCI format 2\_0 for the reference second UL carrier of the serving cell. For each  values of higher layer parameter *slotFormats*, the first  values for the combination of slot formats are applicable to the reference first UL carrier and the next value is applicable to the reference second UL carrier.

The UE expects to be provided with a reference subcarrier spacing configuration of  so that for an active UL BWP in the second UL carrier with subcarrier spacing configuration of , it is . Each slot format for a combination of slot formats indicated by the SFI-index field in DCI format 2\_0 for the reference first UL carrier is applicable to  consecutive slots for the active DL BWP and UL BWP pair in the first UL carrier where the first slot starts at a same time as a first slot in the reference first UL carrier. Each slot format for the combination of slot formats for the reference second UL carrier is applicable to  consecutive slots for the active UL BWP in the second UL carrier where the first slot starts at a same time as a first slot in the reference second UL carrier.

If a BWP in the serving cell is configured with  and with extended CP, the UE expects , , or . A format for a slot with extended CP is determined from a format for a slot with normal CP. A UE determines an extended CP symbol to be a downlink/uplink/flexible symbol if the overlapping normal CP symbols that are downlink/uplink/flexible symbols, respectively. A UE determines an extended CP symbol to be a flexible symbol if one of the overlapping normal CP symbols is flexible. A UE determines an extended CP symbol to be a flexible symbol if the pair of the overlapping normal CP symbols includes a downlink and an uplink symbol.

A reference subcarrier spacing configurations of , or , or , or  is either 0, or 1, or 2 for frequency range 1 and is either 2 or 3 for frequency range 2.

For a set of symbols of a slot, a UE does not expect to detect a DCI format 2\_0 with an SFI-index field value indicating the set of symbols of the slot as uplink and to detect a DCI format 1\_0, a DCI format 1\_1, or DCI format 0\_1 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 does not expect to detect a DCI format 2\_0 with an SFI-index field value indicating the set of symbols in the slot as downlink and to detect a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3 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 parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, or *tdd-UL-DL-ConfigDedicated*, when provided to a UE, the UE does not expect to detect a DCI format 2\_0 with an SFI-index field value indicating the set of symbols of the slotas uplink/downlink, respectively, or as flexible.

For a set of symbols of a slot indicated to a UE by higher layer parameter *ssb-PositionsInBurst* in *SystemInformationBlockType1* or *ssb-PositionsInBurst* in *ServingCellConfigCommon* for reception of SS/PBCH blocks, the UE does not expect to detect a DCI format 2\_0 with an SFI-index field value indicating the set of symbols of the slotas uplink.

For a set of symbols of a slot indicated to a UE by higher layer parameter *prach-ConfigurationIndex* in *RACH-ConfigCommon* for PRACH transmissions, the UE does not expect to detect a DCI format 2\_0 with an SFI-index field value indicating the set of symbols of the slotas downlink.

For a set of symbols of a slot indicated to a UE by higher layer parameters *pdcch-ConfigSIB1* in *MasterInformationBlock* for a control resource set for Type0-PDCCH common search space, the UE does not expect to detect a DCI format 2\_0 with an SFI-index field value indicating the set of symbols of the slotas uplink.

For a set of symbols of a slot indicated to a UE as flexible by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, and *tdd-UL-DL-ConfigDedicated*, when provided to the UE, or when higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, and *tdd-UL-DL-ConfigDedicated* are not provided to the UE, and if the UE detects a DCI format 2\_0 providing a format for the slot using a slot format value other than 255

- If one or more symbols from the set of symbols are symbols in a control resource set configured to the UE for PDCCH monitoring, the UE receives PDCCH in the control resource set only if an SFI-index field value in DCI format 2\_0 indicates that the one or more symbols are downlink symbols.

- If an SFI-index field value in DCI format 2\_0 indicates the set of symbols of the slot as flexible and the UE detects a DCI format 1\_0, DCI format 1\_1, or DCI format 0\_1indicating to the UE to receive PDSCH or CSI-RS in the set of symbols of the slot, the UE receives PDSCH or CSI-RS in the set of symbols of the slot.

- If an SFI-index field value in DCI format 2\_0 indicates the set of symbols of the slot as flexible and the UE detects a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3 indicating to the UE to transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot the UE transmits the PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot.

- If an SFI-index field value in DCI format 2\_0 indicates the set of symbols of the slot as flexible, and the UE does not detect a DCI format 1\_0, DCI format 1\_1, or DCI format 0\_1 indicating to the UE to receive PDSCH or CSI-RS, or the UE does not detect a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3 indicating to the UE to transmit PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot, the UE does not transmit or receive in the set of symbols of the slot.

- If the UE is configured by higher layers to receive PDSCH or CSI-RS in the set of symbols of the slot, the UE receives the PDSCH or the CSI-RS in the set of symbols of the slot only if an SFI-index field value in DCI format 2\_0 indicates the set of symbols of the slot as downlink.

- If the UE is configured by higher layers to transmit PUCCH, or PUSCH, or PRACH in the set of symbols of the slot, the UE transmits the PUCCH, or the PUSCH, or the PRACH in the slot only if an SFI-index field value in DCI format 2\_0 indicates the set of symbols of the slot as uplink.

- If the UE is configured by higher layers to transmit periodic SRS in the set of symbols of the slot, the UE transmits the periodic SRS only in a subset of symbols from the set of symbols of the slot indicated as uplink symbols by an SFI-index field value in DCI format 2\_0.

- A UE does not expect to detect an SFI-index field value in DCI format 2\_0 indicating the set of symbols of the slot as downlink and also detect a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3 indicating to the UE to transmit SRS, PUSCH, PUCCH, or PRACH, in one or more symbols from the set of symbols of the slot.

- A UE does not expect to detect an SFI-index field value in DCI format 2\_0 indicating the set of symbols of the slot as downlink if the set of symbols of the slot includes symbols corresponding to a first repetition of a PUSCH transmission activated by an UL Type 2 grant PDCCH as described in Subclause 10.2.

- A UE does not expect to detect an SFI-index field value in DCI format 2\_0 indicating the set of symbols of the slot as uplink and also detect a DCI format 1\_0 or DCI format 1\_1 or DCI format 0\_1 indicating to the UE to receive PDSCH or CSI-RS in one or more symbols from the set of symbols of the slot.

If a UE is configured by higher layers to receive a CSI-RS or a PDSCH in a set of symbols of a slot and the UE detects a DCI format 2\_0 with a slot format value other than 255 that indicates a slot format with a subset of symbols from the set of symbols as uplink or flexible, or the UE detects a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3 indicating to the UE to transmit PUSCH, PUCCH, SRS, or PRACH in at least one symbol in the set of the symbols, the UE cancels the CSI-RS reception in the set of symbols of the slot or cancels the PDSCH reception in the slot.

If a UE is configured by higher layers to transmit periodic SRS, or PUCCH, or PUSCH, or PRACH in a set of symbols of a slot and the UE detects a DCI format 2\_0 with a slot format value other than 255 that indicates a slot format with a subset of symbols from the set of symbols as downlink or flexible, or the UE detects a DCI format 1\_0, DCI format 1\_1, or DCI format 0\_1 indicating to the UE to receive CSI-RS or PDSCH in at least one symbol in the set of symbols, then

- the UE does not expect to cancel the transmission in symbols from the subset of symbols that occur, relative to a last symbol of a control resource set where the UE detects the DCI format 2\_0, after a number of symbols that is smaller than the PUSCH preparation time N2 for the corresponding PUSCH timing capability [6, TS 38.214];

- the UE cancels the PUCCH, or PUSCH, or PRACH transmission in the remaining symbols of the slot and cancels the periodic SRS transmission in the subset of symbols of the slot.

A PUSCH preparation time N2 throughout Subclause 11.1.1 is defined with respect to the subcarrier spacing of the PDCCH providing DCI format 2\_0.

A UE assumes that flexible symbols in a control resource set configured to the UE for PDCCH monitoring are downlink symbols if the UE does not detect an SFI-index field value in DCI format 2\_0 indicating the set of symbols of the slot as flexible or uplink and the UE does not detect a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3 indicating to the UE to transmit SRS, PUSCH, PUCCH, or PRACH in the set of symbols.

For a set of symbols of a slot that are indicated as flexible by higher layer parameters *tdd-UL-DL-ConfigurationCommon*, *tdd-UL-DL-ConfigurationCommon2*, and *tdd-UL-DL-ConfigDedicated*, when provided to a UE, or when higher layer parameters *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationCommon2*, and *tdd-UL-DL-ConfigDedicated* are not provided to the UE, and if the UE does not detect a DCI format 2\_0 providing a slot format for the slot.

- The UE receives PDSCH or CSI-RS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format 1\_0, DCI format 1\_1, or DCI format 0\_1.

- The UE transmits PUSCH, PUCCH, PRACH, or SRS in the set of symbols of the slot if the UE receives a corresponding indication by a DCI format 0\_0, DCI format 0\_1, DCI format 1\_0, DCI format 1\_1, or DCI format 2\_3.

- The UE receives PDCCH as described in Subclause 11.1.

- If the UE is configured by higher layers to receive PDSCH or CSI-RS in the set of symbols of the slot, the UE does not receive the PDSCH or the CSI-RS in the set of symbols of the slot.

- If the UE is configured by higher layers to transmit periodic SRS, or PUCCH, or PUSCH, or PRACH in the set of symbols of the slot, the UE

- does not transmit the PUCCH, or the PUSCH, or the PRACH in the slot and does not transmit the SRS in symbols from the set of symbols in the slot, if any, starting from a symbol that is a number of symbols equal to the PUSCH preparation time N2 for the corresponding PUSCH timing capability after a last symbol of a control resource set where the UE is configured to monitor PDCCH for DCI format 2\_0;

- is not expected to cancel the transmission of the periodic SRS, or the PUCCH, or the PUSCH, or the PRACH in symbols from the set of symbols in the slot, if any, starting before a symbol that is a number of symbols equal to the PUSCH preparation time N2 for the corresponding PUSCH timing capability after a last symbol of a control resource set where the UE is configured to monitor PDCCH for DCI format 2\_0.

## 11.2 Interrupted transmission indication

If a UE is provided higher layer parameter *DownlinkPreemption*, 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 with:

- a set of serving cells by higher layer parameter *INT-ConfigurationPerServingCell* that includes a set of serving cell indexes provided by corresponding higher layer parameters *servingCellId* and a corresponding set of locations for fields in in DCI format 2\_1 by higher layer parameter *positionInDCI*;

- an information payload size for DCI format 2\_1 by higher layer parameter *dci-PayloadSize*;

- an indication granularity for time-frequency resources by higher layer parameter *timeFrequencySet.*

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 2\_1. The indication by the DCI format 2\_1 is not applicable to receptions of SS/PBCH blocks.

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

If a UE detects a DCI format 2\_1 in a PDCCH transmitted in a control resource set in a slot, the set of symbols indicated by a field in DCI format 2\_1 includes the last  symbols prior to the first symbol of the control resource set in the slot where is the PDCCH monitoring periodicity provided by the value of higher layer parameter *monitoringSlotPeriodicityAndOffset,* as described in Subclause 10.1,  is the number of symbols per slot, is the subcarrier spacing configuration for a serving cell with mapping to a respective field in the DCI format 2\_1,  is the subcarrier spacing configuration of the DL BWP where the UE receives the PDCCH conveying the DCI format 2\_1. If the UE is configured with higher layer parameters *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL- ConfigurationCommon2*, symbols indicated as uplink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL- ConfigurationCommon2* are excluded from the last symbols prior to the first symbol of the control resource set in the slot. The resulting set of symbols includes a number of symbols that is denoted as .

The UE does not expect to be provided values of , , and  resulting to a value of  that is not an integer.

A UE is provided the indication granularity for the set of PRBs and for the set of symbols by higher layer parameter *timeFrequencySet*.

If the value of *timeFrequencySet* 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  symbol groups includes  symbols, each of the last  symbol groups includes  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 *timeFrequencySet* 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  symbol groups includes  symbols, each of the last  symbol groups includes  symbols, a first bit in a pair of bits for a symbol group is applicable to the subset of first  PRBs from the set of  PRBs, a second bit in the pair of bits for the symbol group is applicable to the subset of last  PRBs from the set of  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 Group TPC commands for PUCCH/PUSCH

A UE can be provided with

- a TPC-PUCCH-RNTI for a DCI format 2\_2 by higher layer parameter *tpc-PUCCH-RNTI*

- A field in DCI format 2\_2 is a TPC command of 2 bits mapping to  values as described in Subclause 7.2.1

- an index for a location in DCI format 2\_2 of a first bit for a TPC command field for the PCell, or the SpCell for EN-DC operation, or for a carrier of the PCell by higher layer parameter *tpc-IndexPCell*

- an index for a location in DCI format 2\_2 of a first bit for a TPC command field for the PSCell or for a carrier for the PSCell by higher layer parameter *tpc-IndexPUCCH-Scell*

- a mapping for the PUCCH power control adjustment state , by a corresponding {0, 1} value of a closed loop index field that is appended to the TPC command field for the PCell, or for a carrier of the PCell, or for the PSCell, or for a carrier of the PSCell, in DCI format 2\_2 if the UE indicates a capability to support two PUCCH power control adjustment states by higher layer parameter *twoDifferentTPC-Loop-PUCCH*, and if the UE is configured for two PUCCH power control adjustment states by higher layer parameter *twoPUCCH-PC-AdjustmentStates*.

The UE is also provided on a serving cell with a configuration for a search space set and a corresponding control resource set  for monitoring PDCCH candidates for DCI format 2\_2 with CRC scrambled by a TPC-PUCCH-RNTI as described in Subclause 10.1.

For PUSCH transmissions on an uplink carrier or on a second uplink carrier of a serving cell, a UE can be provided with

- a TPC-PUSCH-RNTI for a DCI format 2\_2 by higher layer parameter *tpc-PUSCH-RNTI*

- A field in DCI format 2\_2 is a TPC command of 2 bits mapping to  values as described in Subclause 7.1.1

- an index for a location in DCI format 2\_2 of a first bit for a TPC command field for the uplink carrier of the serving cell by higher layer parameter *tpc-Index*

- an index for a location in DCI format 2\_2 of a first bit for a TPC command field for the second uplink carrier of the serving cell by higher layer parameter *tpc-IndexSUL*

- an index of the serving cell by higher layer parameter *targetCell*. If higher layer parameter *targetCell* is not provided, the serving cell is the cell of the PDCCH reception for DCI format 2\_2

- a mapping for the PUSCH power control adjustment state , by a corresponding {0, 1} value of a closed loop index field that is appended to the TPC command field for the uplink carrier or for the second uplink carrier of the serving cell in DCI format 2\_2 if the UE indicates a capability to support two PUSCH power control adjustment states, by higher layer parameter *twoDifferentTPC-Loop-PUSCH*, and if the UE is configured for two PUSCH power control adjustment states by higher layer parameter *twoPUSCH-PC-AdjustmentStates*.

The UE is also provided for the serving cell of the PDCCH reception for DCI format 2\_2 with a configuration for a search space set and a corresponding control resource set  for monitoring PDCCH candidates for DCI format 2\_2 with CRC scrambled by a TPC-PUSCH-RNTI as described in Subclause 10.1.

## 11.4 SRS switching

DCI format 2\_3 is applicable for serving cells 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.

A UE configured by higher layers with parameter *SRS-CarrierSwitching* is provided with

- a TPC-SRS-RNTI for a DCI format 2\_3 provided by higher layer parameter *srs-TPC-RNTI*

- an index of a serving cell where the UE interrupts transmission in order to transmit SRS on one or more other serving cells by higher layer parameter *srs-SwitchFromServCellIndex*

- a DCI format 2\_3 field configuration type by higher layer parameter *typeA* or higher layer parameter *typeB*

- for higher layer parameter *typeA*, an index for a set of serving cells is provided by higher layer parameter *cc-SetIndex*, indexes of serving cells in the set of serving cells are provided by higher layer parameter *cc-IndexInOneCC-Set*, and a DCI format 2\_3 field includes a TPC command for each serving cell from the set of serving cells and can also include a SRS request for SRS transmission on the set of serving cells

- for higher layer parameter *typeB*, DCI format 2\_3 field includes a TPC command for a serving cell index and can also include a SRS request for SRS transmission on the serving cell - a mapping between a serving cell index for SRS transmission and a DCI format 2\_3 field is provided by higher layer parameter *srs-CellToSFI*

- an indication for a serving cell for whether or not a field in DCI format 2\_3 includes a SRS request by higher layer parameter *fieldTypeFormat2-3* where a value of 0/1 indicates absence/presence of the SRS request – a mapping for a 2 bit SRS request to SRS resource sets is as provided in [6, TS 38.214]

- an index for a location in DCI format 2\_3 of a first bit for a field by higher layer parameter *startingBitOfFormat2-3*

# 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 *BWP-Downlink* and a set of at most four BWPs for transmissions by the UE (UL BWP set) in an UL bandwidth by parameter *BWP-Uplink* 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 or on a secondary cell, a UE is provided an initial active UL BWP by higher layer parameter *initialuplinkBWP*. If the UE is configured with a supplementary carrier, the UE can be provided an initial UL BWP on the supplementary carrier by higher layer parameter *initialUplinkBWP* in *supplementaryUplink*.

If a UE has dedicated BWP configuration, the UE can be provided by higher layer parameter *firstActiveDownlinkBWP-Id* a first active DL BWP for receptions and by higher layer parameter *firstActiveUplinkBWP-Id* a first active UL BWP for transmissions on the primary cell.

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 *subcarrierSpacing*;

- a cyclic prefix provided by higher layer parameter *cyclicPrefix*;

- a first PRB and a number of contiguous PRBs indicated by higher layer parameter *locationAndBandwidth* that is interpreted as RIV according to [4, TS 38.214], setting =275, and the first PRB is a PRB offset relative to the PRB indicated by higher layer parameters *offsetToCarrier* and *subcarrierSpacing*;

- an index in the set of DL BWPs or UL BWPs by respective higher layer parameter *bwp-Id*;

- a set of BWP-common and a set of BWP-dedicated parameters by higher layer parameters *bwp-Common* and *bwp-Dedicated* [12, TS 38.331]

For unpaired spectrum operation, a DL BWP from the set of configured DL BWPs with index provided by higher layer parameter *bwp-Id* for the DL BWP is linked with an UL BWP from the set of configured UL BWPs with index provided by higher layer parameter *bwp-Id* for the UL BWP when the DL BWP index and the UL BWP index are equal. For unpaired spectrum operation, a UE does not expect to receive a configuration where the center frequency for a DL BWP is different than the center frequency for an UL BWP when the *bwp-Id* of the DL BWP is equal to the *bwp-Id* of the UL BWP.

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 does not expect 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 part indicator field is configured in DCI format 1\_1, the bandwidth part indicator field value indicates the active DL BWP, from the configured DL BWP set, for DL receptions. If a bandwidth part indicator field is configured in DCI format 0\_1, the bandwidth part indicator field value indicates the active UL BWP, from the configured UL BWP set, for UL transmissions. If a bandwidth part indicator field is configured in DCI format 0\_1 or DCI format 1\_1 and indicates an UL BWP or a DL BWP different from the active UL BWP or DL BWP, respectively, the UE shall

- for each information field in the received DCI format 0\_1 or DCI format 1\_1

- if the size of the information field is smaller than the one required for the DCI format 0\_1 or DCI format 1\_1 interpretation for the UL BWP or DL BWP that is indicated by the bandwidth part indicator, respectively, the UE prepends zeros to the information field until its size is the one required for the interpretation of the information field for the UL BWP or DL BWP prior to interpreting the DCI format 0\_1 or DCI format 1\_1 information fields, respectively;

- if the size of the information field is larger than the one required for the DCI format 0\_1 or DCI format 1\_1 interpretation for the UL BWP or DL BWP that is indicated by the bandwidth part indicator, respectively, the UE uses a number of least significant bits of DCI format 0\_1 or DCI format 1\_1 equal to the one required for the UL BWP or DL BWP indicated by bandwidth part indicator prior to interpreting the DCI format 0\_1 or DCI format 1\_1 information fields, respectively;

- set the active UL BWP or DL BWP to the UL BWP or DL BWP indicated by the bandwidth part indicator in the DCI format 0\_1 or DCI format 1\_1, respectively.

A UE expects to detect a DCI format 0\_1 indicating active UL BWP change, or a DCI format 1\_1 indicating active DL BWP change, only if a corresponding PDCCH is received within the first 3 symbols of a slot.

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

If a UE is configured for a secondary cell with higher layer parameter *defaultDownlinkBWP-Id* 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 a UE is configured by higher layer parameter *bwp-InactivityTimer* a timer value for the primary cell [11, TS 38.321] and the timer is running, the UE increments the timer every interval of 1 millisecond for frequency range 1 or every 0.5 milliseconds for frequency range 2 if the UE does not detect a DCI format for PDSCH reception on the primary cell for paired spectrum operation or if the UE does not detect a DCI format for PDSCH reception or a DCI format for PUSCH transmission on the primary cell for unpaired spectrum operation during the interval [11, TS 38.321].

If a UE is configured by higher layer parameter BWP-InactivityTimer a timer value for a secondary cell [11, TS 38.321] and the timer is running, the UE increments the timer every interval of 1 millisecond for frequency range 1 or every 0.5 milliseconds for frequency range 2 if the UE does not detect a DCI format for PDSCH reception on the secondary cell for paired spectrum operation or if the UE does not detect a DCI format for PDSCH reception or a DCI format for PUSCH transmission on the secondary cell for unpaired spectrum operation during the interval. The UE may deactivate the secondary cell when the timer expires.

If a UE is configured by higher layer parameter *firstActiveDownlinkBWP-Id* a first active DL BWP and by higher layer parameter *firstActiveUplinkBWP-Id* a first active UL BWP on a secondary cell or supplementary 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 supplementary carrier.

For paired spectrum operation, a UE does not expect to transmit HARQ-ACK information on a PUCCH resource indicated by a DCI format 1\_0 or a DCI format 1\_1 if the UE changes its active UL BWP on the PCell between a time of a detection of the DCI format 1\_0 or the DCI format 1\_1 and a time of a corresponding HARQ-ACK information transmission on the PUCCH.

A UE does not expect to monitor PDCCH when the UE performs RRM measurements [10, TS 38.133] over a bandwidth that is not within the active DL BWP for the UE.

# 13 UE procedure for monitoring Type0-PDCCH common search space

If during cell search a UE determines that a control resource set for Type0-PDCCH common search space is present, as described in Subclause 4.1, the UE determines a number of consecutive resource blocks and a number of consecutive symbols for the control resource set of the Type0-PDCCH common search space from the four most significant bits of *pdcch-ConfigSIB1* as described in Tables 13-1 through 13-10 and determines PDCCH monitoring occasions from the four least significant bits of *pdcch-ConfigSIB1*, included in *MasterInformationBlock*, as described in Tables 13-11 through 13-15.  and  are the SFN and slot index within a frame of the control resource set based on subcarrier spacing of the control resource set and  and  are the SFN and slot index based on subcarrier spacing of the control resource set, respectively, where the SS/PBCH block with index  overlaps in time with system frame  and slot .

The offset in Tables 13-1 through 13-10 is defined with respect to the subcarrier spacing of the control resource set from the smallest RB index of the control resource set for Type0-PDCCH common search space to the smallest RB index of the common RB overlapping with the first RB of the SS/PBCH block. Condition A or condition B in Tables 13-7 through 13-10 corresponds to the case of  or  [4, TS 38.211], respectively.

For the SS/PBCH block and control resource set (CORESET) multiplexing pattern 1, a UE monitors PDCCH in the Type0-PDCCH common search space over two consecutive slots starting from slot . For SS/PBCH block with index , the UE determines an index of slot  as  located in a frame with system frame number (SFN)  satisfying  if  or in a frame with SFN satisfying  if .  and  are provided by Tables 13-11 and 13-12, and  based on the subcarrier spacing for PDCCH receptions in the control resource set [4, TS 38.211]. The index for the first symbol of the control resource set in slot  is the first symbol index provided by Tables 13-11 and 13-12.

For the SS/PBCH block and control resource set multiplexing patterns 2 and 3, a UE monitors PDCCH in the Type0-PDCCH common search space over one slot with Type0-PDCCH common search space periodicity equal to the periodicity of SS/PBCH block. For the SS/PBCH block and control resource set multiplexing patterns 2 and 3, if the active DL BWP is the initial DL BWP, the UE is expected to be able to perform radio link monitoring, as described in Subclause 5, and measurements for radio resource management [10, TS 38.133] using a SS/PBCH block that provides a control resource set for Type0-PDCCH common search space. For a SS/PBCH block with index , the UE determines the slot index  and  based on parameter provided by Tables 13-13 through 13-15.

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 for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | SS/PBCH block and control resource set multiplexing pattern | Number of RBs | Number of Symbols | 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 for frequency bands with minimum channel bandwidth 5 MHz or 10 MHzIndex | SS/PBCH block and control resource set multiplexing pattern | Number of RBs | Number of Symbols | Offset (RBs) |
| 0 | 1 | 24 | 2 | 5 |
| 1 | 1 | 24 | 2 | 6 |
| 2 | 1 | 24 | 2 | 7 |
| 3 | 1 | 24 | 2 | 8 |
| 4 | 1 | 24 | 3 | 5 |
| 5 | 1 | 24 | 3 | 6 |
| 6 | 1 | 24 | 3 | 7 |
| 7 | 1 | 24 | 3 | 8 |
| 8 | 1 | 48 | 1 | 18 |
| 9 | 1 | 48 | 1 | 20 |
| 10 | 1 | 48 | 2 | 18 |
| 11 | 1 | 48 | 2 | 20 |
| 12 | 1 | 48 | 3 | 18 |
| 13 | 1 | 48 | 3 | 20 |
| 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 for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | SS/PBCH block and control resource set multiplexing pattern | Number of RBs | Number of Symbols | 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 for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | SS/PBCH block and control resource set multiplexing pattern | Number of RBs | Number of Symbols | 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 {30, 15} kHz for frequency bands with minimum channel bandwidth 40MHz

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | SS/PBCH block and control resource set multiplexing pattern | Number of RBs | Number of Symbols | Offset (RBs) |
| 0 | 1 | 48 | 1 | 4 |
| 1 | 1 | 48 | 2 | 4 |
| 2 | 1 | 48 | 3 | 4 |
| 3 | 1 | 96 | 1 | 0 |
| 4 | 1 | 96 | 1 | 56 |
| 5 | 1 | 96 | 2 | 0 |
| 6 | 1 | 96 | 2 | 56 |
| 7 | 1 | 96 | 3 | 0 |
| 8 | 1 | 96 | 3 | 56 |
| 9 | Reserved | | | |
| 10 | Reserved | | | |
| 11 | Reserved | | | |
| 12 | Reserved | | | |
| 13 | Reserved | | | |
| 14 | Reserved | | | |
| 15 | Reserved | | | |

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 {30, 30} kHz for frequency bands with minimum channel bandwidth 40MHz

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | SS/PBCH block and control resource set multiplexing pattern | Number of RBs | Number of Symbols | Offset (RBs) |
| 0 | 1 | 24 | 2 | 0 |
| 1 | 1 | 24 | 2 | 4 |
| 2 | 1 | 24 | 3 | 0 |
| 3 | 1 | 24 | 3 | 4 |
| 4 | 1 | 48 | 1 | 0 |
| 5 | 1 | 48 | 1 | 28 |
| 6 | 1 | 48 | 2 | 0 |
| 7 | 1 | 48 | 2 | 28 |
| 8 | 1 | 48 | 3 | 0 |
| 9 | 1 | 48 | 3 | 28 |
| 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 {120, 60} kHz

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | SS/PBCH block and control resource set multiplexing pattern | Number of RBs | Number of Symbols | 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 | 96 | 1 | -41 if condition A  -42 if condition B |
| 11 | 2 | 96 | 1 | 97 |
| 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 {120, 120} kHz

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

Table 13-9: 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 | Number of Symbols | 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 13-10: 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 | Number of Symbols | 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 | 48 | 1 | -41 if condition A  -42 if condition B |
| 7 | 2 | 48 | 1 | 49 |
| 8 | Reserved | | | |
| 9 | Reserved | | | |
| 10 | Reserved | | | |
| 11 | Reserved | | | |
| 12 | Reserved | | | |
| 13 | Reserved | | | |
| 14 | Reserved | | | |
| 15 | Reserved | | | |

Table 13-11: Parameters for PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing pattern 1 and frequency range 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index |  | Number of search space sets per slot |  | **First symbol index** |
| 0 | 0 | 1 | 1 | 0 |
| 1 | 0 | 2 | 1/2 | {0, if  is even}, {, if  is odd} |
| 2 | 2 | 1 | 1 | 0 |
| 3 | 2 | 2 | 1/2 | {0, if  is even}, {, if  is odd} |
| 4 | 5 | 1 | 1 | 0 |
| 5 | 5 | 2 | 1/2 | {0, if  is even}, {, if  is odd} |
| 6 | 7 | 1 | 1 | 0 |
| 7 | 7 | 2 | 1/2 | {0, if  is even}, {, if  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 13-12: Parameters for PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing pattern 1 and frequency range 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index |  | Number of search space sets per slot |  | **First symbol index** |
| 0 | 0 | 1 | 1 | 0 |
| 1 | 0 | 2 | 1/2 | {0, if  is even}, {7, if  is odd} |
| 2 | 2.5 | 1 | 1 | 0 |
| 3 | 2.5 | 2 | 1/2 | {0, if  is even}, {7, if  is odd} |
| 4 | 5 | 1 | 1 | 0 |
| 5 | 5 | 2 | 1/2 | {0, if  is even}, {7, if  is odd} |
| 6 | 0 | 2 | 1/2 | {0, if  is even}, {, if  is odd} |
| 7 | 2.5 | 2 | 1/2 | {0, if  is even}, {, if  is odd} |
| 8 | 5 | 2 | 1/2 | {0, if  is even}, {, if  is odd} |
| 9 | 7.5 | 1 | 1 | 0 |
| 10 | 7.5 | 2 | 1/2 | {0, if  is even}, {7, if  is odd} |
| 11 | 7.5 | 2 | 1/2 | {0, if  is even}, {, if  is odd} |
| 12 | 0 | 1 | 2 | 0 |
| 13 | 5 | 1 | 2 | 0 |
| 14 | Reserved | | | |
| 15 | Reserved | | | |

Table 13-13: PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing pattern 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 |  | 0, 1, 6, 7 for  , , , |
| 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 13-14: PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing pattern 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, …, 7)** |
| 0 | or | 0, 1, 2, 3, 0, 1 in , , , , ,  ()  12, 13 in ,  () |
| 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 13-15: PDCCH monitoring occasions for Type0-PDCCH common search space - SS/PBCH block and control resource set multiplexing pattern 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 |  | 4, 8, 2, 6 in  , , , |
| 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 | |

If a UE detects a first SS/PBCH block and determines that a control resource set for Type0-PDCCH common search space is not present, and for  for FR1 or for  for FR2, the UE may determine the nearest (in the corresponding frequency direction) global synchronization channel number (GSCN) of a second SS/PBCH block having a control resource set for an associated Type0-PDCCH common search space as .  is the GSCN of the first SS/PBCH block and  is a GSCN offset provided by Table 13-16 for FR1 and Table 13-17 for FR2. If the UE detects the second SS/PBCH block and the second SS/PBCH block does not provide a control resource set for Type0-PDCCH common search space, as described in Subclause 4.1, the UE may ignore the information related to GSCN of SS/PBCH block locations for performing cell search.

If a UE detects a SS/PBCH block and determines that a control resource set for Type0-PDCCH common search space is not present, and for  for FR1 or for  for FR2, the UE determines that there is no SS/PBCH block having an associated Type0-PDCCH common search space within a GSCN range . and  are respectively determined by the four most significant bits and the four least significant bits of *RMSI-PDCCH-Config*.

If a UE does not detect any SS/PBCH block providing a control resource set for Type0-PDCCH common search space, as described in Subclause 4.1, within a time period determined by the UE, the UE may ignore the information related to GSCN of SS/PBCH locations in performing cell search.

Table 13-16: Mapping between the combination of and *RMSI-PDCCH-Config* to  for FR1

|  |  |  |
| --- | --- | --- |
|  | **RMSI-PDCCH-Config** |  |
| 24 | 0, 1, …, 255 | 1, 2, …, 256 |
| 25 | 0, 1, …, 255 | 257, 258, …, 512 |
| 26 | 0, 1, …, 255 | 513, 514, …., 768 |
| 27 | 0, 1, …, 255 | -1, -2, …, -256 |
| 28 | 0, 1, …, 255 | -257, -258, …, -512 |
| 29 | 0, 1, …, 255 | -513, -514, …., -768 |
| 30 | 0, 1, …, 255 | Reserved, Reserved, …, Reserved |

Table 13-17: Mapping between the combination of and *RMSI-PDCCH-Config* to  for FR2

|  |  |  |
| --- | --- | --- |
|  | **RMSI-PDCCH-Config** |  |
| 12 | 0, 1, …, 255 | 1, 2, …, 256 |
| 13 | 0, 1, …, 255 | -1, -2, …, -256 |
| 14 | 0, 1, …, 255 | Reserved, Reserved, …, Reserved |

Annex A:  
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 |
| 2018-03 | RAN#79 | RP-180200 | 0001 | - | CR capturing the NR ad-hoc 1801 and RAN1#92 meeting agreements | 15.1.0 |
| 2018-06 | RAN#80 | RP-181172 | 0002 | 1 | CR to TS 38.213 capturing the RAN1#92bis and RAN1#93 meeting agreements and aligning higher layer parameters with TS 38.331 | 15.2.0 |