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3rd Generation Partnership Project;
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General aspects for User Equipment (UE) Radio Frequency (RF) for NR
(Release 16**)**

Approved by

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Wireless Technologies and Systems Committee

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Contents

Foreword

This Technical Report 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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where:

- x the first digit:
  - 1 presented to TSG for information;
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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 is a technical report for the work item on Work Item on New Radio (NR) Access Technology, covering the general aspects for RF, RRM and demodulation for NR.

2 References

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

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

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

[2] Recommendation ITU-R M.1036-5 (10/2015), “Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR)”.

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

[4] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".

[5] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone".

[6] 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".

[7] 3GPP TS 38.104: "NR; Base Station (BS) radio transmission and reception".

[8] 3GPP TS 38.211: "NR; Physical channels and modulation".

[9] 3GPP TR 36.942: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios".

[10] 3GPP TR 38.803: "Study on new radio access technology: Radio Frequency (RF) and co-existence aspects".

[11] Void.

[12] 47 CFR Part 30, "UPPER MICROWAVE FLEXIBLE USE SERVICE, §30.202 Power limits", FCC.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

Operating band: frequency range in which NR operates (paired or unpaired), that is defined with a specific set of technical requirements.

BS Channel bandwidth: RF bandwidth supporting a single NR RF carrier with the transmission bandwidth configured in the uplink or downlink.

NOTE: The channel bandwidth is measured in MHz and is used as a reference for transmitter and receiver RF requirements.

NOTE: It is possible for the BS to transmit to and/or receive from one or more UE Bandwidth parts that are smaller than or equal to the BS transmission bandwidth configuration, in any part of the BS transmission bandwidth configuration.

UE Channel bandwidth: The RF bandwidth supporting a single NR RF carrier with the transmission bandwidth configured in the uplink or downlink of a cell. The channel bandwidth is measured in MHz and is used as a reference for transmitter and receiver RF requirements.

3.2 Symbols

Δf_{OOB}	Δ Frequency of Out Of Band emission
$BW_{Channel}$	Channel bandwidth
$BW_{Channel\_CA}$	Aggregated channel bandwidth, expressed in MHz.
$BW_{Channel,max}$	Maximum channel bandwidth supported among all bands in a release
F_{DL_low}	The lowest frequency of the downlink operating band
F_{DL_high}	The highest frequency of the downlink operating band
F_{UL_low}	The lowest frequency of the uplink operating band
F_{UL_high}	The highest frequency of the uplink operating band
L_{CRB}	Transmission bandwidth which represents the length of a contiguous resource block allocation expressed in units of resources blocks
$L_{CRB,Max}$	Maximum number of RB for a given Channel bandwidth and sub-carrier spacing
NR_{ACLR}	NR ACLR
N_{RB}	Transmission bandwidth configuration, expressed in units of resource blocks
RB_{START}	Indicates the lowest RB index of transmitted resource blocks.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP 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 3GPP TR 21.905 [1].

ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
BW	Bandwidth
CA	Carrier Aggregation
CC	Component Carrier
CA_nX-nY	Inter-band CA of component carrier(s) in one sub-block within Band X and component carrier(s) in one sub-block within Band Y where X and Y are the applicable NR operating band
EIRP	Equivalent Isotropic Radiated Power
EVM	Error Vector Magnitude
FR	Frequency Range
RAT	Radio Access Technology
REFSENS	Reference Sensistivity
SCS	Subcarrier spacing
SEM	Spectrum Emission Mask
SUL	Supplementary uplink
MPR	Allowed maximum power reduction

4 General and common aspects

4.1 Operating bands

While requirements are often generic and band agnostic, there may in many cases be separate requirements for different bands. In some cases, these are identified directly using the band number. They will also be references to different frequency ranges covering many bands, identified as requirements for sub-6 GHz bands (Frequency Range 1) and mmWave bands (Frequency Range 2). These ranges are for the purpose of the specification defined as follows:

- FR1: 450 – 6000 MHz

NOTE 1: the lower frequency limit of FR1 has been extended down to 410 MHz, from Rel-15 onwards. In order to align with the LTE410_Europe_PPDR work item introducing new band in the frequency range 410 – 430 MHz.

NOTE 2: the upper frequency limit of FR1 has been extended up to 7125 MHz, from Rel-15 onwards. Irrespective of this decision, in this report the FR1 is referred to as "sub-6GHz", reflecting previous agreements on NR spectrum.

- FR2: 24250 – 52600 MHz.

The lowest frequency in FR1 is selected as the lowest frequency identified for IMT by the ITU-R [2]. FR2 is defined starting from the lowest frequency under study for IMT under WRC Agenda item 1.13, up to the highest frequency within the scope of the present work item. In the future when new operating bands may be added outside the frequency ranges of FR1 and FR2, those can be incorporated by extending FR1 or FR2, or by adding new ranges (FR3, etc.).

The definitions of FR1 and FR2 are common the UE and BS and should be specified within clause 4 of the specifications.

As for UTRA and LTE, bands for NR are identified by band numbers. A number of different aspects are considered for developing an NR band numbering scheme:

1) For NR in LTE "refarming" bands, whether to re-use the LTE band numbers for NR.

2) For new NR bands, different alternative options are considered:

    a) To put new NR bands above 6 GHz in a new separate numbering range within existing signaling capability.

    b) To group new NR bands below 6 GHz with the LTE bands, resulting in separate band numbering ranges for below 6 GHz and above 6 GHz bands.

    c) To assign unused numbers to all new bands on a "first come first served" basis, regardless of frequency range, duplex mode or RAT (LTE, NR, etc.)

3) How to consider "Duplex mode" for different types of bands

The final NR band numbering scheme is based on the following:

1) For NR in LTE "refarming" bands, LTE band numbers are reused for NR. This will be consistent with the scheme for UTRA and LTE, where the same number was used for the same frequency range, while written in a different way. It also conserves band numbers.

2) NR band numbers will be written with a prefix "n", to distinguish from band numbers for other RATs. For example, NR Band n7 will correspond to LTE Band 7 and UTRA Band VII.

3) New bands should be assigned band numbers on a "first come first served" basis in reserved frequency ranges as follows:

    - 65 to 256 is reserved for new LTE and new NR bands in FR1.

    - 257 to 512 is reserved for new NR bands in FR2. By avoiding LTE bands in this number range, the present LTE band definition is preserved and will most likely not need any changes in the future.

- New LTE only TDD band can use band number from existing LTE TDD numbering space until all numbers up to 64 are used and after that from the reserved 65-256 space.

4) For both re-farming LTE bands and new NR bands, duplex mode should be assigned and described in band defining table (e.g. in TS 38.101 and TS 38.104 [7])

   - TDD for unpaired bands and FDD for paired bands

   - FFS identifies options under study, such as flexible duplexing for paired bands

   - If multiple duplexing modes are allowed in a specific frequency range, separate bands will be introduced with each duplexing mode

NR DC and CA band combination are defined using a notation similar to LTE, but using the distinct notations for the different RATs: A number (Arabic) for LTE and a number with prefix "n" for NR. The CA bandwidth classes (postfix of the bands) for NR are defined in section 5.1.1 for FR1 and section 7.1.1 for FR2 respectively. Examples for notations of NR CA, DC and EN-DC are given in Table 4.1-1a, 4.1-1b and 4.1-1c.

Table 4.1-1a: Example notation for DC and CA.

Representation	Corresponding functionality
CA_n77-n78	NR CA of band n77 and band n78
DC_1-2_n77	NR-LTE DC with LTE CA of band 1 and band 2 and NR band n77.
DC_1-2_n77-n78	NR-LTE DC with LTE CA of band 1 and band 2 and NR CA of band n77 and band n78.

Table 4.1-1b: Example notation for EN-DC bandwidth class.

Type		Notation	Note
EN-DC	Intraband contiguous	DC_(n)XAA	1 CC LTE Band X + 1 CC NR Band nX with max BW ≤ max LTE BW + max NR BW
		DC_(n)XB	1 CC LTE Band X + 1 CC NR Band nX with max BW ≤ 20 MHz
		DC_(n)XJK	LTE Band X with class J + NR Band nX with class K
	Intraband non-contiguous	DC_XA_nXA	Intraband non-contiguous EN-DC with 2 sub-blocks
		DC_XC_nXC	Intraband non-contiguous EN-DC with 2 contiguous LTE sub blocks and 2 contiguous NR sub-blocks
		DC_XA-XA_nX(3A)	Intraband non-contiguous EN-DC with 2 non-contiguous LTE sub blocks and 3 non-contiguous NR sub-blocks
	Interband	DC_XA_nYA	Interband EN-DC with 1CC LTE Band X + 1CC NR Band nY
NOTE: LTE CA and NR CA bandwidth classes are used in EN-DC respectively			

Table 4.1-1c: Example notation for NR DC bandwidth class.

Type		Notation	Note
NR DC	Interband	DC_nXA-nYA	NR DC with 1CC NR Band nX + 1CC NR Band nY

Editor's note:It is FFS how to handle BCS for NR
- *Reuse exiting BCS concept or adopt simplified BS concept or no BCS*

For SUL and NR-LTE co-existence, example of notation is given in Table 4.1-2.

Table 4.1-2: Example notation for SUL and NR-LTE coexistence.

Representation	Corresponding functionality
SUL_n78-n81	Band combination of NR band n78 and band n81(SUL) for NR operation.
DC_3-SUL_n78-n80	LTE-NR DC between LTE Band 3, and NR bands n80 (SUL) and n78 including NR-LTE coexistence with UL sharing.

The definition of operating band can be inherited from LTE. In TS 38.101 and TS 38.104 [7], there should be separate tables defining the band numbers in FR1 and FR2. This exploits the commonality within frequency ranges and reduces table size. For FR2, the table will only contain unpaired frequency ranges, assuming that there will be no FDD operation. To be consistent, all frequencies are defined in MHz.

For the first version of the spec, bands listed as part of the NR WID should be included. The new bands in Tables 4.1-3 and 4.1-4 are defined for NR.

Table 4.1-3: New NR bands in FR1.

Band number	UL	DL	Duplex mode
n1	1920 – 1980 MHz	2110 – 2170 MHz	FDD
n2	1850 – 1910 MHz	1930 – 1990 MHz	FDD
n3	1710 – 1785 MHz	1805 – 1880 MHz	FDD
n5	824 – 849 MHz	869 – 894MHz	FDD
n7	2500 – 2570 MHz	2620 – 2690 MHz	FDD
n8	880 – 915 MHz	925 – 960 MHz	FDD
n13	777 – 787 MHz	746 – 756 MHz	FDD
n20	832 – 862 MHz	791– 821MHz	FDD
n25	1850 – 1915 MHz	1930 – 1995 MHz	FDD
n26	814 – 849 MHz	859 – 894 MHz	FDD
n28	703 – 748 MHz	758 – 803 MHz	FDD
n34	2010 – 2025 MHz	2010 – 2025 MHz	TDD
n38	2570 – 2620 MHz	2570 – 2620 MHz	TDD
n39	1880 – 1920 MHz	1880 – 1920 MHz	TDD
n40	2300 – 2400 MHz	2300 – 2400 MHz	TDD
n41	2496 – 2690 MHz	2496 – 2690 MHz	TDD
n50	1432 – 1517 MHz	1432 – 1517 MHz	TDD
n51	1427 – 1432 MHz	1427 – 1432 MHz	TDD
n66	1710 – 1780 MHz	2110 – 2200 MHz	FDD
n70	1695 – 1710 MHz	1995– 2020 MHz	FDD
n71	663 – 698 MHz	617 – 652 MHz	FDD
n74	1427 –1470 MHz	1475 – 1518 MHz	FDD
n75	N/A	1432 – 1517 MHz	SDL
n76	N/A	1427 – 1432 MHz	SDL
n77	3300 – 4200 MHz	3300 – 4200 MHz	TDD
n78	3300 – 3800 MHz	3300 – 3800 MHz	TDD
n79	4400 – 5000 MHz	4400 – 5000 MHz	TDD
n80	1710 – 1785 MHz	N/A	SUL
n81	880 – 915 MHz	N/A	SUL
n82	832 – 862 MHz	N/A	SUL
n83	703 – 748 MHz	N/A	SUL
n84	1920 – 1980 MHz	N/A	SUL
n86	1710 – 1780 MHz	N/A	SUL

Table 4.1-4: New NR bands in FR2.

Band number	UL and DL	Duplex mode
n257	26500 -29500 MHz	TDD
n258	24250 - 27500 MHz	TDD
n259	[40500 -43500 MHz]	TDD
n260	37000-40000 MHz	TDD
n261	27500 – 28350 MHz	TDD

4.2 Channel bandwidth

NR channel bandwidths for FR1 and FR2 are shown in Table 4.2-1 and Table 4.2-2. The channel bandwidths are defined as both *BS channel bandwidths* and *UE channel bandwidths* except where indicated.

Table 4.2-1: NR channel bandwidth for FR1

NR band / SCS / Channel bandwidth														
NR Band	**SCS kHz**	**5 MHz**	**10[2,3] MHz**	**15[3] MHz**	**20[3] MHz**	**25[3] MHz**	**30 MHz**	**40 MHz**	**50 MHz**	**60 MHz**	**70 MHz**	**80 MHz**	**90 MHz**	**100 MHz**
n1	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
n2	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
n3	15	Yes	Yes	Yes	Yes	Yes	Yes							
	30		Yes	Yes	Yes	Yes	Yes							
	60		Yes	Yes	Yes	Yes	Yes							
n5	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n7	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
n8	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n20	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n25	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
n26	15	Yes	Yes	Yes										
	30		Yes	Yes										
	60		Yes	Yes										
n28	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n34	15	Yes	Yes	Yes										
	30		Yes	Yes										
	60		Yes	Yes										
n38	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
n39	15	Yes	Yes	Yes	Yes	Yes	Yes	Yes						
	30		Yes	Yes	Yes	Yes	Yes	Yes						
	60		Yes	Yes	Yes	Yes	Yes	Yes						
n40	15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes					
	30		Yes	Yes	Yes	Yes	Yes	Yes	Yes					
	60		Yes	Yes	Yes	Yes	Yes	Yes	Yes					
n41	15		Yes	Yes	Yes			Yes	Yes					
	30		Yes	Yes	Yes			Yes	Yes	Yes	Yes[1]	Yes	Yes[1]	Yes
	60		Yes	Yes	Yes			Yes	Yes	Yes	Yes[1]	Yes	Yes[1]	Yes
n50	15	Yes	Yes	Yes	Yes			Yes	Yes					
	30		Yes	Yes	Yes			Yes	Yes	Yes				
	60		Yes	Yes	Yes									
n51	15	Yes												
	30													
	60													
n66	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes			Yes						
	60		Yes	Yes	Yes			Yes						
n70	15	Yes	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes	Yes								
	60		Yes	Yes	Yes	Yes								
n71	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n74	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									

	60		Yes	Yes	Yes									
n75	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60			Yes	Yes									
n76	15	Yes												
	30													
	60													
n77	15		Yes	Yes	Yes		Yes[1]	Yes	Yes					
	30		Yes	Yes	Yes		Yes[1]	Yes	Yes	Yes	Yes[1]	Yes	Yes[1]	Yes
	60		Yes	Yes	Yes		Yes[1]	Yes	Yes	Yes	Yes[1]	Yes	Yes[1]	Yes
n78	15		Yes	Yes	Yes		Yes[1]	Yes	Yes					
	30		Yes	Yes	Yes		Yes[1]	Yes	Yes	Yes	Yes[1]	Yes	Yes[1]	Yes
	60		Yes	Yes	Yes		Yes[1]	Yes	Yes	Yes	Yes[1]	Yes	Yes[1]	Yes
n79	15							Yes	Yes					
	30							Yes	Yes	Yes		Yes		Yes
	60							Yes	Yes	Yes		Yes		Yes
n80	15	Yes	Yes	Yes	Yes	Yes	Yes							
	30		Yes	Yes	Yes	Yes	Yes							
	60		Yes	Yes	Yes	Yes	Yes							
n81	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n82	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n83	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60													
n84	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
n86	15	Yes	Yes	Yes	Yes									
	30		Yes	Yes	Yes									
	60		Yes	Yes	Yes									
NOTE 1: The channel bandwidth is defined only as a BS channel bandwidth in these bands. NOTE 2: 90% spectrum utilization may not be achieved for 30kHz SCS. NOTE 3: 90% spectrum utilization may not be achieved for 60kHz SCS.														

Table 4.2-2: NR channel bandwidth for FR2

NR band / SCS / Channel bandwidth					
NR Band	**SCS kHz**	**50 MHz**	**100 MHz**	**200 MHz**	**400 MHz**
n257	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n258	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes
n260	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes

4.2.1 BS and UE channel bandwidth

For NR, the term *BS channel bandwidth* has been defined. A contiguous block of transmit / receive spectrum may consist of one or more *BS channel bandwidths*.

For E-UTRA, the channel bandwidth related to the transmit and receive bandwidths of both the BS and all of the UEs with which the BS communicates. For NR, however different *UE channel bandwidths* may be supported within the same spectrum.

The *BS channel bandwidth* is understood to be a range of spectrum which can be used to transmit to UEs with different bandwidths. The essential characteristic of the *BS channel bandwidth* is that placing UEs within the *BS channel bandwidth* is flexible; it is equally possible to assign a single carrier to a UE covering most or all of the *BS channel* *bandwidth*, to transmit a carrier to a UE with less than the *BS channel bandwidth*, but placed anywhere within the *BS channel bandwidth* or to transmit multiple carriers to a UE.

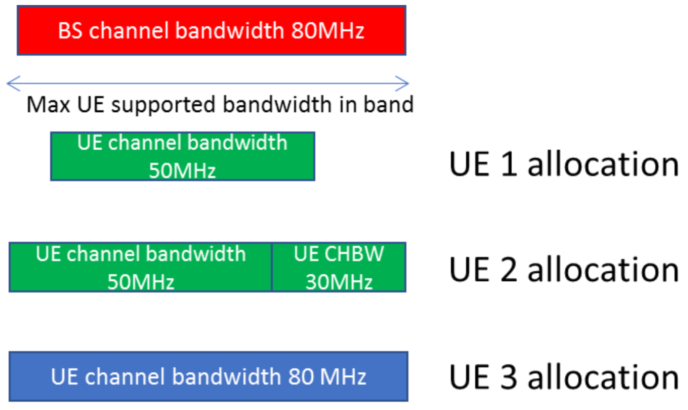


Figure 4.2.1-1: Example of allocation to UEs with different UE channel bandwidth within a BS channel bandwidth

It is not, on the other hand possible to transmit a carrier to a UE that crosses the boundary between two *BS channel bandwidths.*

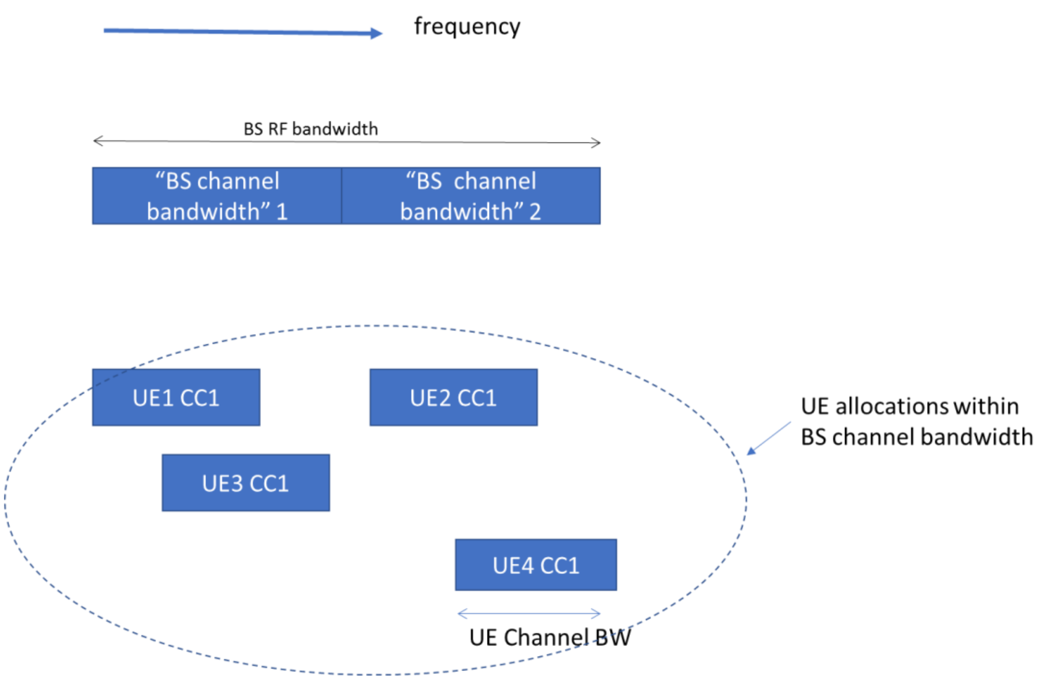


Figure 4.2.1-2: Example of allocation to UEs where there are multiple contiguous BS channel bandwidths. UE carriers may not straddle across BS channel bandwidths.

How RBs used by the BS may be allocated within a BS bandwidth are defined in the SU section 4.5 of this report.

4.2.2 Bandwidth combination sets

Following agreements have been made for NR Bandwidth combination sets (BCSs):

Considering NR bands in inter-band LTE-NR DC:

- BCSs are not specified for NR bands part of LTE-NR inter-band DC configurations
- When UE operates in LTE-NR DC configuration it supports same NR channel bandwidths as it supports for that NR band in standalone operation
- Where IMD is an issue only for a subset of channel bandwidths within a band/band combination, the bandwidths for which MSD is applicable shall be specified in receiver characteristics section.

Considering LTE bands in inter-band LTE-NR DC:

- The need for BCS for LTE band in LTE-NR DC is discussed separately from NR BCS
- LTE-NR DC UE shall signal BCS information to eNodeB (to reduce changes to LTE UE and eNodeB design)
- LTE-NR DC UE shall signal support for all specified LTE BCSs that belong to the LTE CA configuration part of LTE – NR DC (to reduce UE fragmentation and make RAN4 specification effort smaller as no LTE BCS information is needed in NR specs)
- When operating in DC band combinations of LTE 1DL/1UL + NR band(s) UE will support all LTE channel bandwidths that are specified to the LTE band (otherwise LTE bandwidth capability is unknown as single CC operation does not have BCS)

Considering LTE/NR bands in intra-band LTE-NR DC:

- BCSs would reduce the number of permutations of channel bandwidths that need to be supported for intra-band EN-DC
- BCSs shall be supported for intra-band EN-DC band combinations and specified in TS 38.101-3 [6]

Considering NR bands in intra-band LTE-NR DC:

- BCSs are allowed for NR bands part of LTE-NR intra-band DC configurations
- If one or more BCS is defined for a given LTE-NR DC configuration the a UE supports the specified channel bandwidths in the BCS(s) that it supports.
- If a BCS is not defined for a given LTE-NR DC configuration, the UE supports all the NR channel bandwidths as it supports for that NR band in standalone operation
- Where IMD is an issue only for a subset of channel bandwidths within a band/band combination, the bandwidths for which MSD is applicable shall be specified in receiver characteristics section.

Considering LTE bands in intra-band LTE-NR DC:

- LTE-NR DC UE shall signal BCS information to eNodeB (to reduce changes to LTE UE and eNodeB design)
- LTE-NR DC UE shall signal support for all specified LTE bandwidth combinations sets that belong to the LTE CA configuration part of LTE – NR DC (to reduce UE fragmentation and make RAN4 specification effort smaller as no LTE BCS information is needed in NR specs)
- When operating in DC band combinations of LTE 1DL/1UL + NR band(s) where one or more BCS are specified UE will support all LTE channel bandwidths that are specified for the supported BCS(s).
- When operating in DC band combinations of LTE 1DL/1UL + NR band(s) where no BCS are specified UE will support all LTE channel bandwidths that are specified to the LTE band (otherwise LTE bandwidth capability is unknown as single CC operation does not have BCS)

Considering NR bands in standalone operation:

- BCSs are specified for CA configuration in NR bands in standalone operation
- UE should support all specified aggregated bandwidths which are smaller than the indicated aggregated bandwidth and are part of same BCS indicated
- UE should support all specified lower order CA configurations which have same BCS as indicated
- BCS with same number (e.g. BCS0) need to be aligned between lower and higher order fallback configuration

4.3 Channel arrangement

4.3.1 RF channel and sync channel raster

4.3.1.1 Background

The concept of referring to a carrier frequency in UTRA and E-UTRA is based on a channel raster defining possible carrier centre frequencies and a numbering scheme that identifies the raster points. In E-UTRA there are EARFCN (E-UTRA Absolute Radio Frequency Channel Number) for all possible uplink and downlink frequencies. The numbers are mapped to the corresponding UL and DL carrier frequencies through formulas:

$$F_{DL} = F_{DL\_low} + 0.1(N_{DL} – N_{Offs\text{-}DL})$$

$$F_{UL} = F_{UL\_low} + 0.1(N_{UL} – N_{Offs\text{-}UL})$$

The possible EARFCN ranges for each E-UTRA operating band are tabulated together with the parameters for the formula. The resulting RF channel raster identifies all possible RF carrier centre frequencies, which are the same as the potential frequencies that a UE must scan when performing initial access.

The concept has many differences in NR compared to UTRA and E-UTRA, giving a higher complexity. The main difference is that there is a need for two channel rasters for NR:

- **RF channel raster:** Identifies the set of possible frequency locations of the full RF carrier transmitted by the base station.

- **Synchronization channel raster**: Identifies the set of possible frequency location of the SS Block, consisting the synchronization channels PSS/SSS and the PBCH.

The SS block is not in a fixed position within the configured bandwidth of the RF carrier, but can be placed anywhere on the RF carrier. This enables a Sync channel raster that is more “sparse” than the RF channel raster. The advantage of having a more sparse sync channel raster is a reduced search time for the initial access. It relies on the SS block bandwidth being smaller than full channel BW of the RF carrier transmitted from the BS and that it is not in a fixed position within the configured bandwidth. It is the width of the PBCH being 240 subcarriers (20 RBs) that will define the flexibility of how to place the sync channel. The SS block will use a predetermined SCS and minimum channel BW in each operating band.

The relation between the RF channel raster and sync channel raster is demonstrated with an example in Figure 4.3.1.1-1. In the example, two carrier positions 1 and 2 are shown leading to two different placements of the PBCH. The PBCH (and SS) can be placed on a raster that is more sparse than the RF carrier raster and those sync channel raster positions are called $F_{SC,i}$. Position 1 is the highest (rightmost) position of BW_{Confi} on the RF channel raster where the PBCH can be related to the sync channel position $F_{SC,1}$, thus the PBCH occurs as far left as possible on the carrier. Position 2 is the next position on the RF channel raster, thus shifted by $\Delta F_{CH,Raster}$ from Position 1. The sync channel raster spacing $\Delta F_{SC,Raster}$ will be limited by the following equation:

$$\Delta F_{SC,Raster} \leq BW_{Config} – BW_{PBCH} + \Delta F_{CH,Raster} \qquad (4.3.1.1\text{-}1)$$

where BW_{Config} (Tx BW configuration) is the width of the transmitted Resource Blocks, BW_{PBCH} is the width of the PBCH and $\Delta F_{CH,Raster}$ is the channel raster spacing.

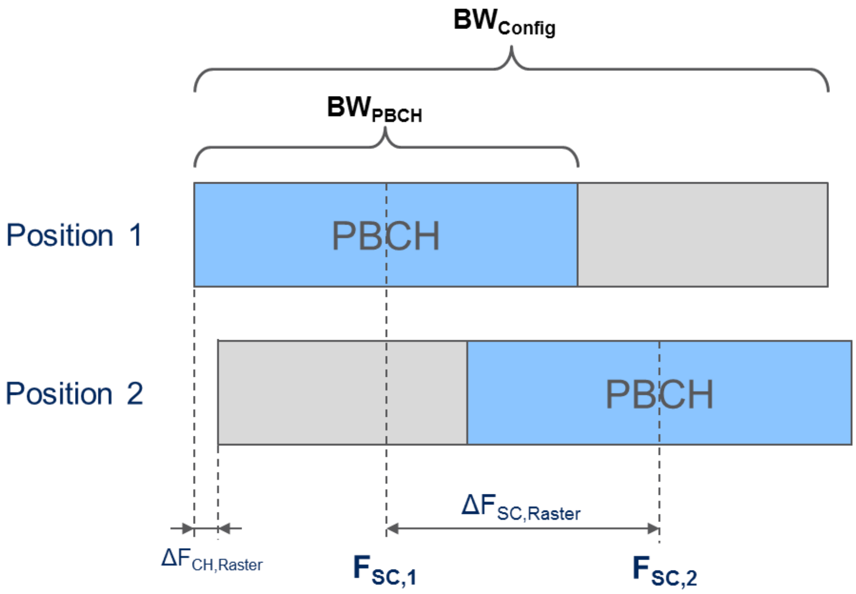


Figure 4.3.1.1-1: Possible shifts for the PBCH as the transmitted carrier is shifted on the RF carrier raster.

4.3.1.2 Overall raster concept

The RF channel raster and sync channel raster need to be defined in relation to one or more of the following parameters:

- **Spectrum blocks**: These are the spectrum block allocations where the RF carriers will be placed. It is essential that the Channel BW is fully contained within an allocated block defined and/or permitted by a regulator, not risking "Channel BW spill-over". The regulation varies across regions and often sets limits on emissions outside the block assigned to an operator. The 200 kHz/100 kHz rasters used for UTRA and E-UTRA are fundamentally adapted to spectrum blocks.
- **Subcarrier spacing (SCS)**: The RF channel consists of subcarriers and the subcarrier spacing becomes important for carrier aggregation and when forming wider channel bandwidths, since the RF channel spacing needs to be a multiple of SCS to keep orthogonality.
- **Physical resource blocks (RB)**: The RF carrier is an integer number of RBs and the physical channels are defined based on RBs in the frequency domain.

The definition of the channel raster will be limited by a number of aspects, also considering the relation between the RF channel and Sync channel raster defined in Equation (4.3.1.1-1). The following aspects are considered:

- The relation to the E-UTRA **100 kHz raster** for LTE re-farming bands.
- How to manage the **asymmetric guard band** if the RF carrier cannot placed in the centre of a spectrum block.
- In case of asymmetric guard band, a **minimum guard band** needs to be defined for different RF Channel bandwidths and SCS
- The achievable **spectral utilization** may be affected, if the guard band is not sufficient and an edge RB cannot be transmitted ("blanking")
- How to achieve **CA operation** and **Wideband operation** with forward compatibility for addition of new channel bandwidths. This should preferably be achieved with zero guard band between carriers.
- The achievable **synchronisation raster granularity** may be affected by the choice of raster scheme.

NR Bands should have the same RF channel raster for both UL and DL. It is noted however that the channel raster for UL sharing band can be decoupled from the NR DL band raster (e.g. UL sharing band can be on 100kHz raster while the NR DL band can use 100kHz raster or RB based raster)

4.3.1.3 RF Channel raster

NR Bands should have the same raster for both UL and DL (for both UL and DL 100kHz or RB based raster is used). Channel raster could also be different for different bands and only a single raster should be defined per band.

The following raster granularity is agreed:

- Channel raster for LTE re-farming bands up to 2.4GHz (frequency range below Band 41) is based on 100kHz(same as LTE)
  - Potential optimization for of the placement of secondary carrier including RB-alignment between primary and secondary carrier is ffs
- Channel raster for Bands above 2.6GHz (above and including Band 41) is tentatively agreed to be a subcarrier based raster (i.e 15kHz for range 1 and 60kHz for range 2), pending further check at AN4 NR AH#3 and RAN1 decision
  - Band n85 (SUL band covering the same frequency range as n41) will use the channel raster defined for SUL bands which is ffs.

"Floating sync" enables SCS based raster and down selection of the sync raster for bands using 100kHz raster as described in subclause 4.3.1.4.

For the 100 kHz based raster:

- Raster entries are given by the following equation for each band
  - Lower band edge(MHz)+ N*0.1MHz, N chosen such that last entry is at Upper band
- Raster to subcarrier position mapping
  - Raster points to the center of the channel
    - SC#0 of RB# NRB/2 for even number of RBs
    - SC#6 of RB# floor(NRB/2) for odd number of RBs

For the SCS-based raster:

- Raster will be based on absolute frequency values
  - The raster positions will be integer multiples of 15kHz for sub6 bands
  - The raster positions will be integer multiples of 60kHz for mmWave range bands
- Raster entries are indexed from 0kHz
- Raster to subcarrier position mapping
  - Raster points to the center of the channel
    - SC#0 of RB# NRB/2 for even number of RBs
    - SC#6 of RB# floor(NRB/2) for odd number of RBs

NR-ARFCN defines the absolute radio frequency of the channel raster points and is globally defined; The frequency band and duplex (uplink or downlink) are not distinguished by the NR-ARFCN. It is for RAN2 to decide how to signal the frequency of Pcell, Scell, SUL, and/or the reference frequency for PRB grid, etc, using NR-ARFCN or other means.NR-ARFCN for FR1 are defined as one global set from 0 Hz to 24 GHz:

- An integer multiple of 5kHz from 0 to 3GHz
- An integer multiple of 15kHz from 3 to 24GHz

NR-ARFCN for FR2 are defined as one global set from 24 GHz to 100 GHz

- An integer multiple of 60kHz

NR-ARFCN range for each frequency band is tabulated in RAN4 specs. The corresponding signalling is for RAN2 to design.

4.3.1.4 Synchronization Channel raster

Sync raster is defined such that there is a minimum number of entries for each band. Sync raster entries will be included in the specifications for each band. Sync raster entries will be defined for initial system acquisition, sync blocks can be transmitted in other frequency locations if the position is signalled to the UE

The sync block is not RB aligned with the data RBs in the channel as shown in Figure 4.3.1.4-1. Instead, there is an arbitrary offset between the edge of the sync block RBs and the edge of the data RBs in the channel, this offset can be up to 11 REs. This enables multiple channels that are subcarrier grid aligned but not RB grid aligned to use the same sync block location. Different channels that are offset by up to 11 REs in frequency can re-use the same sync block frequency location.

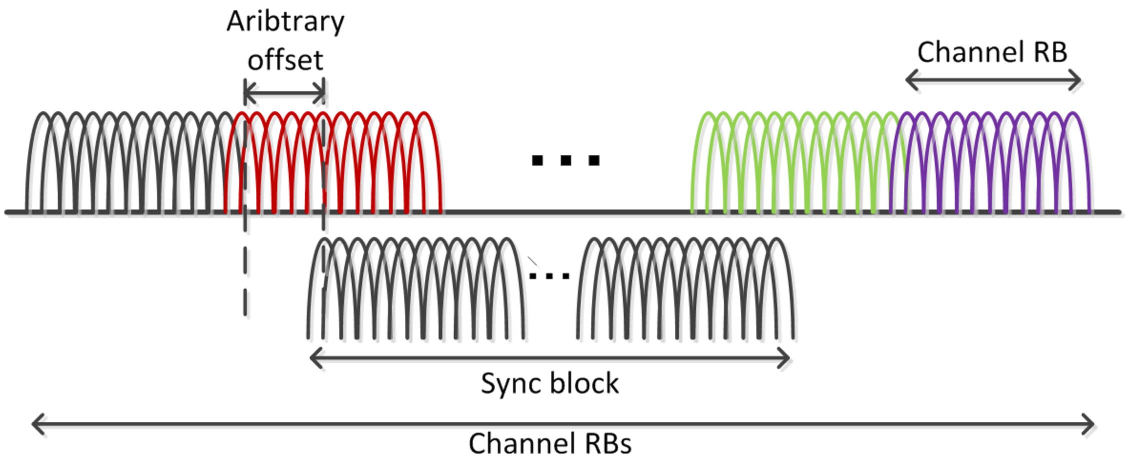


Figure 4.3.1.4-1: Alignment between SS block and channel RBs.

Subcarrier mapping:

- Sync raster will indicate the position of RE=#0(subcarrier #0) of RB#10 of the SS block.

SS Raster Definition for the 0 – 3.0 GHz range:

- SS Raster is defined as
  - Raster entry = N * 1200 kHz + M * 50 kHz, N=1:2499, M ϵ {1,3,5}
    (For operating bands with SCS spaced channel raster, the value M=3 is used.)
  - Raster entry numbering in this range is in increasing order of frequency, starting numbering at #2 (entry #2=1250 kHz, entry #3=1350 kHz, entry #4=1450 kHz, entry#5=2450 kHz…)
  - Total number of entries 7497
  - Raster applies to bands with 100 kHz channel raster and 15 kHz channel raster with 5 MHz minimum bandwidth (bands might be defined in the future) in this frequency range

SS Raster Definition for the 3.0 - 24.25 GHz range:

- SS Raster is defined as:
  - Raster entry = 3000 MHz + N * 1.44 MHz, N= 0: 14756
  - Raster entry numbering is in increasing order of frequency, starting at 7499
  - Total number of entries 14757

- Raster applies to bands with 15 kHz channel raster and 10 MHz minimum bandwidth (n77,n78, n79, etc) in this frequency range

SS Raster Definition for the 24.25-100GHz range

- SS Raster is defined as:
  - Raster entry = 24250.08 MHz + N * 17.28 MHz, N= 0:4383
  - Raster entry numbering is in increasing order of frequency, starting at 22256
  - Total number of entries 4384
- Raster applies to bands with 60 kHz channel raster in this frequency range

4.3.1.5 Calculations of sync raster GSCN per operating band

For each operating band, the GSCN that can be used in the band are tabulated in subclause 5.4.3.3 of TS 38.104 [7], TS 38.101-1 [4] and TS 38.101-2 [5]. Selection of GSCN for Table(s) is done the following way:

- Include GSCN that correspond to SS block that completely fit within the channel bandwidth, accounting for guard bands needed.
- Guard bands are calculated based on the minimum channel BW in table 5.3.5-1 and table 5.3.5-2 of TS 38.104 [7], the SCS for the SS block and the corresponding N_{RB} (spectrum utilization), assuming that the SS block can be in any position within the transmission BW configuration, including at positions adjacent to the edges.
- For GSCN ranges with step size <N>, the GSCN numbers selected should be multiples of N (this ensures that overlapping bands will have the same GSCN sequences)

For specific combinations of minimum channel bandwidth and SS block SCS, the GSCN ranges are down-selected using a step size <N>, as shown in Table 4.3.1.5-1.

Table 4.3.1.5-1: Down selection factors (step size).

Frequency range	Minimum channel bandwidth	SS block SCS	Down selection factor (step size)
0 – 3.0 GHz	10 MHz	15 kHz	<3>
3.0 - 24.25 GHz	40 MHz	30 kHz	<16>
24.25 – 100 GHz	100 MHz	240 kHz	<2>

To determine the GSCN range, let $f_{\min}$ denote the lowest frequency location of the SS block within a band after accounting for the guard band G in subclause 5.3.3 of TS 38.104 [7] corresponding to the minimum channel BW and the bandwidth encompassing the width of all subcarriers from RE#0 of RB#0 to the centre of RE#0 of RB#10 of the SS block. Let $f_{\max}$ denote the high frequency location of the SS block within a band after accounting for the guard band and the bandwidth from the centre of RE#0 of RB#10 and encompassing the width of all subcarriers until RE#11 of RB#19 of the SS block. Let F_{low} represent the lowest frequency of the frequency range in subclause 4.3.1.4, ΔF_{raster} represent the raster spacing in MHz, ΔF_{shift} represent the raster shift in MHz (applicable for the frequency range 0 to 3000MHz).

The lowest frequency location $f_{\min}$ is computed as

$$f_{\min} = F_{\text{low}} + G + \Delta f\left(\frac{N_{RB}^{SS}N_{RE}^{RB}+1}{2}\right)$$

where Δf is the subcarrier spacing, $N_{RE}^{RB} = 12$ is the number of REs per RB, $N_{RB}^{SS} = 20$ is the number of RBs in the SS block.

The highest frequency location $f_{\max}$ is computed as

$$f_{\max} = F_{\text{low}} + W_{Band} - G - \Delta f\left(\frac{N_{RB}^{SS}N_{RE}^{RB}-1}{2}\right)$$

where W_{Band} is the width of the operating band.

The first possible raster location within a band (prior to applying the step size) is given by

$$f_{\min} \leq F_{\text{low}} + N\Delta F_{\text{raster}} + M\Delta F_{\text{shift}}$$

while the last possible raster location within a band (prior to applying the step size) is given by

$$f_{\max} \geq F_{\text{low}} + N\Delta F_{\text{raster}} + M\Delta F_{\text{shift}}$$

where ΔF_{shift} is defined to be 0 outside the frequency range 0 to 3000MHz and where N (and M) are defined in subclause 4.3.1.4.

For the first possible raster location, $N_{\min}$ is the smallest integer satisfying

$$N_{\min} \geq \frac{1}{\Delta F_{\text{raster}}}\left(f_{\min} - F_{\text{low}} - \max(M)\Delta F_{\text{shift}}\right)$$

and the corresponding value of M (if defined and if multiple values are defined)

$$M \geq \frac{1}{\Delta F_{\text{shift}}}\left(f_{\min} - F_{\text{low}} - N_{\min}\Delta F_{\text{raster}}\right)$$

For the last possible raster location, $N_{\max}$ is the largest integer satisfying

$$N_{\max} \leq \frac{f_{\max} - F_{\text{low}} - \min(M)\Delta F_{\text{shift}}}{\Delta F_{\text{raster}}}$$

and the corresponding value of M (if defined and if multiple values are defined)

$$M \leq \frac{f_{\max} - F_{\text{low}} - N_{\max}\Delta F_{\text{raster}}}{\Delta F_{\text{shift}}}$$

For the frequency ranges in subclause 4.3.1.4, table 4.3.1.5-2 indicates the formulas used to compute the values of N and M (if necessary).

Table 4.3.1.5-2: Formulas to compute the minimum and maximum values of GSCN

Type	Parameter	Range	Formula
For GSCNmin	N (compute first)	0-3000 MHz	$N = \left\lceil \frac{f_{\min} - F_{\text{low}} - \max(M)\Delta F_{\text{shift}}}{\Delta F_{\text{raster}}} \right\rceil, M \epsilon \begin{cases} \{1,3,5\} \\ \{3\} \quad Note \end{cases}$
		≥ 3000 MHz	$N = \left\lceil \frac{f_{\min} - F_{\text{low}}}{\Delta F_{\text{raster}}} \right\rceil$
	M	0-3000 MHz	$M' = \max\left(\left\lceil \frac{f_{\min} - F_{\text{low}} - N\Delta F_{\text{raster}}}{\Delta F_{\text{shift}}} \right\rceil, 1\right)$ $M = M' + (M' + 1)\text{mod}2$
		0-3000 MHz, NOTE	3
		≥ 3000 MHz	N/A
For GSCNmax	N (compute first)	0-3000 MHz	$N = \left\lfloor \frac{f_{\max} - F_{\text{low}} - \min(M)\Delta F_{\text{shift}}}{\Delta F_{\text{raster}}} \right\rfloor, M \epsilon \begin{cases} \{1,3,5\} \\ \{3\} \quad Note \end{cases}$
		≥ 3000 MHz	$N = \left\lfloor \frac{f_{\max} - F_{\text{low}}}{\Delta F_{\text{raster}}} \right\rfloor$
	M	0-3000 MHz	$M = \min\left(\left\lfloor \frac{f_{\max} - F_{\text{low}} - N\Delta F_{\text{raster}}}{\Delta F_{\text{shift}}} \right\rfloor, 5\right)$ $M = M' + (M' + 1)\text{mod}2$
		0-3000 MHz, NOTE	3
		≥ 3000 MHz	N/A
NOTE: Refers to Note in Table 5.4.3.1-1 in TS 38.101-1 [4] for bands with SCS-based raster below 3000 MHz.			

To compute the GSCN ranges with step size <N>, the N and M (when defined) values computed with the formulas in table 4.3.1.5-2 are used to determine GSCNmin′ and GSCNmax′ according to the appropriate raster entry formula from subclause 4.3.1.4. The first entry in the GSCN range, GSCNmin, is determined by

$$\text{GSCNmin} = \langle \text{N} \rangle \lceil \text{GSCNmin}' / \langle \text{N} \rangle \rceil$$

and the last entry in the range, GSCNmax, is determined by

$$\text{GSCNmax} = \langle \text{N} \rangle \lfloor \text{GSCNmax}' / \langle \text{N} \rangle \rfloor.$$

The method described above for calculating the GSCN range [GSCNmin, GSCNmax] for an operating band is implemented in the Excel spread sheet ***NR sync raster calculations (2019-06).xlsx***, which is attached to the Technical Report. The spread sheet was used to generate the tables in subclause 5.4.3.3 of TS 38.104 [7], TS 38.101-1 [4] and TS 38.101-2 [5].

4.3.2 Channel spacing for adjacent NR carriers

The spacing between carriers will depend on the deployment scenario, the size of the frequency block available and the channel bandwidths. The nominal channel spacing between two adjacent NR carriers shall be multiple of channel raster. As such, the channel spacing should be specified separately for different channel raster and additional offset may be needed pending on channel raster and different channel bandwidth combination for adjacent NR carriers.

4.3.3 Channel spacing for intra-band CA

For LTE intra-band contiguous CA, the following assumptions are considered:

- the aggregated bandwidth shall be no more than $BW_{Channel(1)} + BW_{Channel(2)}$
- the outer guard bands of the two CCs are symmetric.
- the channel spacing shall be multiple of LCM (least common multiple) of channel raster and SCS (i.e. 300 kHz of 100kHz channel raster and 15kHz SCS for LTE), this is to be compatible with the channel raster and at the same time to maintain the orthogonality of the sub-carriers spacing.

Above three assumptions could be reused for NR intra-band contiguous CA although there are some following differences between LTE and NR:

- Minimum guard band of the outermost carriers should be used, rather than fixed guard bands (= 0.05*BW) for each channel bandwidth
- The channel raster of 100kHz, 15kHz and 60kHz are supported.
- Several SCSs are supported

Considering the combination of channel raster and SCS for each carrier, the NR intra-band contiguous CA channel spacing should be separately defined correspondingly. In order to be compatible with the channel raster and the orthogonality of the sub-carriers spacing, the NR CA channel spacing shall be multiple of LCM of channel raster and SCS, listed in table 4.3.3-1.

Table 4.3.3-1. LCM {channel raster, SCS} for NR intra-band contiguous CA

Frequency range	Channel raster	Data SCS for carrier(s)	LCM {channel raster, SCS}
FR1	100 kHz	15 kHz, 30 kHz, 60 kHz	300 kHz
	15 kHz	15 kHz, 30 kHz, 60 kHz	$15 \cdot 2^n$ kHz $n = \max(\mu_1, \mu_2)$
FR2	60 kHz	60kHz, 120 kHz	$60 \cdot 2^n$ kHz $n = \max(\mu_1, \mu_2) - 2$
Note 1: The SCS for component carrier can be different. In this case, the SCS in the LCM {channel raster, SCS} is the maximum SCS of the carriers. Note 2: μ_1 and μ_2 are the subcarrier spacing configurations of the component carriers as defined in TS 38.211 [8].			

The channel spacing for intra-band contiguous carrier aggregation can be adjusted to any multiple of least common multiple of channel raster and sub-carrier spacing less than the nominal channel spacing to optimize performance in a particular deployment scenario.

4.4 Subcarrier spacing

4.4.1 Non-SS channels

NR supports operation of different numerologies involving different sub-carrier spacings, as well as operation in different parts of the frequency domain.

The subcarrier spacing used for non-SS transmission impacts several aspects of performance, including:

- The maximum channel bandwidth that can be supported using a feasible FFT size
  - Larger subcarrier spacing implies larger bandwidth
- The inter-carrier interference due to phase noise
  - Larger subcarrier spacing implies greater phase noise robustness
- The symbol length and hence delay characteristics
  - Larger subcarrier spacing implies shorter symbols

The characteristics of range 1 and range 2 in terms of achievable phase noise, channel delay profiles and expected bandwidths differ considerably and hence the supported SCS options were decided separately for range 1 and range 2. Several options for SCS are supported for each range. The SCS supported for each band will be selected on a band specific basis from the options defined for the corresponding range.

The SCS options were decided to be as follows:

Table 4.4-1 Non-SS subcarrier spacing options

Frequency range	SCS options (Non-SS)
Range 1 (Below 1GHz)	15, 30 kHz
Range 1 (Above 1GHz)	15, 30, 60 kHz
Range 2	60, 120 kHz

4.5 Spectrum utilization

4.5.1 General

In order to settle spectrum utilization for NR, a number of factors have been taken into account, including:

- Increasing the spectrum utilization compared to E-UTRA
- The spectrum efficiency gains corresponding to the spectrum utilization increase
- The impact of the spectrum utilization on implementations, including both filtering and windowing solutions to spectrum confinement
- The impact of the spectrum confinement technique needed for achieving the spectrum utilization on signal quality (EVM), both across the band and at the band edges
- The impact of the spectrum utilization on receiver performance considering ACS, phase noise reciprocity
- Relevant requirements on SEM, ACS etc.
- Expected transmitter power

Whilst defining a single set of spectrum utilization values in Rel-15 for both UL and DL, three co-existence scenarios were considered for spectrum utilization as depicted in figure 4.5.1-1. In the figure, X% is defined as utilization required to be achievable with the Rel-15 requirements. Y% is defined as utilization not required to be achievable with the Rel-15 requirements.

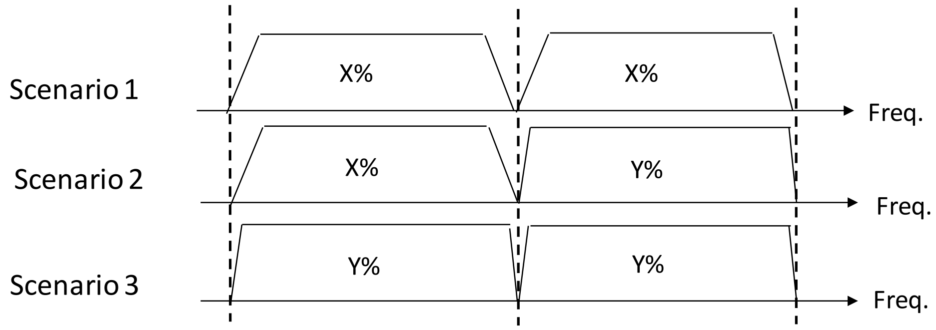


Figure 4.5.1-1 Coexistence scenarios for two adjacent NR channels

From TX side, BS/UE is expected to always meet all TX requirements such as EVM, out-of-band emission requirements (SEM and ACLR) and spurious requirements for the Rel-15 utilization X%. Thus, BS/UE TX and RX requirements were developed for scenario 1.

In addition, it was noted that for a co-ordinated operator deployment, scenarios 2 and 3 may be possible on a “system level” (i.e. from BS perspective). Operating in such a manner could potentially cause interference to other operators, this depends on the scenario.

- Note that this does not require higher spectrum utilization from the UE perspective. More specifically, for such scenarios UE TX / RX baseband processing capabilities are limited by the X% resource utilization and UE may not support higher utilization.
- The impacts to interference, blocking etc. to neighbouring operators will need to be considered and managed by the operator taking into account the specific deployments of the different operators.

Consideration was also given to how to accommodate future potential RAN4 minimum requirements for Y% utilization in scenarios 2 and 3.

- A RAN4 minimum requirement for higher spectrum utilization Y% would be considered only if it could improve system and/or user throughput compared to X% . How to evaluate system and user throughput would need study.
- Feasibility and complexity cost would also need to be considered when evaluating RAN4 minimum requirement for higher spectrum utilisation in a future release
- If future analyses would justify the introduction of minimum higher spectrum utilization Y%:
    - Later release specification and requirements impact is FFS
    - The same BS/UE Tx Rel-15 requirements will continue to be applicable. (i.e. No impact on BS/UE TX and RX Rel-15 requirements defined for X%).
    - If needed, relevant BS/UE RX minimum requirements could be revised/added.
    - Whether Y% would be mandatory for BS/UE or not would be FFS in the future release

EVM requirements measured over edge PRBs is FFS. RB values for NR spectrum utilization are agreed based on the assumption of no edge PRB EVM requirements in Rel-15.

RAN1 and RAN2 confirmed that physical layer and L2/3 signalling supports allocation of PRBs up to the theoretical maximum number for the channel bandwidth.

4.5.2 Maximum RB Allocation, Transmission Bandwidth and Spectrum Utilization for FR1

4.5.2.1 CP-OFDM waveform

Spectrum Utilization refers to the proportion of the channel bandwidth that can be used for transmission. RAN4 defined a single set spectrum utilization values in Rel-15 for both UL and DL. The following maximum RB allocation defines the minimum spectrum utilization to be realized per channel bandwidths and valid sub-carrier spacing.

Table 4.5.2.1-1: Range 1 NR UE and BS maximum RB allocation for CP-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]												
	5	10	15	20	25	30	40	50	60	70[1]	80	90[1]	100
15	25	52	79	106	133	[160]	216	270	N.A	N.A	N.A	N.A	N.A
30	11	24	38	51	65	[78]	106	133	162	[189]	217	[245]	273
60	N.A	11	18	24	31	[38]	51	65	79	[93]	107	[121]	135
NOTE 1: 70MHz and 90MHz are defined only as BS channel bandwidths in release 15.													

Table 4.5.2.1-2: Range 1 NR UE and BS transmission bandwidths in MHz for CP-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]												
	5	10	15	20	25	30	40	50	60	70[1]	80	90[1]	100
15	4.5	9.36	14.22	19.08	23.94	[28.80]	38.88	48.6	N.A	N.A	N.A	N.A	N.A
30	3.96	8.64	13.68	18.36	23.40	[28.08]	38.16	47.88	58.32	[68.04]	78.12	[88.20]	98.28
60	N.A	7.92	12.96	17.28	22.32	[27.36]	36.72	46.8	56.88	[66.96]	77.04	[87.12]	97.20
NOTE 1: 70MHz and 90MHz are defined only as BS channel bandwidths in release 15.													

Transmit bandwidth for CP-OFDM can be significantly different across the different sub-carrier spacing for a given channel bandwidth, this must be taken into account for UE REFSENS thermal noise integration bandwidth as it results in some cases into close to 1dB REFSENS improvement for the higher numerologies.

Table 4.5.2.1-3: Range 1 NR UE and BS spectrum utilization for CP-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]												
	5	10	15	20	25	30	40	50	60	70[1]	80	90[1]	100
15	90.0%	93.6%	94.8%	95.4%	95.8%	[96.0]%	97.2%	97.2%	N.A	N.A	N.A	N.A	N.A
30	79.2%	86.4%	91.2%	91.8%	93.6%	[93.6]%	95.4%	95.8%	97.2%	[97.2]%	97.7%	[98.0]%	98.3%
60	N.A	79.2%	86.4%	86.4%	89.3%	[91.2]%	91.8%	93.6%	94.8%	[95.7]%	96.3%	[96.8]%	97.2%
NOTE 1: 70MHz and 90MHz are defined only as BS channel bandwidths in release 15.													

The minimum requirements in RAN4 are met with the agreed spectral occupancy under the condition that the BS or UE channel bandwidth centre is placed at SC 0 or SC 6 of the PRB grid such that the PRB utilization is symmetrical around the channel centre for the SCS under test.

For the UE, both the channel bandwidth and the position of the PRB grid with respect to the UE channel bandwidth centre depend upon configuration. In some configurations, the centre of the UE channel bandwidth may not align with the PRB grid in a manner that enables symmetric PRB utilization around the centre. For the BS, when multiple SCS are transmitted then the rule that SC 0 should align over all SCS at a point A can mean that the PRB alignment with the channel centre is not ideal for some SCS and asymmetry may arise.

In these cases, the PRB utilization is the set of PRBs that fall within the UE or BS channel bandwidth and do not violate the minimum guard band, as captured in the tables below, and depicted in figure 4.5.2.1-1.

The minimum guard bands have been calculated using the following equation: (CBW x 1000 (kHz) - RB value x SCS x 12) / 2 - SCS/2

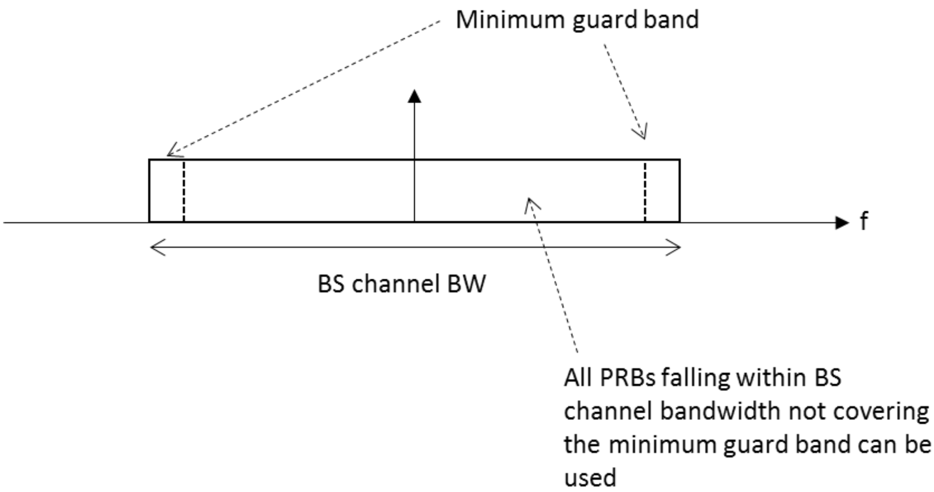


Figure 4.5.2.1-1 UE or BS can use all PRBs that do not overlap with the minimum guard band, considering the centre PRB alignment

Table 4.5.2.1-4: Range 1 NR UE and BS minimum guard band sizes (kHz) for CP-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]												
	5	10	15	20	25	30	40	50	60	70[1]	80	90[1]	100
15	242.5	312.5	382.5	452.5	522.5	[592.5]	552.5	692.5	N.A	N.A	N.A	N.A	N.A
30	505	665	645	805	785	[945]	905	1045	825	[965]	925	[885]	845
60	N.A	1010	990	1330	1310	[1290]	1610	1570	1530	[1490]	1450	[1410]	1370
NOTE 1: 70MHz and 90MHz are defined only as BS channel bandwidths in release 15.													

4.5.2.2 DFT-s-OFDM waveform

The following RB allocation is the closest number lower or equal to CP-OFDM maximum RB allocation satisfying the following equation, partial RB allocations shall also conform to this equation:

$$\text{number of RB}=2^{X}*3^{Y}*5^{Z}$$

Table 4.5.2.2-1: Range 1 NR UE maximum RB allocation for DFT-s-OFDM

SCS [kHz]	Channel bandwidths [MHz]										
	5	10	15	20	25	30	40	50	60	80	100
15	25	50	75	100	128	[160]	216	270	N.A	N.A	N.A
30	10	24	36	50	64	[75]	100	128	162	216	270
60	N.A	10	18	24	30	[36]	50	64	75	100	135

RB numbering for DFT-s-OFDM waveforms is the same than the RB number for CP-OFDM it is aligned with. In the case where DFT-s-OFDM maximum RB allocation is smaller than the CP-OFDM maximum allocation, all positions within the CP-OFDM allocation are valid. This implies that RBstart values can be higher than the maximum allocation for DFT-s-OFDM. The valid RB start values follow the following equation:

RBstart DFT-s-OFDM range = 0 to (CP-OFDM maxRB) – (DFT-s-OFDM #RB)

Table 4.5.2.2-2: Range 1 NR UE transmission bandwidths in MHz for DFT-s-OFDM

SCS [kHz]		Channel bandwidths [MHz]									
	5	10	15	20	25	30	40	50	60	80	100
15	4.5	9	13.5	18	23.04	[28.80]	38.88	48.6	N.A	N.A	N.A
30	3.6	8.64	12.96	18	23.04	[27.00]	36	46.08	58.32	77.76	97.2
60	N.A	7.2	12.96	17.28	21.6	[25.92]	36	46.08	54	72	97.2

For DFT-s-OFDM, when the maximum allocation is smaller than for CP-OFDM the transmit bandwidth is smaller, as a consequence the UE spectrum utilization can be smaller for DFT-s-OFDM than for CP-OFDM and in most cases equivalent to LTE.

Table 4.5.2.2-3: Range 1 NR UE spectrum utilization for DFT-s-OFDM

SCS [kHz]	Channel bandwidths [MHz]										
	5	10	15	20	25	30	40	50	60	80	100
15	90.0%	90.0%	90.0%	90.0%	92.2%	96.0%	97.2%	97.2%	N.A	N.A	N.A
30	72.0%	86.4%	86.4%	90.0%	92.2%	90.0%	90.0%	92.2%	97.2%	97.2%	97.2%
60	N.A	72.0%	86.4%	86.4%	86.4%	86.4%	90.0%	92.2%	90.0%	90.0%	97.2%

4.5.3 Maximum RB Allocation, Transmission Bandwidth and Spectrum Utilization for FR2

4.5.3.1 CP-OFDM Waveform

The following maximum RB allocation defines the minimum spectrum utilization to be realized per channel bandwidths and valid sub-carrier spacing.

Table 4.5.3.1-1: Range 2 NR UE and BS maximum RB allocation for CP-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]			
	50	100	200	400
60	66	132	264	N.A
120	32	66	132	264

Table 4.5.3.1-2: Range 2 NR UE and BS transmission bandwidths in MHz for CP-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]			
	50	100	200	400
60	47.52	95.04	190.08	N.A
120	46.08	95.04	190.08	380.16

Table 4.5.3.1-3: Range 2 NR UE and BS spectrum utilization for CP-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]			
	50	100	200	400
60	95.0%	95.0%	95.0%	N.A
120	92.2%	95.0%	95.0%	95.0%

Table 4.5.3.1-4: Range 2 NR UE and BS minimum guard band sizes (kHz) for CP-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]			
	50	100	200	400
60	1210	2450	4930	N.A
120	1900	2420	4900	9860

4.5.3.2 DFT-s-OFDM waveform

The following RB allocation is the closest number lower or equal to CP-OFDM maximum RB allocation satisfying the following equation, partial RB allocations shall also conform to this equation:

number of RB=$2^X*3^Y*5^Z$

Table 4.5.3.2-1: Range 2 NR UE maximum RB allocation for DFT-S-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]			
	50	100	200	400
60	64	128	264	N.A
120	32	64	128	264

RB numbering for DFT-s-OFDM waveforms is the same than the RB number for CP-OFDM it is aligned with. In the case where DFT-s-OFDM maximum RB allocation is smaller than the CP-OFDM maximum allocation, all positions within the CP-OFDM allocation are valid. This implies that RBstart values can be higher than the maximum allocation for DFT-s-OFDM. The valid RB start values follow the following equation:

RBstart DFT-s-OFDM range = 0 to (CP-OFDM maxRB) – (DFT-s-OFDM #RB)

Table 4.5.3.2-2: Range 2 NR UE transmission bandwidths in MHz for DFT-S-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]			
	50	100	200	400
60	46.08	92.16	190.08	N.A
120	46.08	92.16	184.32	380.16

Table 4.5.3.2-3: Range 2 NR UE spectrum utilization for DFT-S-OFDM

SCS [kHz]	BS / UE Channel bandwidths [MHz]			
	50	100	200	400
60	92.2%	92.2%	95.0%	N.A
120	92.2%	92.2%	92.2%	95.0%

4.5.4 Sub-carrier alignment with DC and between numerologies and their impact to guard bands for FR1

From RAN1 agreement, the lowest valid SCS allocation must be such that one sub-carrier is aligned with DC (channel centre). This results in a shift of ½ SCS for the lowest valid SCS for a given channel bandwidth. Similarly, the different SCS in a given channel bandwidth, must have their sub-carrier 0 aligned for all numerologies. The following table provides the lowest numerology RB number for which the RB0 sub carrier 0 aligns with the lowest numerology sub carrier 0. This alignment is valid for the case where the reference SCS is the lowest valid SCS.

Table 4.5.4-1: Lowest SCS RB number for which the first SC0 are aligned

SCS [kHz]	Channel bandwidths [MHz]									
	5	10	15	20	25	40	50	60	80	100
15	RB0	RB0	RB0	RB0	RB0	RB0	RB0	N.A	N.A	N.A
30	RB2	RB2	RB2	RB2	RB2	RB2	RB2	RB0	RB0	RB0
60	N.A	RB4	RB4	RB6	RB4	RB6	RB6	RB2	RB2	RB2

The following table provides the frequency shift for all the numerologies based on lowest SCS alignment with DC and the SC0 alignment rule between SCS.

Table 4.5.4-2: allocation shift in KHz

SCS [kHz]	Channel bandwidths [MHz]									
	5	10	15	20	25	40	50	60	80	100
15	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	NA	NA	NA
30	75	-15	75	-15	75	-15	-15	-15	-15	-15
60	NA	-30	60	150	-120	-30	150	-30	150	150

From these alignments, the lower and upper guard-bands can be calculated and are provided in the table below.

Table 4.5.4-3: Lower and upper channel guard-bands in kHz

	SCS [kHz]	Channel bandwidths [MHz]									
		5	10	15	20	25	40	50	60	80	100
Lower Guard Band	15	242.5	312.5	382.5	452.5	522.5	552.5	692.5	N.A	N.A	N.A
	30	595	665	735	805	875	905	1045	825	925	845
	60	N.A	1010	1080	1510	1220	1610	1750	1530	1630	1550
Upper Guard Band	15	257.5	327.5	397.5	467.5	537.5	567.5	707.5	N.A	N.A	N.A
	30	445	695	585	835	725	935	1075	855	955	875
	60	N.A	1070	960	1210	1460	1670	1450	1590	1330	1250

4.5.5 Spectrum utilization when operating multiple numerologies

The flexible NR design enables optional frequency multiplexing of transmissions with different subcarrier spacing within the same carrier. If this is the case, then a spectrum occupancy must be calculated taking into account both numerologies. In release 15, for the UE this agreement relates to determining spectrum utilization where SRB and PDSCH have different numerologies and are frequency division multiplexed. For the BS, transmission or reception may be made with multiple numerologies.

In such cases, at each side of the carrier, the guard size is selected corresponding to the numerology operated immediately adjacent to the carrier edge and the bandwidth of the whole carrier. In the example below, if the carrier bandwidth would be e.g. 20MHz, then on the left hand side the guard would be the guard corresponding to 15kHz SCS and 20MHz bandwidth and the guard on the left hand side would be the guard corresponding to 60k SCS and 20MHz bandwidth. The guard sizes would not depend on the proportion of the carrier allocated to each numerology. (Note that the figure does not imply anything about the size of any guard between the numerologies; the inter-numerology guard within the same carrier is implementation dependent).

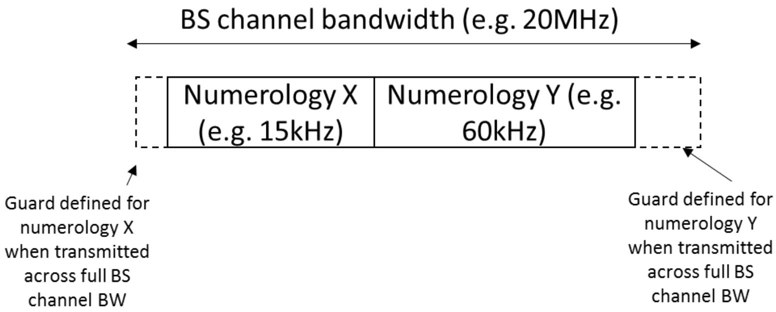


Figure 4.5.x-1 Example of multiple numerology transmission

When following this agreement, the possibility exists that the BS or UE channel bandwidth may be larger than the maximum bandwidth supported by one of the numerologies that is next to the carrier edge. For example, a 100MHz carrier may be transmitted with a 10MHz, 15kHz SCS allocation adjacent to the edge of the carrier. For these situations, a guard band size is defined as follows:

- For FR1, if multiple numerologies are multiplexed in the same symbol and the BS channel bandwidth is >50MHz, the guardband applied adjacent to 15k SCS shall be the same as the guardband defined for 30k SCS for the same BS channel bandwidth.

- For FR2, if multiple numerologies are multiplexed in the same symbol and the BS channel bandwidth is >200MHz, the guardband applied adjacent to 60k SCS shall be the same as the guardband defined for 120k SCS for the same BS channel bandwidth.

4.6 Mixed numerology requirements

4.6.1 Mixed Numerologies FDM operation use cases

A potential feature of NR is that the BS may transmit data using multiple numerologies in the same sub-frame using frequency division multiplexing. It has been agreed that in release 15, UEs will not be required to be able to receive data on multiple numerologies. If different parts of the same carrier are used for transmitting different numerologies, then the numerologies will not be fully orthogonal. Potentially, filtering or windowing could be used to achieve isolation between numerologies. In band emissions or EVM requirements, and receiver selectivity requirements could be considered to improve the inter-numerology isolation.

Two use cases for mixed numerology operation were discussed:

- Use Case #1: Data and Data mixed numerology FDM
  - FDM’ed transmission or reception of physical channels (e.g. NR PDSCH, PDCCH, PUSCH, PUCCH) with different numerologies at the same instance in DL or UL
- Use Case #2: Data and SS block (SS, PBCH) mixed numerology FDM
  - FDM’ed transmission or reception of SS block (SS/PBCH) and other physical channels (e.g. NR PDSCH, PDCCH) with different numerologies in DL

4.6.2 Data/Data mixed numerology FDM operation

The need for introducing RF requirements for isolating numerologies in such scenarios was investigated. The following conclusions were reached:

BS requirements:

- FDMed mixed numerologies for downlink and uplink data channel from BS perspective can be supported without additional in-band RF requirements compared to single numerology.
  - UE shall be able to TX and RX with one of these numerologies.

UE requirements:

- Case 1 mixed numerology FDM can be supported without additional UE in-band RF requirements compared to single numerology (e.g. via using inter-numerology guard bands)
- Do not define in-band UE RF requirements for Case 1 mixed numerology FDM in Rel-15
- FFS if any additional mixed numerologies requirements need to be introduced in future releases

The decision was based around the following observations:

- For systems performing beamforming, spatial isolation between different users/numerologies may be achieved
- Inter-numerology interference does not impact performance at low to medium SINR
- At high SINR, the gNB scheduler can mitigate inter-numerology interference by means of allocating a guard between the numerologies; this would be an implementation decision

RAN4 also made the following working assumption: Rel-15 NR UE is not mandated to support simultaneous DL reception or UL transmission of multiple FDM’ed physical channels (e.g. NR PDSCH, PDCCH, PUSCH, PUCCH) with different numerologies at the same time instance.

4.6.3 Data/SS mixed numerology FDM operation

Transmission of SS and data using different numerologies is needed in systems supporting a different data numerology to the SS. Similar to the data/data case, there may exist interference between the SS and data numerologies. The following decisions were made:

- Data/SS mixed numerology FDM operation can be supported for both BS/UE without additional in-band RF requirements compared to single numerology.
- Do not define dedicated BS and UE in-band RF requirements in Rel-15 related to Data/SS mixed numerology FDM.
- Support of simultaneous reception of Data/SS with mixed numerologies is optional from UE implementation perspective.
- RAN4 will investigate further how UE RRM requirements will take this into account
    - Case 1: Intra-frequency cell identification and measurements on the target cell while receiving Data from the serving cell with different numerology from SS
    - Other cases are not precluded

The decision was based around the following observations about interference of data onto SS:

- The SS is designed for cell search to function at low SINR. In general, inter-numerology interference is not significant
- One potential case in which the interference could be more significant is the case in which data is transmitted using a very narrow beam in the same direction as a user who is attempting to detect SS from the same basestation, and the SS beam is wider. In this case, data may be received with higher power than the SS. However, this scenario only occurs when the user performing cell search is in the same direction as the user to whom data is transmitted, which is low probability and the associated degradation is not seen as significant.

and following observations around the degradation on data caused by SS

- Since the SS beam sweeps and is not transmitted in all subframes, any interference from SS onto data is only for a limited portion of the time
- Data is likely to be always transmitted with the same or grater beamforming gain than SS
- Any interference from SS is only significant at high SINR
- If there is any risk of interference to a high SINR user from SS during a subframe, the gNB scheduler can mitigate the interference by leaving a guard between the two as an implementation decision.

4.7 TRx test metrics

4.7.1 TRx test metrics and link direction in FR2

Table 4.7.1-1 summarizes test metrics and link direction for TRx requirements.

Table 4.7.1-1: Summary of test metrics and link direction in FR2

Requirement		Metrics in TR 38.803 [10] (Range 2 / OTA)	Assumed Link Direction	Assumed Metrics
TX	Transmitter Maximum Output Power	EIRP CDF	Each beam peak search grid (NOTE 1)	EIRP (Link=Beam peak search grids, Meas=Link angle)
		TRP	TX beam peak direction obtained from above	TRP (Link=TX beam peak direction)
TX	Tx Spherical coverage	EIRP CDF	Each beam peak search grid (NOTE 1)	EIRP (Link=Beam peak search grids, Meas=Link angle)
TX	Maximum Power Reduction (MPR)	EIRP	TX beam peak direction (Reuse the result of MOP)	EIRP (Link=TX beam peak direction, Meas=Link angle)
TX	Additional Maximum Power Reduction (A-MPR)	EIRP	TX beam peak direction (Reuse the result of MOP)	EIRP (Link=TX beam peak direction, Meas=Link angle)
TX	Configured transmitted Output Power	EIRP	TX beam peak direction (Reuse the result of MOP)	EIRP (Link=TX beam peak direction, Meas=Link angle)
TX	Minimum Output Power	EIRP	TX beam peak direction (Reuse the result of MOP)	EIRP (Link=TX beam peak direction, Meas=Link angle)
TX	Transmit OFF power	TRP	TX beam peak direction (Reuse the result of MOP)	TRP (Link=TX beam peak direction)
TX	ON/OFF time mask	Beam peak	TX beam peak direction (Reuse the result of MOP)	EIRP (Link=TX beam peak direction, Meas=Link angle)
TX	Power Control tolerance (Absolute)	Beam peak	TX beam peak direction (Reuse the result of MOP)	EIRP (Link=TX beam peak direction, Meas=Link angle)
TX	Power Control tolerance (Relative)	Beam peak	TX beam peak direction (Reuse the result of MOP)	EIRP (Link=TX beam peak direction, Meas=Link angle)
TX	Power Control tolerance (Aggregated)	Beam peak	TX beam peak direction (Reuse the result of MOP)	EIRP (Link=TX beam peak direction, Meas=Link angle)
TX	Frequency error	Beam peak	TX beam peak direction (Reuse the result of MOP)	Frequency (Link=TX beam peak direction, Meas=Link angle)
TX	Error Vector Magnitude (EVM)	Beam peak	TX beam peak direction (Reuse the result of MOP)	EVM (Link=TX beam peak direction, Meas=Link angle)
TX	Error Vector Magnitude (EVM) - Spectrum Flatness	Beam peak	TX beam peak direction (Reuse the result of MOP)	EVM SF (Link=TX beam peak direction, Meas=Link angle)
TX	Carrier leakage	Beam peak	TX beam peak direction (Reuse the result of MOP)	Carrier Leakage (Link=TX beam peak direction, Meas=Link angle)
TX	In-band emissions (non allocated RB)	Beam peak	TX beam peak direction (Reuse the result of MOP)	In-band emission (Link=TX beam peak direction, Meas=Link angle)
TX	Occupied bandwidth	TRP -> Beam peak (NOTE 2)	TX beam peak direction (Reuse the result of MOP)	OBW (Link=TX beam peak direction, Meas=Link angle)
TX	Spectrum Emission Mask	TRP	TX beam peak direction (Reuse the result of MOP)	TRP (Link=TX beam peak direction)
TX	Adjacent Channel Leakage power Ratio	TRP	TX beam peak direction (Reuse the result of MOP)	TRP (Link=TX beam peak direction)
TX	General Spurious emissions	TRP	TX beam peak direction (Reuse the result of MOP)	TRP (Link=TX beam peak direction)
TX	Spurious emission UE-to-UE coexistence	TRP	TX beam peak direction (Reuse the result of MOP)	TRP (Link=TX beam peak direction)
TX	Additional spurious emissions	TRP	TX beam peak direction (Reuse the result of MOP)	TRP (Link=TX beam peak direction)
TX	[Beam correspondence]	[TBD]	[TBD]	[TBD]
RX	Reference sensitivity level	EIS CDF	Each beam peak search grid (NOTE 1)	EIS (Link=Beam peak search grids, Meas=Link Angle)
RX	Maximum input level	Beam peak	RX beam peak direction (Reuse the result of REFSENS)	EIS (Link=RX beam peak direction, Meas=Link angle)
RX	Adjacent Channel Selectivity (ACS)	Beam peak	RX beam peak direction (Reuse the result of REFSENS)	EIS (Link=RX beam peak direction, Meas=Link angle)

RX	In-band blocking	Beam peak	RX beam peak direction (Reuse the result of REFSENS)	EIS (Link=RX beam peak direction, Meas=Link angle)
RX	[Out-of-band blocking and Spurious response]	[TBD]	[TBD]	[TBD]
RX	Receiver Spurious emissions	TRP	TX beam peak direction (Reuse the result of MOP)	TRP (Link=TX beam peak direction)
RX	Receiver image	[TBD]	[TBD]	[TBD]
RX	In-channel selectivity	[TBD]	[TBD]	[TBD]
NOTE 1: Total number of points for measurement grid is up to TE vendors or test houses as far as it guarantees the agreement on the deviation (0.5 dB). NOTE 2: Metric of OBW was changed from TRP to Beam peak to align BS specification.				

5 UE Transmitter characteristics (frequency range 1)

5.1 General

5.1.1 CA Bandwidth Class

For intra-band contiguous carrier aggregation, a carrier aggregation configuration is a single operating band supporting a carrier aggregation bandwidth class with associated bandwidth combination sets. For each carrier aggregation configuration, requirements are specified for all aggregated channel bandwidths contained in a bandwidth combination set, A UE can indicate support of several bandwidth combination sets per carrier aggregation configuration.

For intra-band non-contiguous carrier aggregation, a carrier aggregation configuration is a single operating band supporting two or more sub-blocks, each supporting a carrier aggregation bandwidth class.

For inter-band carrier aggregation, a carrier aggregation configuration is a combination of operating bands, each supporting a carrier aggregation bandwidth class.

Table 5.1.1-1 gives the proposed NR CA bandwidth class for FR1.

Table 5.1.1-1: NR CA Bandwidth Class for FR1

NR CA bandwidth class	Aggregated channel bandwidth	Number of contiguous CC
A	$BW_{Channel\_CA} \leq BW_{Channel,max}$	1
B	20 MHz ≤ CBW ≤ 100 MHz	2
C	100 MHz < $BW_{Channel\_CA} \leq 2 \times BW_{Channel,max}$	2
D	200 MHz < $BW_{Channel\_CA} \leq 3 \times BW_{Channel,max}$	3
E	300 MHz < $BW_{Channel\_CA} \leq 4 \times BW_{Channel,max}$	4
NOTE: $BW_{Channel,max}$ is maximum channel bandwidth supported among all bands in a release		

5.2 Transmit power

5.2.1 Power Class

The following NR UE Power Classes define the maximum output power for any transmission bandwidth within the channel bandwidth for non-CA configuration unless otherwise stated.

Table 5.2.1-1: NR UE power classes

NR Operating band	Class 2	Class 3	Comments
n1		23 dBm ± 2 dB	LTE refarming band
n2		23 dBm ± 2 dB	LTE refarming band
n3		23 dBm ± 2 dB	LTE refarming band
n5		23 dBm ± 2 dB	LTE refarming band
n7		23 dBm ± 2 dB	LTE refarming band
n8		23 dBm ± 2 dB	LTE refarming band
n20		23 dBm ± 2 dB	LTE refarming band
n25		23 dBm ± 2 dB	LTE refarming band
n26		23 dBm ± 2 dB	LTE refarming band
n28		23 dBm +2/-2.5 dB	LTE refarming band
n34		23 dBm ± 2 dB	LTE refarming band
n38		23 dBm ± 2 dB	LTE refarming band
n39		23 dBm ± 2 dB	LTE refarming band
n40		23 dBm ± 2 dB	LTE refarming band
n41	26 dBm +2/-3 dB	23 dBm ± 2 dB	LTE refarming band
n50		23 dBm ± 2 dB	LTE refarming band
n51		23 dBm ± 2 dB	LTE refarming band
n66		23 dBm ± 2 dB	LTE refarming band
n70		23 dBm ± 2 dB	LTE refarming band
n71		23 dBm +2/-2.5 dB	LTE refarming band
n74		23 dBm ± 2 dB	LTE refarming band
n77	26 dBm +2/-3 dB	23 dBm +2/-3 dB	3.3 - 4.2 GHz
n78	26 dBm +2/-3 dB	23 dBm +2/-3 dB	3.3 - 3.8 GHz
n79	26 dBm +2/-3 dB	23 dBm +2/-3 dB	4.4 - 5 GHz
n80		23 dBm ± 2 dBTBD	SUL 1710 - 1785 MHz
n81		23 dBm ± 2 dBTBD	SUL 880 - 915 MHz
n82		23 dBm ± 2 dBTBD	SUL 832 - 862 MHz
n83		23 dBm +2/-2.5 dB	SUL 703 - 748 MHz
n84		23 dBm ± 2 dB	SUL 1920 - 1980 MHz
n86		23 dBm ± 2 dB	SUL 1710 - 1780 MHz
NOTE: If the uplink/downlink configuration is 0 or 6, the requirements for power class 2 are not applicable, and the corresponding requirements for a power class 3 UE shall apply.			

For UE with two transmit antenna connectors in closed-loop spatial multiplexing scheme, the maximum output power for any transmission bandwidth within the channel bandwidth is specified in Table 5.2.1-2.

Table 5.2.1-2: NR UE Power Class for UL-MIMO in closed loop spatial multiplexing scheme

EUTRA band	Class 1 (dBm)	Tolerance (dB)	Class 2 (dBm)	Tolerance (dB)	Class 3 (dBm)	Tolerance (dB)	Class 4 (dBm)	Tolerance (dB)
n1					23	+2/-3		
n2					23	+2/-3[1]		
n3					23	+2/-3[1]		
n5					23	+2/-3		
n7					23	+2/-3[1]		
n8					23	+2/-3[1]		
n20					23	+2/-3[1]		
n25					23	+2/-3[1]		
n26					23	+2/-3[1]		
n28					23	+2/-3		
n34					23	+2/-3		
n38					23	+2/-3		
n39					23	+2/-3		
n40					23	+2/-3		
n41			26	+2/-3[1]	23	+2/-3[1]		
n50					23	+2/-3		
n51					23	+2/-3		
n66					23	+2/-3		
n70					23	+2/-3		
n71					23	+2/-3		
n74					23	+2/-3		
n77			26	+2/-3	23	+2/-3		
n78			26[2]	+2/-3	23	+2/-3		
n79			26	+2/-3	23	+2/-3		
NOTE 1: [1] refers to the transmission bandwidths confined within F_{UL_low} and F_{UL_low} + 4 MHz or F_{UL_high} – 4 MHz and F_{UL_high}, the maximum output power requirement is relaxed by reducing the lower tolerance limit by 1.5 dB NOTE 2: How to mandate Power Class 2 UE in certain regions is FFS.								

If UE is configured for transmission on single-antenna port, the requirements in Table 5.2.1-1 apply.

5.2.2 MPR /A-MPR

5.2.3 UE maximum output power for modulation / RB allocation

For UE Power Class 3, the allowed Maximum Power Reduction (MPR) for the maximum output power in Table 5.2.1-1, due to higher order modulation and transmit bandwidth configuration (resource blocks) is specified in Table 5.2.3-1. The Maximum Power Reduction is constant across channel bandwidths up to 100MHz and all valid sub-carrier spacing and only depends on modulation type and order and RB allocation type: Outer RB allocations see higher MPR than Inner RB allocations, except for 64QAM and 256QAM where a single MPR value applies to any RB allocation.

Table 5.2.3-1: Maximum Power Reduction (MPR) for Power Class 3, Channel bandwidths up to 100MHz

Modulation	MPR (dB)	
	Outer RB allocations	Inner RB allocations
DFT-s-OFDM PI/2 BPSK	≤ [TBD]	≤ [TBD]
DFT-s-OFDM QPSK	≤ [TBD]	≤ [TBD]
DFT-s-OFDM 16 QAM	≤ [TBD]	≤ [TBD]
DFT-s-OFDM 64 QAM	≤ [TBD]	
DFT-s-OFDM 256 QAM	≤ [TBD]	
CP-OFDM QPSK	≤ [TBD]	≤ [TBD]
CP-OFDM 16 QAM	≤ [TBD]	≤ [TBD]
CP-OFDM 64 QAM	≤ [TBD]	
CP-OFDM 256 QAM	≤ [TBD]	

Where the following parameters are defined to specify valid RB allocation ranges for Outer and Inner RB allocations:

L_{CRBmax} is the maximum number of RB for a given Channel bandwidth and sub-carrier spacing derived from from spectrum utilization.

$RB_{startLow} = L_{CRB}/2$ rounded down to next integer with floor at 1

$RB_{startHigh} = L_{CRBmax} – RBs_{tartLow} – L_{CRB}$

Where Inner RB allocation range is specified as follows: Inner RB allocation are $L_{CRB}/2$ away from each edge of the maximum RB allocation for all $L_{CRB} \leq L_{CRBmax}/2$ rounded up to the next integer.

$RB_{startInner}$: valid RB_{start} values for Inner RB allocations

For $L_{CRB} \leq L_{CRBmax}/2$ rounded up to the next integer, $RB_{startLow} \leq RB_{startInner} \leq RB_{startHigh}$

Where Outer RB allocation range is all allocations which are not Inner RB allocation

5.2.4 Inner RB allocation range for all 5MHz – 100MHz channel bandwidths and SCS

Figure 5.2.4-1 is illustrating Outer RB allocations in orange and Inner RB allocation in yellow for the two valid SCS for 5MHz channel. On the left side the two triangles correspond to the CP-OFDM allocations with 15kHz SCS in the lower left and 30kHz on the upper right, similarly, the same triangles for DFT-s-OFDM allocation can be found on the right side of the figure.

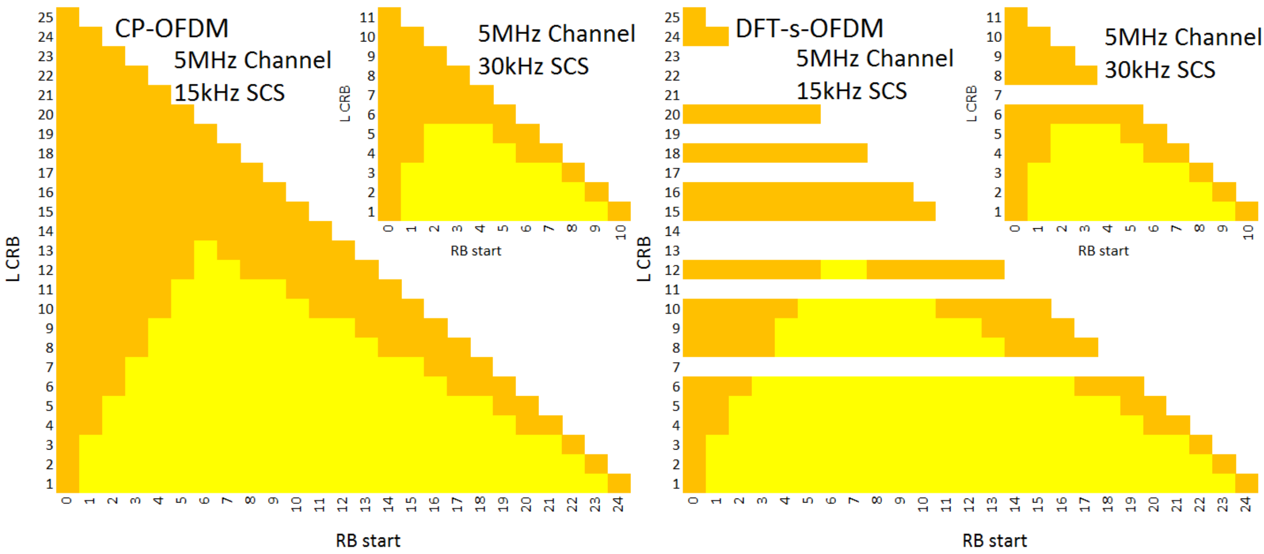


Figure 5.2.4-1: Inner and outer RB allocations of 15kHz and 30kHz 5MHz channel bandwidth for CP-OFDM and DFT-s-OFDM

Table 5.2.4-1 provides the valid Inner RB allocation RB_{start} range for channel bandwidths and SCS having a L_{CRBmax} range of 11 to 51 for the different RB allocation lengths $L_{CRB} \leq L_{CRBmid}$. The yellow highlighted column corresponds to the inner RB allocation of the 15kHz and 30kHz SCS 5MHZ channels described in Figure 5.2.4-1.

Table 5.2.4-2 provides the valid Inner RB allocation RB_{start} range for channel bandwidths and SCS having a L_{CRBmax} range of 52 to 133 for the different RB allocation lengths $L_{CRB} \leq L_{CRBmid}$.

Table 5.2.4-3 provides the valid Inner RB allocation RB_{start} range for channel bandwidths and SCS having a L_{CRBmax} range of 135 to 273 for the different RB allocation lengths $L_{CRB} \leq L_{CRBmid}$.

RBsL is the lowest valid RB_{start} value for Inner RB allocations

RBsH is the highest valid RB_{start} value for Inner RB allocations

Table 5.2.4-1: RB_{start} range for inner RB allocations, L_{CRBmax} range 11-51

	Channel bandwidth and SCS													
	20/40 MHz 30/60 kHz		**15 MHz 30 kHz**		**25 MHz 60 kHz**		**5 MHz 15 kHz**		**10/20 MHz 30/60 kHz**		**15 MHz 60 kHz**		**5/10 MHz 30/60 kHz**	
L_{CRBmax}	51		38		31		25		24		18		11	
L_{CRBmid}	26		19		16		13		12		9		6	
L_{CRB}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}
1	1	49	1	36	1	29	1	23	1	22	1	16	1	9
2	1	48	1	35	1	28	1	22	1	21	1	15	1	8
3	1	47	1	34	1	27	1	21	1	20	1	14	1	7
4	2	45	2	32	2	25	2	19	2	18	2	12	2	5
5	2	44	2	31	2	24	2	18	2	17	2	11	2	4
6	3	42	3	29	3	22	3	16	3	15	3	9	NA	
7	3	41	3	28	3	21	3	15	3	14	3	8	NA	
8	4	39	4	26	4	19	4	13	4	12	4	6	NA	
9	4	38	4	25	4	18	4	12	4	11	4	5	NA	
10	5	36	5	23	5	16	5	10	5	9	NA		NA	
11	5	35	5	22	5	15	5	9	5	8	NA		NA	
12	6	33	6	20	6	13	6	7	6	6	NA		NA	
13	6	32	6	19	6	12	6	6	NA		NA		NA	
14	7	30	7	17	7	10	NA		NA		NA		NA	
15	7	29	7	16	7	9	NA		NA		NA		NA	
16	8	27	8	14	NA		NA		NA		NA		NA	
17	8	26	8	13	NA		NA		NA		NA		NA	
18	9	24	9	11	NA		NA		NA		NA		NA	
19	9	23	9	10	NA		NA		NA		NA		NA	
20	10	21	NA		NA		NA		NA		NA		NA	
21	10	20	NA		NA		NA		NA		NA		NA	
22	11	18	NA		NA		NA		NA		NA		NA	
23	11	17	NA		NA		NA		NA		NA		NA	
24	12	15	NA		NA		NA		NA		NA		NA	
25	12	14	NA		NA		NA		NA		NA		NA	

Table 5.2.4-2: RB_{start} range for inner RB allocations, L_{CRBmax} range 52-133

	Channel bandwidth and SCS											
	25/50 MHz 15/30 kHz		**80 MHz 60 kHz**		**20/40 MHz 15/30 kHz**		**15/60 MHz 15/60 kHz**		**25/50 MHz 30/60 kHz**		**10 MHz 15 kHz**	
L_{CRBmax}	133		107		106		79		65		52	
L_{CRBmid}	67		54		53		40		33		26	
L_{CRB}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}
1	1	131	1	105	1	104	1	77	1	63	1	50
2	1	130	1	104	1	103	1	76	1	62	1	49
3	1	129	1	103	1	102	1	75	1	61	1	48
4	2	127	2	101	2	100	2	73	2	59	2	46
5	2	126	2	100	2	99	2	72	2	58	2	45
6	3	124	3	98	3	97	3	70	3	56	3	43
7	3	123	3	97	3	96	3	69	3	55	3	42
8	4	121	4	95	4	94	4	67	4	53	4	40
9	4	120	4	94	4	93	4	66	4	52	4	39
10	5	118	5	92	5	91	5	64	5	50	5	37
11	5	117	5	91	5	90	5	63	5	49	5	36
12	6	115	6	89	6	88	6	61	6	47	6	34
13	6	114	6	88	6	87	6	60	6	46	6	33
14	7	112	7	86	7	85	7	58	7	44	7	31
15	7	111	7	85	7	84	7	57	7	43	7	30
16	8	109	8	83	8	82	8	55	8	41	8	28
17	8	108	8	82	8	81	8	54	8	40	8	27
18	9	106	9	80	9	79	9	52	9	38	9	25
19	9	105	9	79	9	78	9	51	9	37	9	24
20	10	103	10	77	10	76	10	49	10	35	10	22
21	10	102	10	76	10	75	10	48	10	34	10	21
22	11	100	11	74	11	73	11	46	11	32	11	19
23	11	99	11	73	11	72	11	45	11	31	11	18
24	12	97	12	71	12	70	12	43	12	29	12	16
25	12	96	12	70	12	69	12	42	12	28	12	15
26	13	94	13	68	13	67	13	40	13	26	13	13
27	13	93	13	67	13	66	13	39	13	25	NA	
28	14	91	14	65	14	64	14	37	14	23	NA	
29	14	90	14	64	14	63	14	36	14	22	NA	
30	15	88	15	62	15	61	15	34	15	20	NA	
31	15	87	15	61	15	60	15	33	15	19	NA	
32	16	85	16	59	16	58	16	31	16	17	NA	
33	16	84	16	58	16	57	16	30	16	16	NA	
34	17	82	17	56	17	55	17	28	NA		NA	
35	17	81	17	55	17	54	17	27	NA		NA	
36	18	79	18	53	18	52	18	25	NA		NA	
37	18	78	18	52	18	51	18	24	NA		NA	
38	19	76	19	50	19	49	19	22	NA		NA	
39	19	75	19	49	19	48	19	21	NA		NA	
40	20	73	20	47	20	46	NA		NA		NA	
41	20	72	20	46	20	45	NA		NA		NA	
42	21	70	21	44	21	43	NA		NA		NA	
43	21	69	21	43	21	42	NA		NA		NA	
44	22	67	22	41	22	40	NA		NA		NA	
45	22	66	22	40	22	39	NA		NA		NA	
46	23	64	23	38	23	37	NA		NA		NA	
47	23	63	23	37	23	36	NA		NA		NA	
48	24	61	24	35	24	34	NA		NA		NA	
49	24	60	24	34	24	33	NA		NA		NA	
50	25	58	25	32	25	31	NA		NA		NA	
51	25	57	25	31	25	30	NA		NA		NA	
52	26	55	26	29	26	28	NA		NA		NA	
53	26	54	26	28	26	27	NA		NA		NA	
54	27	52	NA		NA		NA		NA		NA	
55	27	51	NA		NA		NA		NA		NA	
56	28	49	NA		NA		NA		NA		NA	
57	28	48	NA		NA		NA		NA		NA	
58	29	46	NA		NA		NA		NA		NA	
59	29	45	NA		NA		NA		NA		NA	

60	30	43	NA	NA	NA	NA	NA
61	30	42	NA	NA	NA	NA	NA
62	31	40	NA	NA	NA	NA	NA
63	31	39	NA	NA	NA	NA	NA
64	32	37	NA	NA	NA	NA	NA
65	32	36	NA	NA	NA	NA	NA
66	33	34	NA	NA	NA	NA	NA
67	33	33	NA	NA	NA	NA	NA

Table 5.2.4-3: RB_{start} range for inner RB allocations, L_{CRBmax} range 135-273

	Channel bandwidth and SCS											
	100 MHz 30 kHz		50 MHz 15 kHz		80 MHz 30 kHz		40 MHz 15 kHz		60 MHz 30 kHz		100 MHz 60 kHz	
L_{CRBmax}	273		270		217		216		162		135	
L_{CRBmid}	137		135		109		108		81		68	
L_{CRB}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}	RB_{sL}	RB_{sH}
1	1	271	1	268	1	215	1	214	1	160	1	133
2	1	270	1	267	1	214	1	213	1	159	1	132
3	1	269	1	266	1	213	1	212	1	158	1	131
4	2	267	2	264	2	211	2	210	2	156	2	129
5	2	266	2	263	2	210	2	209	2	155	2	128
6	3	264	3	261	3	208	3	207	3	153	3	126
7	3	263	3	260	3	207	3	206	3	152	3	125
8	4	261	4	258	4	205	4	204	4	150	4	123
9	4	260	4	257	4	204	4	203	4	149	4	122
10	5	258	5	255	5	202	5	201	5	147	5	120
11	5	257	5	254	5	201	5	200	5	146	5	119
12	6	255	6	252	6	199	6	198	6	144	6	117
13	6	254	6	251	6	198	6	197	6	143	6	116
14	7	252	7	249	7	196	7	195	7	141	7	114
15	7	251	7	248	7	195	7	194	7	140	7	113
16	8	249	8	246	8	193	8	192	8	138	8	111
17	8	248	8	245	8	192	8	191	8	137	8	110
18	9	246	9	243	9	190	9	189	9	135	9	108
19	9	245	9	242	9	189	9	188	9	134	9	107
20	10	243	10	240	10	187	10	186	10	132	10	105
21	10	242	10	239	10	186	10	185	10	131	10	104
22	11	240	11	237	11	184	11	183	11	129	11	102
23	11	239	11	236	11	183	11	182	11	128	11	101
24	12	237	12	234	12	181	12	180	12	126	12	99
25	12	236	12	233	12	180	12	179	12	125	12	98
26	13	234	13	231	13	178	13	177	13	123	13	96
27	13	233	13	230	13	177	13	176	13	122	13	95
28	14	231	14	228	14	175	14	174	14	120	14	93
29	14	230	14	227	14	174	14	173	14	119	14	92
30	15	228	15	225	15	172	15	171	15	117	15	90
31	15	227	15	224	15	171	15	170	15	116	15	89
32	16	225	16	222	16	169	16	168	16	114	16	87
33	16	224	16	221	16	168	16	167	16	113	16	86
34	17	222	17	219	17	166	17	165	17	111	17	84
35	17	221	17	218	17	165	17	164	17	110	17	83
36	18	219	18	216	18	163	18	162	18	108	18	81
37	18	218	18	215	18	162	18	161	18	107	18	80
38	19	216	19	213	19	160	19	159	19	105	19	78
39	19	215	19	212	19	159	19	158	19	104	19	77
40	20	213	20	210	20	157	20	156	20	102	20	75
41	20	212	20	209	20	156	20	155	20	101	20	74
42	21	210	21	207	21	154	21	153	21	99	21	72
43	21	209	21	206	21	153	21	152	21	98	21	71
44	22	207	22	204	22	151	22	150	22	96	22	69
45	22	206	22	203	22	150	22	149	22	95	22	68
46	23	204	23	201	23	148	23	147	23	93	23	66
47	23	203	23	200	23	147	23	146	23	92	23	65
48	24	201	24	198	24	145	24	144	24	90	24	63
49	24	200	24	197	24	144	24	143	24	89	24	62
50	25	198	25	195	25	142	25	141	25	87	25	60
51	25	197	25	194	25	141	25	140	25	86	25	59
52	26	195	26	192	26	139	26	138	26	84	26	57
53	26	194	26	191	26	138	26	137	26	83	26	56
54	27	192	27	189	27	136	27	135	27	81	27	54
55	27	191	27	188	27	135	27	134	27	80	27	53
56	28	189	28	186	28	133	28	132	28	78	28	51
57	28	188	28	185	28	132	28	131	28	77	28	50
58	29	186	29	183	29	130	29	129	29	75	29	48
59	29	185	29	182	29	129	29	128	29	74	29	47

60	30	183	30	180	30	127	30	126	30	72	30	45
61	30	182	30	179	30	126	30	125	30	71	30	44
62	31	180	31	177	31	124	31	123	31	69	31	42
63	31	179	31	176	31	123	31	122	31	68	31	41
64	32	177	32	174	32	121	32	120	32	66	32	39
65	32	176	32	173	32	120	32	119	32	65	32	38
66	33	174	33	171	33	118	33	117	33	63	33	36
67	33	173	33	170	33	117	33	116	33	62	33	35
68	34	171	34	168	34	115	34	114	34	60	NA	
69	34	170	34	167	34	114	34	113	34	59	NA	
70	35	168	35	165	35	112	35	111	35	57	NA	
71	35	167	35	164	35	111	35	110	35	56	NA	
72	36	165	36	162	36	109	36	108	36	54	NA	
73	36	164	36	161	36	108	36	107	36	53	NA	
74	37	162	37	159	37	106	37	105	37	51	NA	
75	37	161	37	158	37	105	37	104	37	50	NA	
76	38	159	38	156	38	103	38	102	38	48	NA	
77	38	158	38	155	38	102	38	101	38	47	NA	
78	39	156	39	153	39	100	39	99	39	45	NA	
79	39	155	39	152	39	99	39	98	39	44	NA	
80	40	153	40	150	40	97	40	96	40	42	NA	
81	40	152	40	149	40	96	40	95	40	41	NA	
82	41	150	41	147	41	94	41	93	NA		NA	
83	41	149	41	146	41	93	41	92	NA		NA	
84	42	147	42	144	42	91	42	90	NA		NA	
85	42	146	42	143	42	90	42	89	NA		NA	
86	43	144	43	141	43	88	43	87	NA		NA	
87	43	143	43	140	43	87	43	86	NA		NA	
88	44	141	44	138	44	85	44	84	NA		NA	
89	44	140	44	137	44	84	44	83	NA		NA	
90	45	138	45	135	45	82	45	81	NA		NA	
91	45	137	45	134	45	81	45	80	NA		NA	
92	46	135	46	132	46	79	46	78	NA		NA	
93	46	134	46	131	46	78	46	77	NA		NA	
94	47	132	47	129	47	76	47	75	NA		NA	
95	47	131	47	128	47	75	47	74	NA		NA	
96	48	129	48	126	48	73	48	72	NA		NA	
97	48	128	48	125	48	72	48	71	NA		NA	
98	49	126	49	123	49	70	49	69	NA		NA	
99	49	125	49	122	49	69	49	68	NA		NA	
100	50	123	50	120	50	67	50	66	NA		NA	
101	50	122	50	119	50	66	50	65	NA		NA	
102	51	120	51	117	51	64	51	63	NA		NA	
103	51	119	51	116	51	63	51	62	NA		NA	
104	52	117	52	114	52	61	52	60	NA		NA	
105	52	116	52	113	52	60	52	59	NA		NA	
106	53	114	53	111	53	58	53	57	NA		NA	
107	53	113	53	110	53	57	53	56	NA		NA	
108	54	111	54	108	54	55	54	54	NA		NA	
109	54	110	54	107	54	54	NA		NA		NA	
110	55	108	55	105	NA		NA		NA		NA	
111	55	107	55	104	NA		NA		NA		NA	
112	56	105	56	102	NA		NA		NA		NA	
113	56	104	56	101	NA		NA		NA		NA	
114	57	102	57	99	NA		NA		NA		NA	
115	57	101	57	98	NA		NA		NA		NA	
116	58	99	58	96	NA		NA		NA		NA	
117	58	98	58	95	NA		NA		NA		NA	
118	59	96	59	93	NA		NA		NA		NA	
119	59	95	59	92	NA		NA		NA		NA	
120	60	93	60	90	NA		NA		NA		NA	
121	60	92	60	89	NA		NA		NA		NA	
122	61	90	61	87	NA		NA		NA		NA	
123	61	89	61	86	NA		NA		NA		NA	
124	62	87	62	84	NA		NA		NA		NA	

125	62	86	62	83	NA	NA	NA	NA
126	63	84	63	81	NA	NA	NA	NA
127	63	83	63	80	NA	NA	NA	NA
128	64	81	64	78	NA	NA	NA	NA
129	64	80	64	77	NA	NA	NA	NA
130	65	78	65	75	NA	NA	NA	NA
131	65	77	65	74	NA	NA	NA	NA
132	66	75	66	72	NA	NA	NA	NA
133	66	74	66	71	NA	NA	NA	NA
134	67	72	67	69	NA	NA	NA	NA
135	67	71	67	68	NA	NA	NA	NA
136	68	69	NA		NA	NA	NA	NA
137	68	68	NA		NA	NA	NA	NA

5.3 Output power dynamics

5.3.1 Minimum output power

5.3.1.1 Current LTE requirement

Current LTE singe carrier requirement is defined as the same output level as shown in the following table which is copied from TS 36.101 [3].

Table 5.3.1.1-1: Minimum output power (Table 6.3.2.1-1 of TS 36.101 [3])

	Channel bandwidth / Minimum output power / Measurement bandwidth					
	1.4 MHz	**3.0 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
Minimum output power	-40 dBm					
Measurement bandwidth	1.08 MHz	2.7 MHz	4.5 MHz	9.0 MHz	13.5 MHz	18 MHz

For the CA requirement, the following is the current definition.

For inter-band carrier aggregation with uplink assigned to two E-UTRA bands and intra-band contiguous and non-contiguous carrier aggregation, the minimum controlled output power of the UE is defined as the transmit power of the UE per component carrier, i.e., the power in the channel bandwidth of each component carrier for all transmit bandwidth configurations (resource blocks), when the power on both component carriers are set to a minimum value.

And each carrier requirement is defined as the single carrier requirement, i.e. -40 dBm.

For the minimum output power, it should be noted that -30 dBm is the minimum output power that can support 256QAM modulation.

Table 5.3.1.1-2: Parameters for Error Vector Magnitude (Table 6.5.2.1.1-2 of TS 36.101 [3])

Parameter	Unit	Level
UE Output Power	dBm	≥ -40
UE Output Power for 256 QAM	dBm	≥ -30
Operating conditions		Normal conditions

5.3.1.2 NR requirement

For the NR requirement, there could be two approaches being considered. The first is that all of the CBW reuses the same level requirement as LTE. The second is that the CBW enlarge can be treated as the LTE CA then the minimum output power can be defined as the same PSD with LTE 20MHz.

The first approach tightens the UE implementation if UL SNR is considered. If 100MHz reuses 20MHz absolute level, i.e. -40 dBm for QPSK, 16QAM, 64QAM modulation and -30 dBm for 256QAM modulation, the SNR decreases 7 dB which is a large improvement request to the link design. When LTE UL256QAM was discussed, the link budget was very tough that 7 dB improvement is a big challenge.

According to current TS 36.101 [3] arrangement, the UL 256QAM challenge was not reflected in the minimum output power section but in the EVM clause. Therefore, the same approach was used in the requirement. The following requirements were agreed for NR minimum output power.

Table 5.3.1.2-1: NR minimum output power

	Channel bandwidth / Minimum output power / Measurement bandwidth									
	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	40MHz	50MHz	60MHz	80MHz	100MHz
Minimum output power (dBm)	-40				-39	-37	-36	-35.2	-34	-33
Measurement bandwidth	See Transmission bandwidth configuration defined in 4.2									

Table 5.3.1.2-2: Parameters for Error Vector Magnitude

Parameters	Channel bandwidth / Minimum output power / Measurement bandwidth									
	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	40MHz	50MHz	60MHz	80MHz	100MHz
UE output power (dBm)	≥ -40				≥ -39	≥ -37	≥ -36	≥ -35.2	≥ -34	≥ -33
UE output power for UL 256QAM (dBm)	≥ -30				≥ -29	≥ -27	≥ -26	≥ -25.2	≥ -24	≥ -23

5.4 Transmit signal quality

5.4.1 IQ-Image and Carrier leakage

IQ Image and Carrier leakage for NR Range 1 are specified as follows.

Table 5.4.1-1: NR range 1 IQ Image and Carrier leakage requirement

IQ Image	dB	-28	Image frequencies when carrier center frequency < 6 GHz and Output power > 10 dBm
		-25	Image frequencies when carrier center frequency < 6 GHz and Output power ≤ 10 dBm
Carrier leakage	dBc	-28	Output power > 10 dBm and carrier center frequency < 6 GHz
		-25	0 dBm ≤ Output power ≤10 dBm
		-20	-30 dBm ≤ Output power ≤ 0 dBm
		-10	-40 dBm ≤ Output power < -30 dBm
Note: Positions of carrier leakage will be captured later.			

5.4.2 Error vector magnitude

Error vector magnitude presented in Table 5.4.2-1 is specified as a minimum requirement for NR range 1 UE. pi/2 BPSK value subject to change due to spectrum shaping discussion.

Table 5.4.2-1: EVM per modulation for NR range 1 UE

Modulation	EVM
pi/2 BPSK	[25%]
QPSK	17.5%
16QAM	12.5%
64QAM	8%
256QAM	3.5%

5.4.3 In-band emissions

Based on analysis general section of LTE in-band emission mask requirement can be largely re-used for NR when the evaluation period is changed to be longer and the interference power is measured average power. Reason for this is that when OFDM becomes clipped by the PA, the caused IBE spikes are basically impulsive noise. Hence the IBE of a single slot is quite noisy and vary between the slots. When multiple slots are measured and average value is calculated this instantaneous variation between the slots is averaged out. Impact of using 10 subframe test time vs one slot test time can be seen in Figure 5.4.3-1 which shows the histogram of in-band emission at a single RB as offset from the limit value. Hence, positive values indicate violation of the in-band limit. Without averaging, the standard deviation of the measurement result is large, and the measurement is unreliable. Therefore, NR Range 1 in-band emission measurement period is specified to be 10 sub-frames. The in-band emission is averaged over slots.

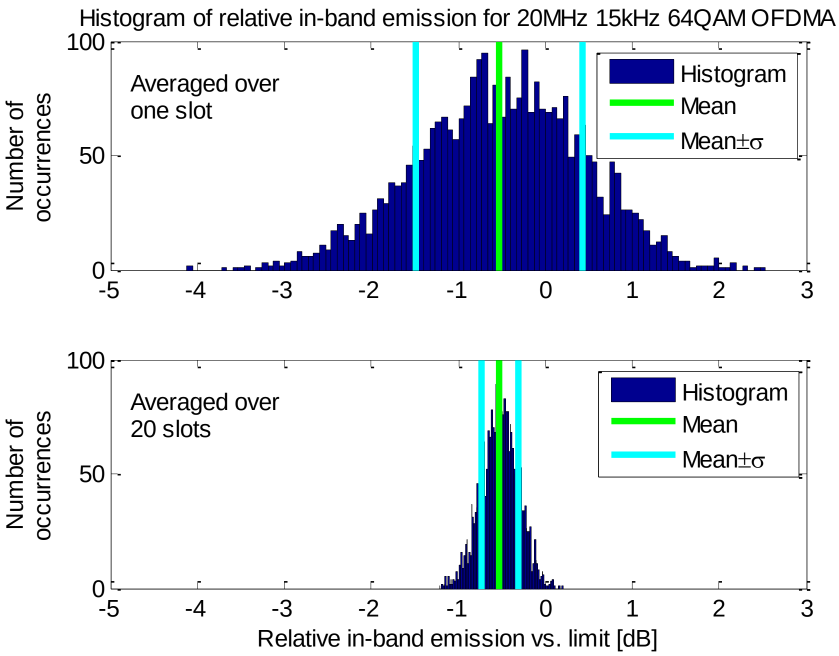


Figure 5.4.3-1: Effect of averaging in-band emission over one slot vs.10 subframes, i.e., 20 slots.

The third expression of the general IBE limit (-57 dBm/180 kHz) takes into account the subcarrier spacing. In LTE, the -57 dB refers to the 180 kHz bandwidth of a single RB. In NR, this must be scaled to maintain the same spectral density for all SCSs. This modification is established by adding +10Log$_{10}$(SCS/15 kHz) term into the IBE formula, see Table 5.4.3-1 where SCS is the applicaple subcarrier spacing.

Table 5.4.3-1: general section of LTE in-band emission mask

General	dB	$\max\{-25-10\cdot\log_{10}(N_{RB}/L_{CRB}),$ $20\cdot\log_{10} EVM-3-5\cdot(\lvert\Delta_{RB}\rvert-1)/L_{CRB},$ $-57\,dBm+10\log_{10}(SCS/15kHz)-P_{RB}\}$

5.5 Output RF spectrum emissions

5.5.1 Occupied bandwidth

5.5.2 Spectrum emission mask

5.5.2.1 General spectrum emission mask

LTE general SEM and LTE CA general SEM the emission requirement for the first MHz outside the channel edge is scaled proportionately to the channel bandwidth. Logic behind this is that as transmission bandwidth gets larger the PSD of fully populated channel gets lower and UE can meet the tighter requirement. It is noted than from co-existence perspective this is not needed as smaller channel bandwidths are anyways allowed to emit more and system must work also with those channels.

However scaling cannot continue forever due to the fact that some small allocations (1RB) inside the channel are mixing with LO and image and create IMD3 that lands on the first MHz outside the channel. It can be seen from simulations that with 25 dBc IQ-Image performance IMD3 created by 1 RB transmission is in the order of -22 dBm/30 kHz. This would violate then SEM for larger channel bandwidth if scaling is continued to all channel bandwidths.

Thus it is safest that scaling is not used for channel bandwidths > 40 MHz for NR general SEM for sub-6 GHz bands. For those regions that have regulatory requirements for emissions to first MHz outside the channel region specific SEMs can be defined similarly as for LTE.

NR Sub-6 GHz general emission mask is presented in Table 5.5.2.1-1.

Table 5.5.2.1-1: NR spectrum target emission mask

<table>
<tr><th>ΔfOOB (MHz)</th><th>5 MHz</th><th>10 MHz</th><th>15 MHz</th><th>20 MHz</th><th>25 MHz</th><th>40 MHz</th><th>50 MHz</th><th>60 MHz</th><th>80 MHz</th><th>100 MHz</th><th>Measurement bandwidth</th></tr>
<tr><td>± 0-1</td><td>-15</td><td>-18</td><td>-20</td><td>-21</td><td>-22</td><td>-24</td><td>-24</td><td>-24</td><td>-24</td><td>-24</td><td>30 kHz</td></tr>
<tr><td>± 1-5</td><td>-10</td><td>-10</td><td>-10</td><td>-10</td><td>-10</td><td>-10</td><td>-10</td><td>-10</td><td>-10</td><td>-10</td><td rowspan="16">1 MHz</td></tr>
<tr><td>± 5-6</td><td>-13</td><td rowspan="2">-13</td><td rowspan="3">-13</td><td rowspan="4">-13</td><td rowspan="5">-13</td><td rowspan="7">-13</td><td rowspan="9">-13</td><td rowspan="10">-13</td><td rowspan="12">-13</td><td rowspan="14">-13</td></tr>
<tr><td>± 6-10</td><td>-25</td></tr>
<tr><td>± 10-15</td><td></td><td>-25</td></tr>
<tr><td>± 15-20</td><td></td><td></td><td>-25</td></tr>
<tr><td>± 20-25</td><td></td><td></td><td></td><td>-25</td></tr>
<tr><td>± 25-30</td><td></td><td></td><td></td><td></td><td>-25</td></tr>
<tr><td>± 30-40</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>± 40-45</td><td></td><td></td><td></td><td></td><td></td><td>-25</td></tr>
<tr><td>± 45-50</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>± 55-60</td><td></td><td></td><td></td><td></td><td></td><td></td><td>-25</td></tr>
<tr><td>± 60-65</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>-25</td></tr>
<tr><td>± 65-80</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>± 80-85</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>-25</td></tr>
<tr><td>± 85-100</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>± 100-105</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>-25</td></tr>
</table>

5.5.2.2 Additional spectrum emission requirements

Additional spectrum emission requirements are signalled by the network with network signalling value indicated by the field *additionalSpectrumEmission*.

5.5.2.2.1 Requirements for network signalled value "NS_04"

Additional spectrum emission requirements are signalled by the network to indicate that the UE shall meet an additional requirement for a specific deployment scenario as part of the cell handover/broadcast message.

The n41 SEM transition point from -13 dBm/MHz to -25 dBm/MHz is based on the emission bandwidth. The emission bandwidth is defined as the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, outside of which all emissions are attenuated at least 26 dB below the transmitter power. Since the 26 dB emission bandwidth is implementation dependent, the transmission bandwidths occupied by RBs is used for the SEM.

Table 5.5.2.2.1-1: n41 transmission bandwidths for CP-OFDM

SCS [kHz]	Channel bandwidths [MHz]							
	10	15	20	40	50	60	80	100
15	9.36	14.22	19.08	38.88	48.6	N.A	N.A	N.A
30	8.64	13.68	18.36	38.16	47.88	58.32	78.12	98.28
60	7.92	12.96	17.28	36.72	46.8	56.88	77.04	97.20

Table 5.5.2.2.1-2: n41 transmission bandwidths for DFT-S-OFDM

SCS [kHz]	Channel bandwidths [MHz]							
	10	15	20	40	50	60	80	100
15	9.00	13.50	18.00	38.88	48.60	N/A	N/A	N/A
30	8.64	12.96	18.00	36.00	46.08	58.32	77.76	97.20
60	7.20	12.96	17.28	36.00	46.08	54.00	72.00	97.20

When "NS_04" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 5.5.2.2.1-3.

Table 5.5.2.2.1-3: n41 SEM with NS_04

	Spectrum emission limit (dBm)/ measurement bandwidth for each channel bandwidth								
Δf_{OOB} MHz	10 MHz	15 MHz	20 MHz	40 MHz	50 MHz	60 MHz	80 MHz	100 MHz	Measurement bandwidth
± 0 - 1	-18	-20	-21	-24	-25				30 kHz
± 1 - 5	-10								1 MHz
± 5 - X	-13								
± X - ($BW_{Channel}$ + 5 MHz)	-25								
Note 1: X is defined in Table 6.5.2.3.2-1 for CP-OFDM or 6.5.2.3.2-2 for DFT-S-OFDM									

5.5.3 Adjacent Channel Leakage ratio

Concerning NR Range 1 UE ACLR requirement following agreements have been made

5.5.3.1 NR ACLR

ACLR is the ratio of power of wanted signal to the power falling into Adjacent Channel. ACLR measurement bandwidth for both the wanted and adjacent channels is the maximum transmission bandwidth among the different SCSs of CP-OFDM SU for a channel BW with addition of one SCS to account for half SCS shift due to SCS alignment to DC, this measurement bandwidth is centred within the channels.

Offset for the adjacent measurement BW centre is +/- Channel BW from wanted channel centre (in the middle of the Channel).

For PC3 requirement is NRACLR = 30 dBc for channel bandwidths up to 100 MHz.

For PC2 requirement is NRACLR = 31 dBc for channel bandwidths up to 100 MHz.

Table below provides measurement BWs in the last row

Table 5.5.3.1-1: ACLR measurement bandwidth

Sub-6GHz	SCS [kHz]	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	40 MHz	50 MHz	60 MHz	80 MHz	100 MHz
		N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}
SU_CP-OFDM [#RB]	15	25	52	79	106	133	216	270	N.A	N.A	N.A
	30	11	24	38	51	65	106	133	162	217	273
	60	N.A	11	18	24	31	51	65	79	107	135
RX&TXBW CP [MHz]	15	4.5	9.36	14.22	19.08	23.94	38.88	48.6	NA	NA	NA
	30	3.96	8.64	13.68	18.36	23.4	38.16	47.88	58.32	78.12	98.28
	60	NA	7.92	12.96	17.28	22.32	36.72	46.8	56.88	77.04	97.2
TXBWsym [MHz]	15	4.515	9.375	14.235	19.095	23.955	38.895	48.615	NA	NA	NA
	30	3.99	8.67	13.71	18.39	23.43	38.19	47.91	58.35	78.15	98.31
	60	NA	7.98	13.02	17.34	22.38	36.78	46.86	56.94	77.1	97.26
maxTXBWsym [MHz]	**lowest**	**4.515**	**9.375**	**14.235**	**19.095**	**23.955**	**38.895**	**48.615**	**58.35**	**78.15**	**98.31**

5.5.3.2 E-UTRA ACLR

For E-UTRA ACLR it has been agreed that if EUTRA CHBW = NR CHBW only the NR ACLR of 30 dBc shall be measured. This means that for channel bandwidths up to 20 MHz it is not necessary to measure E-UTRA ACLR as NR ACLR is tighter because the requirements in same 30 dBc but measurement bandwidth is larger.

Considering recent agreement on NR ACLR which stated that ACLR MBW is same as the bandwidth of transmitted NR signal it is evident that E-UTRA ACLR is always more relaxed thus is not necessary.

Therefore, no E-UTRA ACLR requirement is not specified for NR as NR ACLR requirement will be always more stringent.

5.5.3.3 UTRA ACLR

For bands defined also for UTRA, adopt UTRAACLR1 = 33dB and UTRAACLR2 =36dB for power class 3.

UTRA ACLR requirement is indicated to the UE by NS-signalling when applicable. Dedicated NS-value is assigned to UTRA ACLR requirement and it is used when no other additional requirement needs to indicated to the UE.

In case power reduction is necessary to meet the UTRA ACLR requirement it will be defined as A-MPR_{UTRA_ACLR}. A-MPR_{UTRA_ACLR} is only allowed only in case other power reductions such as MPR and A-MPR coming from other requirement than UTRA ACLR are not sufficient. Allowed power reduction = Max (A-MPR_{UTRA_ACLR}, (MPR+A-MPR_{other}).

5.5.4 Spurious emission

5.5.4.1 General requirements

Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products, but exclude out of band emissions unless otherwise stated.

In the same way as was described for UTRA and E-UTRA, the spurious emission limits shall be specified in terms of general requirements in line with SM.329.And the stricter Category B limits defined in SM.329 shall be applied for UE considering that UEs are intended for global circulation, there cannot be any regional requirements. Thus, the following spurious emission limits for E-TRUA would be reused in NR.

Table 5.5.4-1: Spurious emissions limits

Frequency Range	Maximum Level	Measurement bandwidth	NOTE
9 kHz ≤ f < 150 kHz	-36 dBm	1 kHz	
150 kHz ≤ f < 30 MHz	-36 dBm	10 kHz	
30 MHz ≤ f < 1000 MHz	-36 dBm	100 kHz	
1 GHz ≤ f < 12.75 GHz	-30 dBm	1 MHz	
1 GHz ≤ f < 12.75 GHz	-25 dBm	1 MHz	3
12.75 GHz ≤ f < 5th harmonic of the upper frequency edge of the UL operating band in GHz	-30 dBm	1 MHz	1
12.75 GHz < f < 26GHz	-30dBm	1MHz	2
NOTE 1: Applies for Band that the upper frequency edge of the UL Band more than [2.69] GHz NOTE 2: Applies for Band that the upper frequency edge of the UL Band more than [5.2] GHz NOTE 3: Applies for n41 and EN-DC combinations that include n41 only when NS_04 is signalled.			

In LTE, the boundary between out of band and Spurious emission is $BW_{Channel}$ + 5MHz for all bandwidth (channel bandwidth and CA bandwidth) more than 5 MHz, which is derived from the table 5.5.4-2 cited from ITU-R SM.1541 by assigning B_U to be 5 MHz and changing the starting position of the offset from the centre of channel bandwidth to the edge of channel bandwidth.

Table 5.5.4-2: Start and end of OOB domain

Type of emission	If necessary bandwidth B_N is:	Offset (±) from the centre of the necessary bandwidth for the start of the OoB domain	Frequency separation between the centre frequency and the spurious boundary
Narrow-band	*<B_L (see Note1)*	*0.5 B_N*	*2.5 B_L*
Normal	*B_L to B_U*	*0.5 B_N*	*2.5 B_N*
Wideband	*>B_U*	*0.5 B_N*	*B_U + (1.5 B_N)*
NOTE 1: When BN < BL, no attenuation of unwanted emissions is recommended at frequency separations between 0.5 BN to 0.5 BL. NOTE 2: BL and BU are given in Recommendation ITU-R SM.1539 and SM.329			

The above guideline in SM.1541 and SM.329 should be also followed to define spurious domain for NR range 1. In NR, the minimum channel bandwidth is 5 MHz, thus similar to E-UTRA, the boundary (F_{OOB}) between OOB and spurious for NR Range 1 shall be also $BW_{Channel}$ + 5 MHz for all possible channel bandwidth for NR range 1.

5.5.4.2 Spurious emission band UE co-existence

5.5.4.3 Additional spurious emissions

These requirements are specified in terms of an additional spectrum emission requirement. Additional spurious emission requirements are signalled by the network to indicate that the UE shall meet an additional requirement for a specific deployment scenario as part of the cell handover/broadcast message.

NOTE: For measurement conditions at the edge of each frequency range, the lowest frequency of the measurement position in each frequency range should be set at the lowest boundary of the frequency range plus MBW/2. The highest frequency of the measurement position in each frequency range should be set at the highest boundary of the frequency range minus MBW/2. MBW denotes the measurement bandwidth defined for the protected band.

5.5.4.3.1 Minimum requirement (network signalled value "NS_04")

When "NS 04" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 5.5.4.3.1-1. This requirement also applies for the frequency ranges that are less than F_{OOB} (MHz) in Table 5.5.2.2.1-3 from the edge of the channel bandwidth.

Table 5.5.4.3.1-1: Additional requirements

Frequency band (MHz)	Channel bandwidth / Spectrum emission limit (dBm)	Measurement bandwidth
	10, 15, 20, 40, 50, 60, 80, 100 MHz	
2495 ≤ f < 2496	-13	1% of Channel BW
2490.5 ≤ f < 2495	-13	1 MHz
0 < f < 2490.5	-25	1 MHz

5.6 Transmit intermodulation

UE transmitting in close vicinity of each other can produce intermodulation products, which can fall into the UE, or eNode B receive band as an unwanted interfering signal. Although various uplink signals from other UEs in the same area, for instance NR UL signal, LTE UL signal, UMTS UL (FDD or TDD) or GSM/GPRS signal, can be an interference signal for the interested UE, interference signal of CW (continuous wave signal) would give a good indication on UE intermodulation .thus ,similar to LTE, The UE intermodulation attenuation shall be defined by the ratio of the mean power of the wanted signal to the mean power of the intermodulation product on wanted signal when an interfering CW signal is added at a level below the wanted signal at each of the transmitter antenna port with the other antenna port(s) if any is terminated. In addition, considering the similar deployment scenario of the NR and E-UTRA for sub 6GHz,it is reasonable the level of the CW Interference signal should be kept as -40dBc (same as in LTE).

Similar with UMTS and LTE, the transmitter intermodulation requirements should be specified in conjunction with ACLR requirements. Namely Tx intermodulation level measured in the interested adjacent channel is not masked by the contribution of the ACLR. In that case, the intermodulation requirements can be estimated through ACLR requirement and inherent Tx intermodulation, which can be shown by the following equation:

$$\text{Intermodulation requirement}=10\lg\left(10^{-ACLR/10}+10^{\text{inherent TX IM}/10}\right)$$

For UMTS and LTE case, inherent Tx intermodulation of -35 dBc (with interferer CW at 20 MHz offset) and -45 dBc (with interferer CW at 40 MHz offset) are assumed. considering most of LTE RF equipment (such as PA, front-end filter, duplexer) shall be reused for NR especially when reframing LTE band, the nonlinearity characteristic will be roughly the same between LTE signal and NR signal. Thus, it can be expected above inherent Tx intermodulation values could be reused for NR. Since the requirements of NR ACLR is defined as NR ACLR= 30 dBc for channel bandwidth up to 100 MHz, the following intermodulation level (Tx IM [measured]) would be applied. it shall be noted that the intermodulation product level in the table is aligned with LTE. The measurement bandwidth of intermodulation product and wanted signal should follow the same principle as NR ACLR MPR assumption i.e. an available maximum transmission bandwidth among the SCSs for a channel BW.

Table 5.6-1,Tx IM level for NR

	1st adjacent channel	2nd adjacent channel	
Interference signal frequency offset	$BW_{Channel}$	$2*BW_{Channel}$	dBc
ACLR	30	36	dBc
Tx IM [inherent]	-35	-45	dBc
Tx IM [measured]	-29	-35	dBc
Note 1: $BW_{Channel}$ is the channel bandwidth of NR wanted signal. Note 2: Measure bandwidth should follow the same principle as NR ACLR. MPR assumption i.e. an available maximum transmission configuration bandwidth among the SCSs for a channel bandwidth.			

5.7 ON/OFF time mask

5.7.1 UE transient time

For NR, the following three different transient time parameters are defined as below:

- **ON-to-ON time**: ON-to-ON time refers to switching time related to change of power between consecutive UL transmissions. Other switching time requirements due to e.g. antenna switching, frequency hopping which require PLL retuning, beam switching, etc are discussed separately.

- **ON-to-OFF time**: ON-to-OFF time refers to time required for switching from ON state to OFF state for a transmitter.

- **OFF-to-ON time**: OFF-to-ON time refers to time required for switching from OFF state to ON state for a transmitter.

Following transient times are defined for FR1 in Table 5.7.1-1:

Table 5.7.1-1: Transient times for FR1

	FR1
ON-to-ON	10µs
OFF-to-ON	10µs
ON-to-OFF	10µs

5.8 Additional UE RF Tx requirements for SUL and LTE-NR co-existence

It should be noted that simultaneously LTE and NR UL transmission in one carrier or one band is almost unfeasible in Rel-15 because MPR is very hard to determine for this case. So in the following, it is assumed that LTE and NR transmissions are not simultaneously configured in one carrier or one band.

5.8.1 Transmit power

For standalone SUL with non-simultaneous transmission, transmit power requirement can be applied separately for UL and SUL carrier. Then for configured transmit power, as the UL carrier and SUL carrier share a same cell, the configured transmit power should be specified for each UL carrier in a serving cell. The requirement for each UL carrier can reuse the definition of configured transmit power for serving cell in general NR.

For LTE-NR DC with SUL, the transmit power related requirements can reuse the general DC transmit power related requirements, only the configured transmit power for the serving cell with SUL carrier shall apply the configured transmit power for each UL carrier in the serving cell for non-simultaneous transmission.

5.8.2 Output power dynamics

As LTE and NR should not be simultaneously transmitted in one carrier or one band, the requirements of minimum/OFF output power, time mask and power control should be kept unchanged, and LTE and NR requirements can be applied separately.

In addition, a new requirement of time mask between LTE and NR slot/subframe boundary needs to be specified for DC scenarios since UE needs to switch from LTE to NR and vice versa to maintain two connections for both LTE and NR on the shared carrier when operating in TDM based UL sharing from the UE perspective.

For LTE, 20us transient period is needed for each slot at the boundary. And for NR, only 5us is needed for each slot at the boundary. For LTE, there is difference between the mask with PUSCH and SRS in the last symbol because SRS is high priority and need to be protected. However, for LTE to NR switching in TDM based UL sharing from the UE perspective, this kind of protection of SRS is not needed because LTE can configure no SRS in this specific subframe. So there is no need to specify multiple time masks for LTE to NR switching in UL sharing from the UE perspective.

For TDM based UL sharing from the UE perspective with LTE/NR switching at slot boundary, time masks combined with LTE and NR requirements are illustrated in Figure 5.8.2-1 for almost 0us switching time.

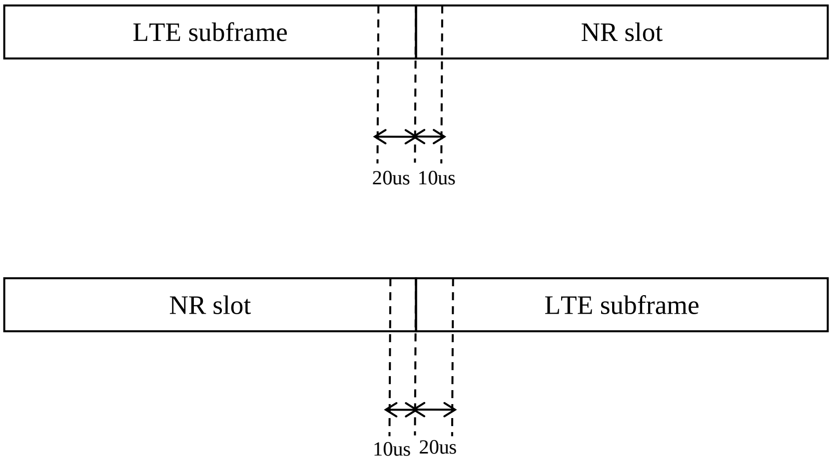


Figure 5.8.2-1 Slot/subframe boundary time mask between LTE and NR in TDM based UL sharing from the UE perspective for type1 UE with switching time 0.5us

By ways of configuring cell-specific SRS subframes in LTE, we can make the LTE last symbol vacant with no transmission of either PUSCH or SRS. In LTE, SRS does not have to be configured for transmission in all cell-specific SRS subframes. In which subframe SRS is transmitted by a UE is according to UE specific SRS configuration. Therefore, the 20us switching time can be placed in LTE subframe for LTE/NR switching in the TDM based UL sharing from the UE perspective because it will not degrade either LTE or NR performance through certain configuration.

For TDM based UL sharing from the UE perspective with LTE/NR switching on the shared carrier at slot boundary, time masks combined with LTE and NR requirements are illustrated in Figure 5.8.2-2 for less than 20us switching time.

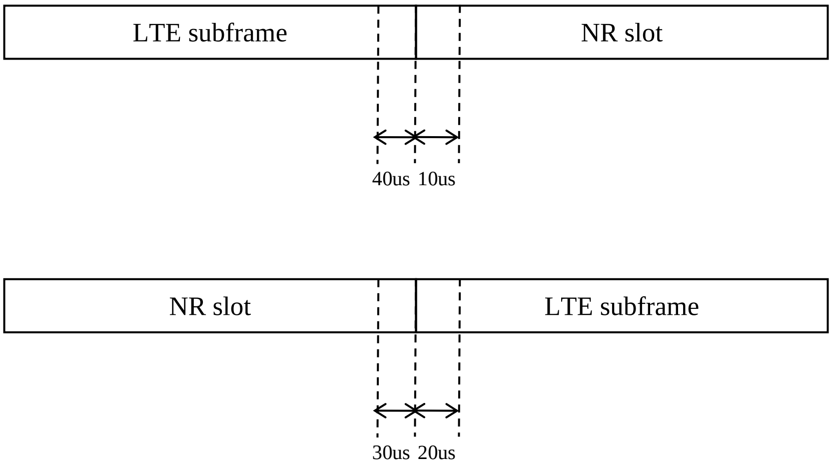


Figure 5.8.2-2 Slot/subframe boundary time mask between LTE and NR in TDM based UL sharing from the UE perspective for type2 UE with switching time <20us

5.8.3 Transmit signal quality

On the condition that LTE and NR transmissions are not simultaneously configured in one carrier or one band, the requirement of frequency error, EVM and in-band emission should be kept unchanged, and LTE and NR requirements can be applied separately.

It should be noted that for SUL, the downlink reference comes from another band. However, as the local crystal oscillator should be calibrated with the relative error of 0.1ppm, all the output of the PLL including the TX RF PLL should be also locked with the relative frequency error of 0.1ppm. So the maximum allowed frequency error for SUL can be defined as 0.1ppm.

For the carrier leakage requirement, the carrier leakage rejection should be kept unchanged, and LTE and NR requirements can be applied separately. However, it should be noted that the carrier leakage frequency is still under discussion for NR, and whether it still should be at the carrier frequency is FFS.

For NR-LTE co-existence, in order to achieve sub-carrier alignment between LTE and NR, the channel raster for NR may be shifted by 7.5kHz compared to general NR channel raster, in this case the carrier leakage frequency may or may not at the carrier frequency in order not to exclude any implementations.

5.8.4 Output RF spectrum emissions

On the condition that LTE and NR transmissions are not simultaneously configured in one carrier or one band, these requirements should be kept unchanged, and LTE and NR requirements can be applied separately.

5.8.5 Transmit intermodulation

On the condition that LTE and NR transmissions are not simultaneously configured in one carrier or one band, these requirements should be kept unchanged, and LTE and NR requirements can be applied separately.

6 UE Receiver characteristics (frequency range 1)

6.1 General

6.2 Receiver Sensitivity

For below 6GHz, the REFSENS level can be calculated by the equation below:

$$\text{Sensitivity} = -174\text{dBm(kT)} + 10*\log(R_X\ \text{BW}) + \text{NF} + \text{SNR} + \text{IM} - \text{diversity gain}$$

It is noted that the Rx BW is identical to the transmission bandwidth configuration, which is determined by the spectrum utilization. The RB values in the analysis of this contribution are based on the agreed SU for NR.

SNR in Nagoya meeting was tentatively agreed as -1dB, the tentative value is the same as that for LTE. However, SNR will be further evaluated by link level simulation. Actually, the SNR under AWGN channel has no difference for different SCS and the demodulation performance for DFT-s-OFDM and CP-OFDM is the same as well. Therefore, the same SNR will be used to calculate REFSENS for different SCS.

The REFSENS for E-UTRA assumes that the receiver is equipped with two Rx port as a baseline. If 2Rx is considered, the diversity gain is 3dB and the Implementation Margin (IM) uses 2.5dB. In the following calculation, same assumptions are used for LTE refarming bands for NR.

The NF for the NR bands can reuse those for E-UTRA. For the three new NR bands, i.e. Bands n77~79, the agreed NR values are 10.5dB, 10dB and 10dB respectively.

The REFSENS values for 15kHz, 30kHz and 60kHz SCS are provided in Table 6.2-1 to Table 6.2-3. It is noted that the REFSENS values are subjected to changes due to the final determined SNR.

Table 6.2-1: Reference sensitivity QPSK PREFSENS for 15 kHz SCS

Operating Band	Channel bandwidth											Duplex Mode
	5 MHz (dBm)	10 MHz (dBm)	15 MHz (dBm)	20 MHz (dBm)	25 MHz (dBm)	30 MHz (dBm)	40 MHz (dBm)	50 MHz (dBm)	60 MHz (dBm)	80 MHz (dBm)	100 MHz (dBm)	
n1	-100.0	-96.8	-95.0	-93.8								FDD
n2	[-98.0]	[-94.8]	[-93.0]	[-91.8]								FDD
n3	[-97.0	[-93.8]	[-92.0]	[-90.8]	[-89.7]	[-88.9]						FDD
n5	[-98.0]	[-94.8]	[-93.0]	[-91.8]								FDD
n7	-98.0	-94.8	-93.0	-91.8								FDD
n8	[-97.0	[-93.8]	[-92.0]	[-90.8]								FDD
n20	[-97.0	[-93.8]	[-91.0]	[-89.8]								FDD
n25	[-96.5]	[-93.3]	[-91.5]	[-90.3]								FDD
n26	[-97.5][1]	[-94.3][1]	[-92.5][1]									FDD
n28	[-98.5	[-95.5]	[-93.5]	[-90.8]								FDD
n34	-100.0	-96.8	-95.0									TDD
n38	-100.0	-96.8	-95.0	-93.8								TDD
n39	-100.0	-96.8	-95.0	-93.8	-92.7	[-91.9]	-90.6					TDD
n40	-100.0	-96.8	-95.0	-93.8	-92.7	[-91.9]	-90.6	-89.6				TDD
n41		-94.8	-93.0	-91.8			-88.6	-87.6				TDD
n50	-100.0	-96.8	-95.0	-93.8			-90.6	-89.6				TDD
n51	-100.0											TDD
n66	-99.5	-96.3	-94.5	-93.3								FDD
n70	-100.0	-96.8	-95.0	-93.8	-92.7							FDD
n71	-97.2	-94.0	-91.6	-86								FDD
n74	-99.5	-96.3	-94.5	-93.3								FDD
n77		-95.8	-94.0	-92.7			-89.6	-88.6				
n77(3.8-4.2GHz)		-95.3	-93.5	-92.2			-89.1	-88.1				TDD
n78		-95.8	-94.0	-92.7			-89.6	-88.6				TDD
n79							-89.6	-88.6				TDD
Note 1: Indicates that the requirement is modified by -0.5 dB when the carrier frequency of the assigned E-UTRA channel bandwidth is within 865-894 MHz.												

Table 6.2-2: Reference sensitivity QPSK PREFSENS for 30 kHz SCS

Channel bandwidth												
Operating Band	5 MHz (dBm)	10 MHz (dBm)	15 MHz (dBm)	20 MHz (dBm)	25 MHz (dBm)	30 MHz (dBm)	40 MHz (dBm)	50 MHz (dBm)	60 MHz (dBm)	80 MHz (dBm)	100 MHz (dBm)	Duplex Mode
n1		-97.1	-95.1	-94.0								FDD
n2		[-95.1]	[-93.1]	[-92.0]								FDD
n3		[-94.1]	[-92.1]	[-91.0]	[-89.8]	[-89]						FDD
n5		[-95.1]	[-93.1]	[-92.0]								FDD
n7		-95.1	-93.1	-92.0								FDD
n8		[-94.1]	[-92.1]	[-91.0]								FDD
n20		[-94.1]	[-91.1]	[-90.0]								FDD
n25		[-93.6]	[-91.6]	[-90.5]								FDD
n26		[-94.7][1]	[-92.7][1]									FDD
n28		[-95.6]	[-93.6]	[-91.0]								FDD
n34		-97.1	-95.1									TDD
n38		-97.1	-95.1	-94.0								TDD
n39		-97.0	-95.1	-94.0	-92.8	[-92.0]	-90.7					TDD
n40		-97.0	-95.1	-94.0	-92.8	[-92.0]	-90.7	-89.7	-88.9	-87.6		TDD
n41		-95.1	-93.1	-92.0			-88.7	-87.7	-86.9	-85.6	-84.7	TDD
n50		-97.1	-95.1	-94.0			-90.7	-89.7	-88.9			TDD
n51												TDD
n66		-96.6	-94.6	-93.5			-90.2					FDD
n70		-97.1	-95.1	-94.0	-92.8							FDD
n71		[-94.3]	[-91.9]	[-87.5]								FDD
n74		-96.6	-94.6	-93.5								FDD
n77		-96.1	-94.1	-92.9			-89.7	-88.7	-87.9	-86.6	-85.6	TDD
n77 (3.8-4.2GHz)		-95.6	-93.6	-92.4			-89.2	-88.2	-87.4	-86.1	-85.1	TDD
n78		-96.1	-94.1	-92.9			-89.7	-88.7	-87.9	-86.6	-85.6	TDD
n79							-89.7	-88.7	-87.9	-86.6	-85.6	TDD
NOTE 1: Indicates that the requirement is modified by -0.5 dB when the carrier frequency of the assigned E-UTRA channel bandwidth is within 865-894 MHz.												

Table 6.2-3: Reference sensitivity QPSK $P_{REFSENS}$ for 60 kHz SCS

Operating Band	Channel bandwidth											Duplex Mode
	5 MHz (dBm)	10 MHz (dBm)	15 MHz (dBm)	20 MHz (dBm)	25 MHz (dBm)	30 MHz (dBm)	40 MHz (dBm)	50 MHz (dBm)	60 MHz (dBm)	80 MHz (dBm)	100 MHz (dBm)	
n1		-97.5	-95.4	-94.2								FDD
n2		[-95.5]	[-93.4]	[-92.2]								FDD
n3		[-94.5]	[-92.4]	[-91.2]	[-90.0]	[-89.1]						FDD
n5												FDD
n7		-95.5	-93.4	-92.2								FDD
n8												FDD
n20												FDD
n25		[-94.0]	[-91.9]	[-90.7]								FDD
n26		[-95.0][1]	[-92.9][1]									FDD
n28												FDD
n34		-97.5	-95.4									TDD
n38		-97.5	-95.4	-94.2								TDD
n39		-97.5	-95.4	-94.2	-93.0	[-92.1]	-90.9					TDD
n40		-97.5	-95.4	-94.2	-93.0	[-92.1]	-90.9	-89.8	-89.1	-87.6		TDD
n41		-95.5	-93.4	-92.2			-88.9	-87.8	-87.1	-85.6	-84.7	TDD
n50		-97.5	-95.4	-94.2								TDD
n51												TDD
n66		-97.0	-94.9	-93.7								FDD
n70		-97.5	-95.4	-94.2	-93.0							FDD
n71												FDD
n74		-97.0	-94.9	-93.7								FDD
n77		-96.5	-94.4	-93.1			-89.9	-88.8	-88.0	-86.7	-85.7	TDD
n77 (3.8-4.2GHz)		-96	-93.9	-92.6			-89.4	-88.3	-87.5	-86.2	-85.2	TDD
n78		-96.5	-94.4	-93.1			-89.9	-88.8	-88.0	-86.7	-85.7	TDD
n79							-89.9	-88.8	-88.0	-86.7	-85.7	TDD
Note 1: indicates that the requirement is modified by -0.5 dB when the carrier frequency of the assigned E-UTRA channel bandwidth is within 865-894 MHz.												

When we define the REFSENS for these values for E-UTRA, due to the close frequency range between UL and DL, REFSENS for some CBWs are relaxed, i.e. 1 dB relaxation for 15MHz and 20MHz CBW for Band 20, 1.5dB relaxation for 20MHz CBW for Band 28, and 0.4dB relaxation for 15MHz and 3.7dB for 20MHz for Band 71.

As SU for NR is increased compared to that of E-UTRA, the relaxation for these bands may need to be further enlarged. Currently, the same relaxation values are tentatively used for these NR bands, thus the values are put in brackets in the tables.

The other aspect needs to be considered for REFSENS is the uplink configuration. For NR bands, the similar constrains on the UL RB allocation as those for E-UTRA can be considered as well, however, the new SU shall be considered in determine the uplink configurations. Some principles are considered to derive the UL RB allocation in Table 6.2-4:

1. The full RB allocation for counterpart E-UTRA CBW will be extended for NR based on new SU
2. For the CBW with RB allocation constraints but without REFSENS relaxation, the RBs will be adjusted based on NR SU, e.g. for E-UTRA Band 3, 50 RB is utilized for 15MHz CBW, thus the RB will be adjusted to 52RB for NR Band n3 for the same CBW.
3. For the E-UTRA band with REFSENS relaxation for some CBWs, the same RB allocations for 15kHz SCS will be kept for the counterpart NR band.
4. For 30kHz and 60kHz SCS, if full RB allocation cannot be supported for the CBW, the floor value most close to the transmission BW configuration of 15kHz SCS will be adopted.

Table 6.2-4 gives the uplink configuration for NR REFSENS for the proposed NR bands.

Table 6.2-4: Uplink configuration for NR reference sensitivity

NR Band / Channel bandwidth / NRB / Duplex mode													
Operating Band	**SCS (kHz)**	**5 MHz (NRB)**	**10 MHz (NRB)**	**15 MHz (NRB)**	**20 MHz (NRB)**	**25 MHz (NRB)**	**30 MHz (NRB)**	**40 MHz (NRB)**	**50 MHz (NRB)**	**60 MHz (NRB)**	**80 MHz (NRB)**	**100 MHz (NRB)**	**Duplex Mode**
n1	15	25	52	79	106								FDD
	30		24	38	51								
	60		11	18	24								
n2	15	25	52	52[1]	52[1]								FDD
	30	11	24	24[1]	24[1]								
	60		11	11[1]	11[1]								
n3	15	25	52	52[1]	52[1]	TBD	TBD						FDD
	30		24	24[1]	24[1]	TBD	TBD						
	60			11[1]	11[1]	TBD	TBD						
n5	15	25	25[1]	TBD	TBD								FDD
	30		11[1]	TBD	TBD								
	60												
n7	15	25	52	79	79[1]								FDD
	30		24	38	38[1]								
	60		11	18	18[1]								
n8	15	25	25[1]	TBD	TBD								FDD
	30		11[1]	TBD	TBD								
	60												
n20	15	25	20[1]	20[2]	20[2]								FDD
	30		10[1]	10[2]	10[2]								
	60												
n25	15	25	52	52[1]	52[1]								FDD
	30	11	24	24[1]	24[1]								
	60			11[1]	11[1]								
n26	15	25	25[1]	25[1]									FDD
	30		11[1]	11[1]									
	60		5[1]	5[1]									
n28	15	25	25[1]	25[1]	25[1]								FDD
	30		11[1]	11[1]	11[1]								
	60												
n34	15	25	52	79									TDD
	30		24	38									
	60		11	18									
n38	15	25	52	79	106								TDD
	30		24	38	51								
	60		11	18	24								
n39	15	25	52	79	106	133	[160]	206					TDD
	30		24	38	51	65	[78]	106					
	60		11	18	24	31	[38]	51					
n40	15	25	52	79	106	133	[160]	206	270				TDD
	30		24	38	51	65	[78]	106	133	162	217		
	60		11	18	24	31	[38]	51	65	79	107		
n41	15		52	79	106			216	270				TDD
	30		24	38	51			106	133	162	217	273	
	60		11	18	24			51	65	79	107	135	
n50	15	25	52	79	106			216	270				TDD
	30	11	24	38	51			106	133	162			
	60		11	18	24								
n51	15	25											TDD
	30												
	60												
n66	15	25	52	79	106								FDD
	30		24	38	51								
	60			18	24								
n70	15	25	52	79	106	133							FDD
	30		24	38	51	65							
	60		11	18	24	31							
n71	15	25	25[1]	20[1]	20[1]								FDD
	30		12[1]	10[1]	10[1]								
	60												
n74	15	25	25[1]	25[1]	25[1]								FDD

	30		11[1]	11[1]	11[1]								
	60		5[1]	5[1]	5[1]								
n77	15		52	79	106			216	270				TDD
	30		24	38	51			106	133	162	217	273	
	60		11	18	24			51	65	79	107	135	
n78	15		52	79	106			216	270				TDD
	30		24	38	51			106	133	162	217	273	
	60		11	18	24			51	65	79	107	135	
n79	15							216	270				TDD
	30							106	133	162	217	273	
	60							51	65	79	107	135	

NOTE 1: 1 refers to the UL resource blocks shall be located as close as possible to the downlink operating band but confined within the transmission bandwidth configuration for the channel bandwidth.

NOTE 2: 2 refers to Band 20; for 15kHz SCS, in the case of 15MHz channel bandwidth, the UL resource blocks shall be located at RBstart 11 and in the case of 20MHz channel bandwidth, the UL resource blocks shall be located at RBstart 16; for 30kHz SCS, in the case of 15MHz channel bandwidth, the UL resource blocks shall be located at RBstart 6 and in the case of 20MHz channel bandwidth, the UL resource blocks shall be located at RBstart 8; for 60kHz SCS, in the case of 15MHz channel bandwidth, the UL resource blocks shall be located at RBstart 3 and in the case of 20MHz channel bandwidth, the UL resource blocks shall be located at RBstart 4;

6.2.1 MSD (Maximum sensitivity degradation)

6.3 Selectivity

6.4 Blocking performance

6.5 Spurious response

6.6 Intermodulation performance

6.7 Spurious emission

6.8 Additional UE RF Rx requirements for SUL and LTE-NR co-existence

6.8.1 REFSENS

Reference sensitivity for NR band with uplink configured in LTE refarming band is a band combination specific requirement.

6.8.2 Other receiver requirements

Other receiver requirements will be kept unchanged for NR band.

7 UE Transmitter characteristics (frequency range 2)

7.1 General

7.1.1 CA Bandwidth Class

For intra-band contiguous carrier aggregation, a carrier aggregation configuration is a single operating band supporting a carrier aggregation bandwidth class with associated bandwidth combination sets. For each carrier aggregation configuration, requirements are specified for all aggregated channel bandwidths contained in a bandwidth combination set, A UE can indicate support of several bandwidth combination sets per carrier aggregation configuration.

For intra-band non-contiguous carrier aggregation, a carrier aggregation configuration is a single operating band supporting two or more sub-blocks, each supporting a carrier aggregation bandwidth class.

For inter-band carrier aggregation, a carrier aggregation configuration is a combination of operating bands, each supporting a carrier aggregation bandwidth class.

Table 7.1.1-1 gives the proposed NR CA bandwidth class for FR2.

Table 7.1.1-1: NR CA Bandwidth Class for FR2

NR CA bandwidth class	Aggregated channel bandwidth	Number of contiguous CC	Fallback group
A	$BW_{Channel} \leq 400$ MHz	1	-
B	400 MHz < $BW_{Channel\_CA} \leq 800$ MHz	2	1
C	800 MHz < $BW_{Channel\_CA} \leq 1200$ MHz	3	
D	200 MHz < $BW_{Channel\_CA} \leq 400$ MHz	2	2
E	400 MHz < $BW_{Channel\_CA} \leq 600$ MHz	3	
F	600 MHz < $BW_{Channel\_CA} \leq 800$ MHz	4	
G	100 MHz < $BW_{Channel\_CA} \leq 200$ MHz	2	3
H	200 MHz < $BW_{Channel\_CA} \leq 300$ MHz	3	
I	300 MHz < $BW_{Channel\_CA} \leq 400$ MHz	4	
J	400 MHz < $BW_{Channel\_CA} \leq 500$ MHz	5	
K	500 MHz < $BW_{Channel\_CA} \leq 600$ MHz	6	
L	600 MHz < $BW_{Channel\_CA} \leq 700$ MHz	7	
M	700 MHz < $BW_{Channel\_CA} \leq 800$ MHz	8	
O	100 MHz $\leq BW_{Channel\_CA} \leq 200$ MHz	2	4
P	150 MHz $\leq BW_{Channel\_CA} \leq 300$ MHz	3	
Q	200 MHz $\leq BW_{Channel\_CA} \leq 400$ MHz	4	
NOTE 1: Maximum supported component carrier bandwidths for fallback groups 1, 2, 3 and 4 are 400 MHz, 200 MHz, 100 MHz and 100 MHz respectively. NOTE 2: It is mandatory for a UE to be able to fallback to lower order CA bandwidth class configuration within a fallback group. It is not mandatory for a UE to be able to fallback to lower order CA bandwidth class configuration that belong to a different fallback group.			

7.2 Transmit power

7.2.1 Power Class

Power class of FR2 UEs is specified as a package of the minimum peak EIRP, maximum allowed TRP, maximum allowed EIRP and spherical coverage.

<u>Minimum Peak EIRP Requirement:</u>

The peak EIRP is the maximum EIRP capability of UE to all directions and represents the beam forming capability of UE. Unlike LTE, where each UE power class is specified as a nominal value with +/- tolerance, mmWave UE peak EIRP requirement only specifies a lower limit, i.e., no power class-dependent peak EIRP upper limit is specified. UE meets the requirement as long as it exceeds the defined limit in one direction and, since the requirement is only lower limit, no tolerance is specified.

Maximum TRP/EIRP Requirement:

On the other hand, an upper limit of TRP requirement is introduced in conjunction with EIRP-based power class to constrain UL co-channel interference. This encourages UE to achieve as better as possible EIRP performance by implementation improvement without causing additional co-channel interference. Some countries/regions have regulatory requirement on the maximum allowed EIRP for the mmWave UE. The requirement depends on UE types. For handheld UE that is supposed to be carried by people, a lower maximum allowed EIRP is required. But a higher EIRP is allowed for other UE types to enable higher data rates and better coverage. To meet the regulatory requirement, the requirement for the maximum allowed EIRP is captured. The requirement varies depending on UE type and the peak EIRP shall not exceed the maximum allowed value.

Spherical Coverage Requirement

The spherical coverage requirement is defined by EIRP value at certain percentile on the CDF curve, where the percentile depends on power class (i.e., UE type). The reason to specify UE type-dependent percentile is because different UE types may have different applicable sphere area, e.g. for some UE types, a specific portion of its radiation sphere may be blocked and the spatial coverage requirement on the blocked directions should be excluded.

The CDF curve is obtained by plotting the measured EIRP on test directions with uniform surface density over the whole sphere even if the target beam coverage area for certain UE type is less than 100% sphere. The spherical coverage requirement assures that UE can transmit EIRP no lower than the defined EIRP limit over the required percentile.

The power class is used to distinguish different UE types and each power class corresponds to a single UE type. Several UE types were identified and their power class were specified as summarized in Table 7.2.1-1.

Table 7.2.1-1: Classification of UE Types

UE Power class	UE type
1	Fixed Wireless Access (FWA) UE following US FCC 55dBm EIRP power limit
2	Vehicle mounted UE following US FCC 43dBm EIRP power limit
3	Handheld UE following US FCC 43dBm EIRP power limit
4	High power non- handheld UE following US FCC 43dBm EIRP power limit

7.2.1.1 UE Power class 1

Power class 1 is specified, assuming to be applied for FWA UE.

Table 7.2.1.1-1: (Void)

Table 7.2.1.1-1: (Void)

7.2.1.1.1 Minimum Peak EIRP requirement

How to derive the requirement

Proposal for FWA peak EIRP evaluation which contributes to the peak EIRP link budget is shown in Table 7.2.1.1.1-1 below. After discussion, Minimum peak EIRP is defined as 40dBm for 28GHz and as 38.0dBm for 39GHz.

Table 7.2.1.1.1-1: Proposal for FWA peak EIRP evaluation

Parameter	Unit	Freq. range 24.25-29.5 GHz			Freq. range 37.0-40.0 GHz		
		Source 1	Source 2	Source 3	Source 1	Source 2	Source 3
P_out per element	dBm	14	14	14	14	14	14
# of antennas in array		16	16	16	16	16	16
Total conducted power per polarization	dBm	26	26	26	26	26	24.6
Avg. antenna element gain	dBi	4.5	5	5	4.5	4	5
Antenna roll-off loss vs frequency	dB	-1.0	-2.0	-1	-1.5	-2.5	-0.7
Realized antenna array gain	dBi	15.5	14	17	15.0	13.5	17
Polarization gain	dB	2.5	2.80	2.50	2.8	2.80	2.50
Mismatch and transmission line loss including load pull	dB	-2.1	-3.00	--	-2.7	-3.50	--
Beam forming loss (phase shifter and amplitude error)	dB	-0.5	-0.5	--	-0.5	-0.5	--
Finite beam table	dB	-0.25	-0.25	--	-0.25	-0.25	--
Beam forming loss (one beam table fits all)	dB	-0.25	-0.25	--	-0.25	-0.25	--
Form-factor integration losses	dB	-4.5	-3.5	--	-5.5	-4.5	--
Total implementation loss (worst-case)	dB	-7.6	-7.5	-5.00	-9.2	-9.00	-7.00
Peak EIRP (Minimum)	dBm	36.4	35.3	39.5	34.6	33.3	36.4

Conclusion

The minimum Peak EIRP values is specified in Table 7.2.1.1.1-2.

Table 7.2.1.1.1-2: UE Minimum Peak EIRP for Power class 1

Operating Band	Min Peak EIRP (dBm)
n257	40.0
n258	40.0
n260	38.0
n261	40.0
NOTE 1: minimum peak EIRP is defined as the lower limit without tolerance	

7.2.1.1.2 Maximum TRP/EIRP requirement

The maximum output power values for TRP and EIRP are found in Table 7.2.1.1.2-1 below. The maximum allowed EIRP is derived from regulatory requirements [12].

Table 7.2.1.1.2-1: UE Maximum Output Power Limits for Power class 1

Operating Band	Max TRP (dBm)	Max EIRP (dBm)
n257	35	55
n258	35	55
n260	35	55
n261	35	55

7.2.1.1.3 Spherical coverage requirement

How to derive the requirement

Fixed Wireless Access UE is installed on outside wall of building by professional, who can guarantee the direction difference between ideal boresight beam direction and LOS direction from FWA UE to gNB be well controlled within the angle of half beam width. Therefor the target beam coverage of power class 1 was allowed limited area of sphere.

Specifically, based on knowledge of FR2 CPE device deployment, it is expected that the beam coverage area should be +/-50 degree, i.e., the top sphere area with $\theta \leq 50^{\circ}$ in elevation direction provided that the boresight direction is along with z-coordinate.

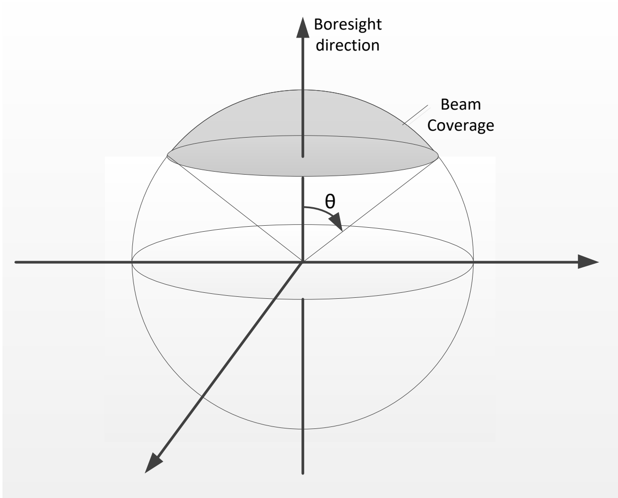


Figure 7.2.1.1.3-1: Beam coverage area, i.e., top sphere area with θ≤50°in elevation direction

With the simple math for sphere area, the beam coverage area is 17.8% of total surface area of sphere i.e., $\frac{2\pi r^2 \int_0^{\theta=50^{\circ}} sin\theta d\theta}{4\pi r^2} = 17.8\%$. To reserve certain margin for the outer range of beam coverage area, it was derived to use 85%-tile requirement for EIRP CDF of FWA's spherical coverage performance.

The minimum allowed min Peak EIRP at 85%-tile CDF is derived from the simulation which evaluate an achievable Spherical Coverage Performance. Based on the 4x4 array panel by which one direction is covered, the following beamforming pattern can be simulated, where beams with 39 directions are utilized for the beam coverage area with θ≤50°in elevation direction. Two observation angles are shown in below figures.

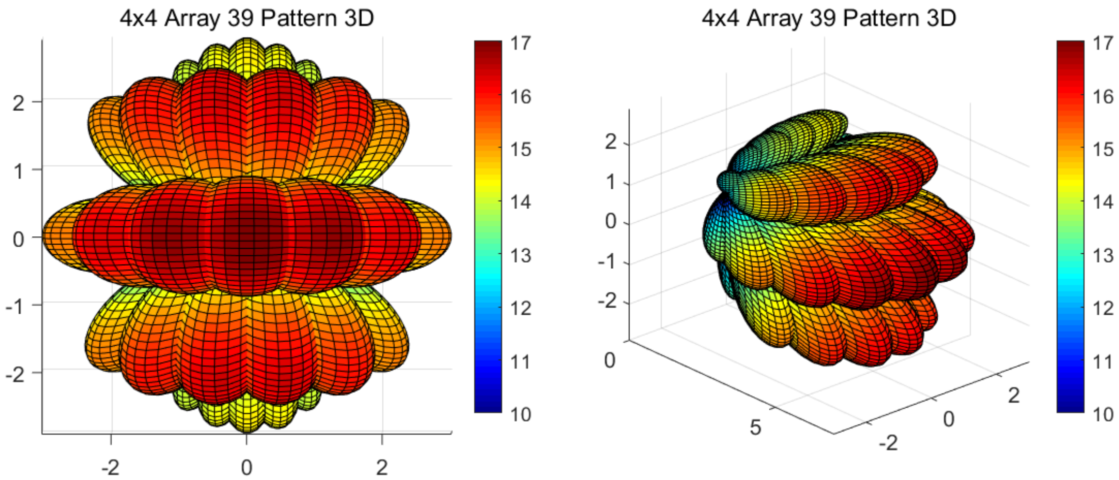


Figure 7.2.1.1.3-2: Beam coverage area, i.e., top sphere area with θ≤50°in elevation direction

It can be observed that the antenna gain achieved by beams in the outermost beam layer can be at least 3dB less than the center boresight direction, while the boundary areas between individual beams can be further degraded with the amount as much as around 6-7 dB.

CDF plot of achievable antenna gain based on ideal simulation environment is provided in the following figure, in which around 4dB degradation from peak direction can be observed at 85%-tile CDF point, i.e., 13.18dB at 85%-tile from 17dB in peak direction. In other words, the beam scanning loss without radome into account could be 4dB.

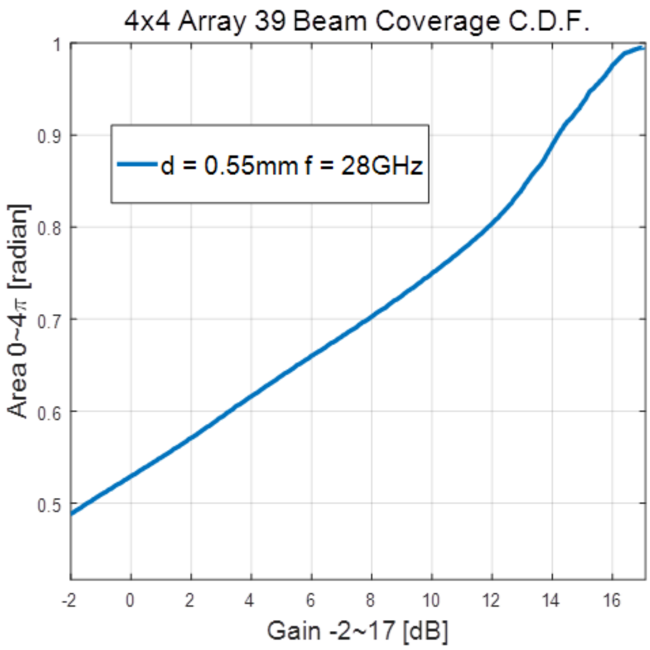


Figure 7.2.1.1.3-3: CDF of ideal antenna gain for 4x4 panel at 28GHz, 5.5mm element-spacing in both x- & y-directions

Furthermore, additional radome loss should also be considered, which arises when beam is steered away from boresight direction considering radome material can be beam-direction dependent and this loss has not been reflected in above simulation for ideal propagation environment. Based on our understanding and experience, at least 2.5dB should be reserved for this additional radome loss. Finally, additional 1.5dB should be reserved for implementation margin, to account for mmWave radiation distortion, practical design options for directional beam book design, and inaccuracy of pre-coder implementation etc.

As a summary, it was proposed to have 8.0dB at 85%-tile from peak EIRP value, with the breakdown of 8.0 dB as below:

Scan Loss w/o Radome: ~4 dB

Additional Radome Loss: 2.5 dB

Implementation Margin: ~1.5 dB

Conclusion

The minimum EIRP at the 85th percentile of the distribution of radiated power measured over the full sphere around the UE is defined as the spherical coverage requirement and is found in Table 7.2.1.1.3-1 below.

Table 7.2.1.1.3-1: UE spherical coverage requirement for Power class 1

Operating Band	Min EIRP at 85%-tile CDF [dBm]
n257	32.0
n258	32.0
n260	32.0
n261	32.0
NOTE 1: Minimum EIRP at 85 %-tile CDF is defined as the lower limit without tolerance NOTE 2: The requirements in this table are only applicable for UE which supports single band in FR2	

7.2.1.2 (Void)

7.2.1.3 UE Power class 2

Power class 2 is specified, assuming to be applied for only Vehicle mounted UE, which is installed on a motor vehicle like a car.

7.2.1.3.1 Minimum Peak EIRP requirement

How to derive the requirement

Several companies proposed the minimum allowed Peak EIRP for Power class 2 as shown in following Table 7.2.1.3.1-1. After discussion, minimum peak EIRP for power class 2 was defined as 29 dBm at band n257, n258, n261.

Table 7.2.1.3.1-1: survey of reported UE Minimum Peak EIRP for Power class 2

Parameter	Unit	Source 1	Source 2	Source 3
Pout per element	dBm	12	13	16
# of antennas in array		8	8	8
Total conducted power per polarization	dBm	21	22	25
Avg. antenna element gain	dBi	4.5	4	5
Antenna roll-off loss vs frequency	dB	-1.0	-2.0	-1
Realized antenna array gain	dBi	12.5	11	14
Polarization gain	dB	2.5	--	--
Mismatch and transmission line loss including load pull	dB	-2.5	--	--
Beam forming loss (phase shifter and amplitude error)	dB	-0.5	--	--
Finite beam table	dB	-0.25	--	--
Beam forming loss (one beam table fits all)	dB	-0.25	-1	--
Form-factor integration losses	dB	-4.5	-1.5	--
Total implementation loss (worst-case)	dB	-8.0	-4	-5
Peak EIRP (Minimum)	**dBm**	**28**	**29**	**29.5**

Conclusion

The minimum Peak EIRP values is found in Table 7.2.1.3.1-2 below.

Table 7.2.1.3.1-2: UE Minimum Peak EIRP for Power class 2

Operating Band	Min Peak EIRP (dBm)
n257	29.0
n258	29.0
n261	29.0
NOTE 1: minimum peak EIRP is defined as the lower limit without tolerance	

7.2.1.3.2 Maximum TRP/EIRP requirement

The maximum output power values for TRP and EIRP are found in Table 7.2.1.3.2-1 below. The maximum allowed EIRP is derived from regulatory requirements [12].

Table 7.2.1.3.2-1: UE Maximum Output Power Limits for Power class 2

Operating Band	Max TRP (dBm)	Max EIRP (dBm)
n257	23	43
n258	23	43
n261	23	43

7.2.1.3.3 Spherical coverage requirement

How to derive the requirement

Vehicle Mounted UE is attached on a body or a rooftop of a motor vehicle. Therefor the target beam coverage is limited half sphere because the body of vehicle blocks off radiation from vehicle mounted UE at the body side of the contact face. The spherical coverage requirement is originally agreed as 20%-tile on half spherical coverage. However, the definition of spherical coverage is full sphere so that spherical coverage of power class 2 is redefined at 60%-tile on full spherical coverage. This does not mean to relax the requirement. Practically EIRP at blocked side of vehicle should be sufficiently small and original requirement of half spherical coverage should be satisfied.

The value at CDF percentile of 20% (for half spherical) coverage was obtain to evaluate CDF of antenna gain for 28GHz based on the half sphere as show in Figure 7.2.1.3.3-1.

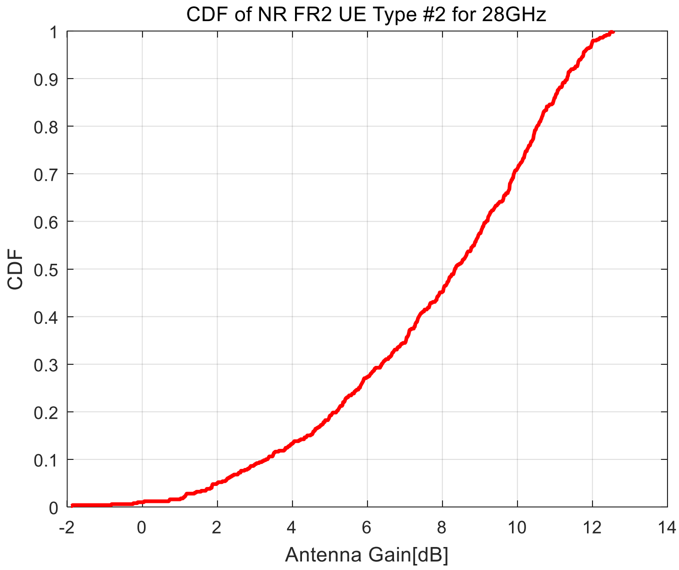


Figure 7.2.1.3.3-1: Antenna gain for Power class 2 UE

Based on the above CDF curves, it was proposed to define the required EIRP corresponding to 20% CDF percentile of the half spherical coverage considering some implementation margin, it was defined as 11dB at 20%-tile from peak EIRP value for half spherical coverage, i.e. 18dBm.

Conclusion

The minimum EIRP at the 60^{th} percentile of the distribution of radiated power measured over the full sphere around the UE is defined as the spherical coverage requirement and is found in Table 7.2.1.3.3-1 below.

Table 7.2.1.3.3-1: UE spherical coverage requirement for Power class 2

Operating Band	Min EIRP at 60%-tile CDF [dBm]
n257	18.0
n258	18.0
n261	18.0
NOTE 1: Minimum EIRP at 60 %-tile CDF is defined as the lower limit without tolerance NOTE 2: The requirements in this table are only applicable for UE which supports single band in FR2	

7.2.1.4 UE Power class 3

Power class 3 is specified, assuming to be applied for Handheld UE like a smartphone.

7.2.1.4.1 Minimum Peak EIRP requirement

How to derive the requirement

Several companies have provided minimum peak EIRP numbers based on feasible implementation assumptions. A summary of the reported minimum peak EIRP values is found in Table 7.2.1.4.3. After discussion, minimum peak EIRP was agreed as 22.4dBm for 28GHz and as 20.6dBm for 39GHz.

Table 7.2.1.4.1-1: Survey of reported minimum peak EIRP for Power class

Parameter	**Unit**	**Source 1**		**Source 2**		**Source 3**		**Source 4**		**Source 5**		**Source 6**		**Source 7**	
Frequency range	GHz	24.2-29.5	37-40	24.2-29.5	37-40	24.2-29.5	37-40	24.2-29.5	37 - 40	24.2-29.5	37 – 40	24.2-29.5	37 – 40	24.2-29.5	37-40
# ant elements		4	4	4	4	4	4	4	4	4	4	4	4	4	4
Avg. element gain (per polarization)	dBi	4.00	4.00	5.00	4.0	4.50	4.50	4.0	4.50	4.50	4.50	2.50	1.50	4.00	4.00
Antenna roll-off loss vs frequency	dB	-2.00	-2.50	-1.00	-1.50	-3.00	-1.50	-1.00	-1.00	-1.00	-1.50	-0.50	-0.50	-1.00	-1.50
Realized antenna array gain	dBi	8.00	7.50	10.00	8.50	7.50	9.00	9.00	9.50	9.50	9.00	8.00	7.00	9.00	8.50
Polarization gain	dB	2.80	2.80	2.50	2.50	2.50	2.50	2.00	2.00	2.50	2.80	2.80	2.80	2.80	2.80
Total implementation loss (nominal)	dB	-6.75	-7.95	-7.25	-8.50	-5.10	-6.10	-4.85	-5.85	-6.75	-7.75	-4.25	-4.25	-7.95	-9.15
Total implementation loss (worst-case)	dB	-9.60	-10.90	-10.00	-11.45	-7.45	-8.55	-8.70	-8.80	-9.60	-10.20	-6.10	-6.70	-10.80	-12.10
P1d per PA (nominal)	dBm	14.00	14.00	14.00	14.00	14.00	12.50	14.00	12.00	14.00	12.50	14.00	14.00	14.00	14.00
P1d per PA (minimum)	dBm	14.00	14.00	14.00	14.00	14.00	12.50	14.00	12.00	14.00	12.50	14.00	14.00	14.00	14.00
Peak EIRP (nominal)	**dBm**	**24.05**	**22.35**	**25.25**	**22.5**	**24.90**	**23.90**	**26.15**	**23.65**	**25.25**	**24.05**	**26.55**	**25.55**	**23.85**	**22.15**
Tolerance	dB	3.85	3.95	3.75	3.95	3.85	3.45	3.85	3.95	2.85	3.45	2.85	3.45	3.85	3.95
Peak EIRP (minimum)	**dBm**	**20.20**	**18.40**	**21.50**	**18.55**	**21.05**	**20.45**	**22.30**	**19.70**	**22.40**	**20.60**	**23.70**	**22.10**	**20.00**	**18.20**

NOTE 1: We encourage companies to provide implementation losses and P1d numbers for nominal and worst cases to facilitate the analysis of nominal and minimum definitions of max EIRP; the current RAN4 agreement is to define power class as the minimum of the max EIRP without tolerance

Conclusion

The minimum Peak EIRP values are found in Table 7.2.1.4.1-2 below.

Table 7.2.1.4.1-2: UE Minimum Peak EIRP for Power class 3

Operating Band	Min Peak EIRP (dBm)
n257	22.4
n258	22.4
n260	20.6
n261	22.4
NOTE 1: minimum peak EIRP is defined as the lower limit without tolerance	

7.2.1.4.2 Maximum TRP/EIRP requirement

The maximum output power values for TRP and EIRP are found in Table 7.2.1.4.2-1 below. The maximum allowed EIRP is derived from regulatory requirements [12].

Table 7.2.1.4.2-1: UE Maximum Output Power Limits for Power class 3

Operating Band	Max TRP (dBm)	Max EIRP (dBm)
n257	23	43
n258	23	43
n260	23	43
n261	23	43

7.2.1.4.3. Spherical coverage requirement

How to derive the requirement

Due to study the sensitivity of the network performance to the EIRP percentile, outage performance and throughput performance were evaluated through system simulation. Network simulation assumptions are found in Table 7.2.1.4.3-1.

Table 7.2.1.4.3-1: Network simulation assumptions used to derive Rel-15 PC3 requirements

Scenario (in TR 38.803 [10])	Indoor hotspots	Dense Urban	Urban Macro
UE Elevation distribution	Uniform from 0 to 180 degree.		
Indoor ratio	100%	0%(baseline), 20%, 100%	
Resource Allocation (UL)	・20 MHz for outage evaluation ・200 MHz for mean throughout evaluation		
Blockage Modeling	No body blockage and hand grip modelling		
Target UL SNR	22 dB		
Antenna pattern Modeling	Option 1: Based on mathematical modelling Option 2: Based on measured simulated pattern		

Following the adoption of the MPR = 0 dB region in the specification, the UL resource allocation of the network simulation assumptions is updated as shown in Table 7.2.1.4.3-2.

Table 7.2.1.4.3-2: Updated network simulation assumptions

Scenario (in TR 38.803 [10])	Indoor hotspots	Dense Urban	Urban Macro
UE Elevation distribution	Uniform from 0 to 180 degree.		
Indoor ratio	100%	0%(baseline), 20%, 100%	
Resource Allocation (UL)	・15 MHz for outage evaluation ・60 MHz for mean throughout evaluation		
Blockage Modeling	No body blockage and hand grip modelling		
Target UL SNR	22 dB		
Antenna pattern Modeling	Option 1: Based on mathematical modelling Option 2: Based on measured simulated pattern		

To understand the sensitivity of the network performance to the 50%-tile value, the EIRP was degraded by several dB for all UEs whose EIRP percentile is lower than 50%. In another sets of simulations, the EIRP was reduced as same for all UEs whose EIRP percentile is lower than 20%. By comparing the outage and throughput loss performances, it was observed that the network performance was less sensitive to the variations of EIRP at 20%-tile and slightly decreased at 50%-tile case. Therefor several companies suggested that defining the spherical coverage requirement at 20%-tile value for Power class 3 is impractical but should be specified at not smaller than 50%-tile value. On the other hand, due to lack of sufficient measurement experience, there was the opinion not to be specified below 50%-tile. After discussion, percentile of spherical coverage for Power class 3 was agreed as 50%-tile.

Based on above evaluation, several companies proposed 50%-tile value. But there was a variety of assumptions for the reported data and some was based of simulations, while a few were based on measurements. To help analyze the data, two tables are provided below summarizing the 50%-tile values for 1 panel and 2 panels. After discussion, spherical coverage in one power class is one specification. Finally, minimum EIRP at 50%-tile CDF is defined as 11.5dBm for 28GHz and as 8dBm for 39Hz.

Table 7.2.1.4.3-2: Summary of 50%-tile values – 1 panel

Source	Data type	28GHz		39GHz	
		Drop	EIRP	Drop	EIRP
Source 1	Simulated	-14.50	8.00	-18.0	2.5
Source 2	Measured	-14.00	8.40	-15.4	5.2
Source 3	Simulated	-11.60	10.8	-13.6	7.0
Source 4	Measured	-13.10	9.30	-	-
Source 5	Simulated	-11.70	10.7	-	-
Average		**-12.98**	**9.44**	**[-18 to -13.6]**	**[2.5-7.0]**

Table 7.2.1.4.3-3: Summary of 50%-tile values – 2 panel

Source	Data type	28GHz		39GHz	
		Drop	EIRP	Drop	EIRP
Source 1	Simulated	-13.0	9.5	-16.5	4.0
Source 2	Simulated	-8.00	14.4	-10.0	10.6
Source 3	Measured	-11.6	10.8	-11.6	9.0
Source 4	Measured	-9.10	13.3	-9.20	11.4
Source 5	Simulated	-10	12.4	-12.2	8.4
Source 6	Simulated	-7.40	15.0	**[-8.90]**	**[11.7]**
Source 7	Simulated	-10.3	12.1	-	-
Source 8	Simulated	-12.2	10.2	-	-
Source 9	Simulated	-9.0	13.4		
Average		**-10.1**	**12.3**	**[-11.4]**	**[9.2]**

Conclusion

The minimum EIRP at the 50th percentile of the distribution of radiated power measured over the full sphere around the UE is defined as the spherical coverage requirement and is found in Table 7.2.1.4.3-3 below.

Table 7.2.1.4.3-4: UE spherical coverage requirement for Power class 3

Operating Band	Min EIRP at 50%-tile CDF [dBm]
n257	11.5
n258	11.5
n260	8
n261	11.5
NOTE 1: Minimum EIRP at 50 %-tile CDF is defined as the lower limit without tolerance NOTE 2: The requirements in this table are only applicable for UE which supports single band in FR2	

7.2.1.5 UE Power class 4

Power class 4 is specified, assuming to be applied for High power non-handheld UE

7.2.1.5.1 Minimum Peak EIRP requirement

How to derive the requirement

Proposal for Power class 4 peak EIRP evaluation which contributes to the peak EIRP link budget is shown in Table 7.2.1.5.1-1 below.

Table 7.2.1.5.1-1: Power class 4 EIRP budgets for 24-30GHz frequency bands

Parameter	Unit	Case 1				Case 2			
		08 patches	16 patches	32 patches	64 patches	08 patches	16 patches	32 patches	64 patches
Pout per element	dBm	16	10	4	-1.5	19	13	7	1
# of antennas in array		8	16	32	64	8	16	32	64
Total conducted power per polarization	dBm	25	22	19	16.5	28	25	22	19
Avg. antenna element gain	dBi	4	4	4	4	4	4	4	4
Antenna roll-off loss vs frequency	dB	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
Realized antenna array gain	dBi	11.5	14.5	17.5	20.5	11.5	14.5	17.5	20.5
Polarization gain	dB	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Total implementation loss	dB	-4	-4	-4	-4	-7	-7	-7	-7
Peak EIRP (Minimum)	**dBm**	**35.3**	**35.3**	**35.3**	**35.8**	**35.3**	**35.3**	**35.3**	**35.3**

After discussion, Minimum peak EIRP is defined as 34dBm for 28GHz and as 31.0dBm for 39GHz.

Conclusion

The minimum Peak EIRP values is found in Table 7.2.1.5.1-3 below.

Table 7.2.1.5.1-2: UE Minimum Peak EIRP for Power class 4

Operating Band	Min Peak EIRP (dBm)
n257	34.0
n258	34.0
n260	31.0
n261	34.0
NOTE 1: minimum peak EIRP is defined as the lower limit without tolerance	

7.2.1.5.2 Maximum TRP/EIRP requirement

The maximum output power values for TRP and EIRP are found in Table 7.2.1.5.2-1 below. The maximum allowed EIRP is derived from regulatory requirements [12].

Table 7.2.1.5.2-1: UE Maximum Output Power Limits for Power class 4

Operating Band	Max TRP (dBm)	Max EIRP (dBm)
n257	23	43
n258	23	43
n260	23	43
n261	23	43

7.2.1.5.3 Spherical coverage requirement

<u>How to derive the requirement</u>

The spherical coverage requirement is originally agreed as 20%-tile on half spherical coverage. The value at CDF percentile of 20% coverage was obtain to evaluate CDF of antenna gain for 28GHz as show in Figure 7.2.1.5.3-1.

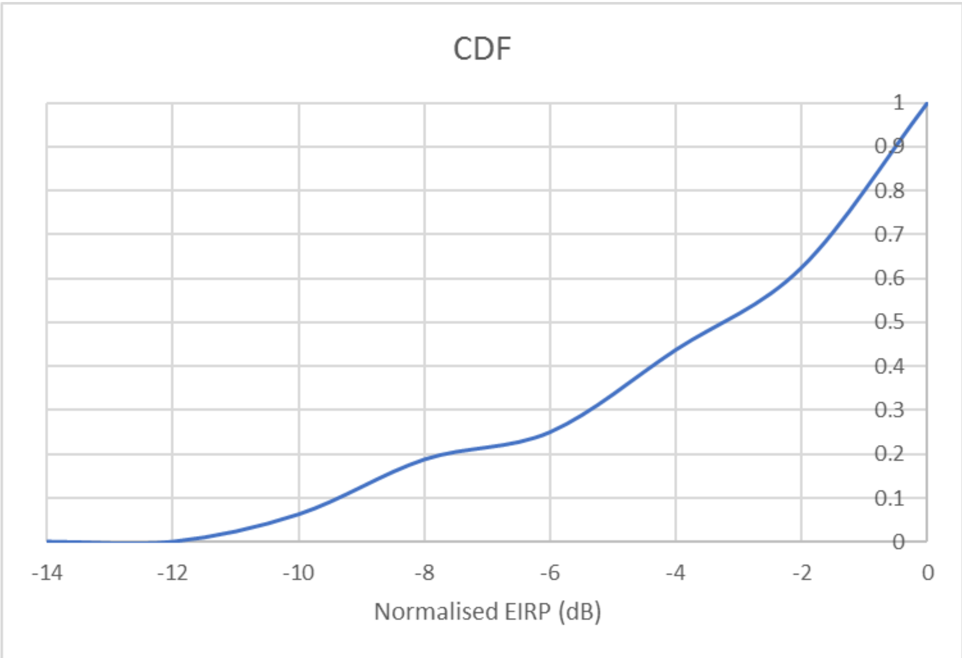


Figure 7.2.1.5.3-1: Simulated CDF of EIRP at 28GHz

Based on the above CDF curves, it was proposed to define the required EIRP corresponding to 20% CDF percentile considering some implementation margin, it was defined as 9dB at 20%-tile from peak EIRP value. Similar approach has been undertaken for 39GHz band.

<u>Conclusion</u>

The minimum EIRP at the 20th percentile of the distribution of radiated power measured over the full sphere around the UE is defined as the spherical coverage requirement and is found in Table 7.2.1.5.3-1 below.

Table 7.2.1.5.3-2: UE spherical coverage requirement for Power class 4

Operating Band	Min EIRP at 20%-tile CDF [dBm]
n257	25
n258	25
n260	19
n261	25
NOTE 1: Minimum EIRP at 20 %-tile CDF is defined as the lower limit without tolerance NOTE 2: The requirements in this table are only applicable for UE which supports single band in FR2	

7.2A Transmit power for CA

7.2A.1 Void

7.2A.2 Maximum power reduction for CA

FR2 enables very wideband aggregated channel bandwidths for CA. For Release 15, RAN4 has agreed to limit contiguous UL CA to 800 MHz of aggregated bandwidth, and up to 8 CCs. Non-contiguous intra-band UL CA was deemed out of Rel-15 scope, but non-contiguous DL CA is defined with frequency separation of up to 1400 MHz (see Table 6.2A.2.2-1 of TS 38.101-2 [5]). In the FR2 UE, because of the wide bandwidths, most stages of analog cricuitry have gain that is not constant over frequency. The baseband section in particular has gain droop which increases as a function of baseband BW. These gain slopes and droops play a prominent part in determining MPR, especially for wide baseband BWs.

Some UEs employ a common LO for both, UL and DL, for frequency translation of the signal between RF and baseband. Since, in FR2 CA, a CC can be configured either only for DL, or for both, UL and DL, the configured frequency span from the lowest edge of the lowest CC edge to the highest edge of the highest CC (‘instantaneous bandwidth’) in the UL may be significantly different from that of the DL. For these UEs, the baseband BW is not determined by the individual instantaneous bandwidths in either the UL or DL, but by the *aggregate* of the instantaneous bandwidths. This quantity is termed the *cumulative aggregated channel bandwidth,* and is defined in TS 38.101-2 [5] as the frequency band from the lowest edge of the lowest CC to the upper edge of the highest CC of all UL and DL configured CCs.

Note that for UEs that employ a common LO for both, UL and DL, CA MPR is applicable even when the UL is not configured for CA, but the DL is configured for CA. Figure 7.2A.2-1 shows the principle.

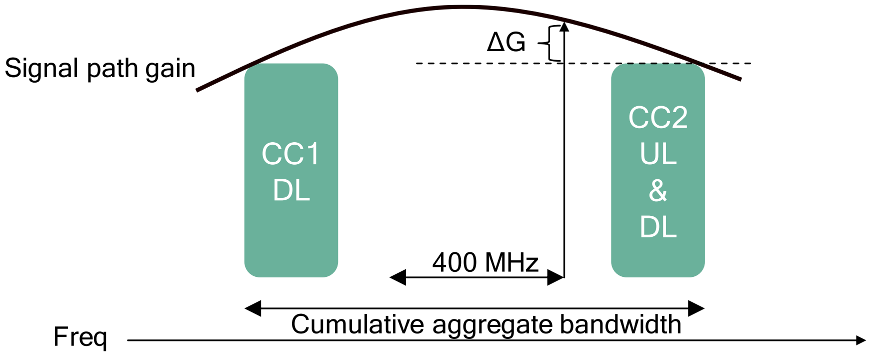


Figure 7.2A.2-1: Gain limitation in TX lineup for large *cumulative aggregated channel bandwidth*

Consider a UE with a common LO for UL and DL, sized to deliver full power when a single 400 MHz channel is configured. This operation corresponds to a baseband BW of 200MHz. In a CA mode that supports 1400 MHz of DL instantaneous bandwidth, the required operational baseband BW is 700 MHz for both UL and DL. This UE will suffer power droop ‘ΔG’ for UL CCs that happen to be configured at one of the edges as shown, which in turn drives MPR for this condition.

UEs with other LO implementations are not precluded. MPR requierments derived for UEs with common LO are automatically inclusive of UEs with other LO implementations.The justification is below:

For UEs with fast LO switching, or with dedicated LOs for Tx and Rx paths, UL signal path bandwidth can cover only the configured UL component carreirs instead of cumulative aggregate bandwidth. For these UEs, with CA configured per figure 7.2A.2-1, UL signal path is centered at the frequency range covering only the UL component carriers , as shown in figure 7.2A.2-2. These UEs do not have larger gain droop in the UL path, which in turn represents one less factor that forces PA back off by having tigher LO retuning implementation or doubling the number of LOs, compared to UEs with common LO.

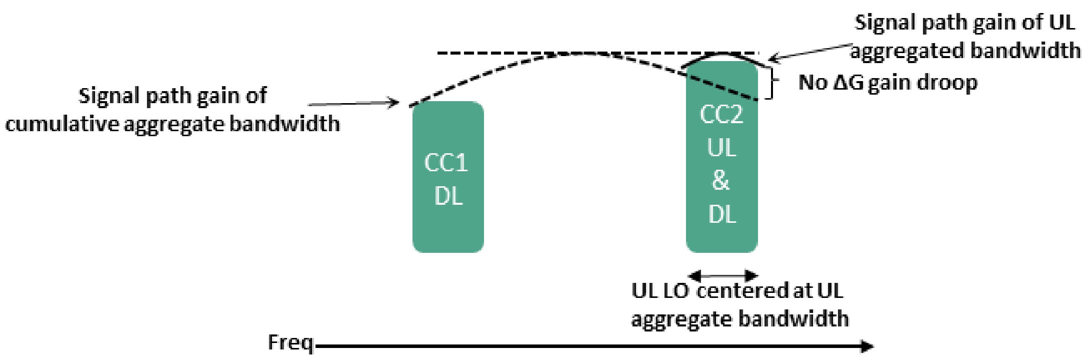


Figure 7.2A.2-2: ΔG gain between large *cumulative aggregated channel bandwidth vs small UL aggregate bandwidth*

7.3 Output power dynamics

7.3.1 Minimum output power

For the NR requirement on frequency range 2, it is agreed that

- 13dBm for EIRP regardless of channel bandwidth up to 400MHz from system level perspective.
- Considering efficiently, linearity for mmWave PA implementation, the minimum output power level is relaxed by [3] dB and [7] dB for EVM test for 16QAM and 64QAM.

The NR UE minimum output power requirement for frequency range 2 is defined in Table 7.3.1-1 and 7.3.1-2.

Table 7.3.1-1: NR minimum output power

	Channel bandwidth / Minimum output power / Measurement bandwidth				
	50 MHz	100 MHz	200 MHz	[300] MHz	400 MHz
Minimum output power (EIRP)	-13dBm				
Measurement bandwidth	See Transmission bandwidth configuration defined in 4.2				

Table 7.3.1-2: Parameters for Error Vector Magnitude

Parameters	Channel bandwidth / Minimum output power / Measurement bandwidth				
	50 MHz	100 MHz	200 MHz	[300] MHz	400 MHz
UE output power (EIRP)	≥ -13 dBm				
UE output power for UL 16QAM (EIRP)	≥ [-10] dBm				
UE output power for UL 64QAM (EIRP)	≥ [-6] dBm				

7.4 Transmit signal quality

7.5 Output RF spectrum emissions

7.5.1 Occupied bandwidth

7.5.2 Spectrum emission mask

7.5.3 Adjacent Channel Leakage ratio

7.5.4 Spurious emission

7.6 Transmit intermodulation

7.7 ON/OFF time mask

7.7.1 UE transient time

Similar to FR1, three different transient times are defined for FR2. The definition of these three transient time parameters is described in the section 5.7.1.

The following transient times are defined for FR2 in Table 7.7.1-1:

Table 7.7.1-1: Transient times for FR2

	FR1
ON-to-ON	5µs
OFF-to-ON	5µs
ON-to-OFF	5µs

7.8 Beam correspondence

7.8.1 General

Beam correspondence is the ability of the UE to select a suitable beam for UL transmission based on DL measurements with or without relying on UL beam sweeping. The beam correspondence requirement is satisfied assuming the presence of both SSB and CSI-RS signals and Type D QCL is maintained between SSB and CSI-RS.

7.8.2 Beam correspondence for PC1

7.8.3 Beam correspondence for PC2

7.8.4 Beam correspondence for PC3

The detailed formulation of the general beam correspondence requirement for PC3 and the beam correspondence tolerance requirement for PC3 is provided in TS 38.101-2 [5]. This clause contains the simulation assumptions and simulation results that are used to derive the beam correspondence tolerance requirement.

The simulation assumptions are shown in Table 7.8.4-1 below.

Table 7.8.4-1: Simulation assumptions for beam correspondence tolerance derivation

UE RF parameters	Unit	Value	Notes
Frequency band		n257/n258/n260/n261	Antenna performance can be different
Measurement grid	deg	7.5º or 15º	Peak EIRP is 7.5 Spherical EIRP is 15
Number of antenna elements in a module/set (number of panels, number of analog beam(K), etc.)		4 (2 panels, # total beam: 8, 16, 32)	Consider switched 2 panels. These parameters will be depend on UE implementation. Other values are not precluded
Polarization		2 polarizations	
Antenna location (front, back, top-side, left-side, right-side, bottom-side)		left/right	combination of the lists are not precluded
Phase error per antenna element (δ_{pk}) Amplitude error per antenna element (δ_{ak})	deg / dB	δ_{pk} ~ N(0,σ^2) with σ=[0~30]º δ_{ak} ~ N(0,σ^2) with σ=[0~2] dB	Used in Model 1 Other distributions are not precluded
Phase error per beam (δ_{pk}) Amplitude error per beam (δ_{ak})	deg / dB	δ_{pk} ~ N(0,σ^2) with σ=[10~45]º δ_{ak} ~ N(0,σ^2) with σ=[1~3] dB	Used in Model 2 Other distributions are not precluded
Error in RSRP estimation (Δ_k)	dB	Δ_k ~ N(0,Δ_k^2) with Δ_k=[1.5, 2] dB	
Front cover (plastic, glass, ceramic, metal)		Glass	This information is meaningful only if it's the same with the material which covers antennas
Back cover (plastic, glass, ceramic, metal)		Glass	
Side cover / frame (plastic, glass, ceramic, metal)		Metal	
Display panel – full (Y) or partial (N)	Y/N	Y	
Bezel margin	mm	1.5	Module can't be placed outer edge of UE to secure mechanical reliability

The procedure to model the beam correspondence impairments and to generate the CDF of ΔEIRP is as follows:

- Set ideal analog beam weight table (AWT) for K beams, where the number of beams depends on UE implementation
    - AWT = [$\mathbf{W}_1$ $\mathbf{W}_2$ $\mathbf{W}_3$ … $\mathbf{W}_K$]
- Let the composite antenna pattern for given Q direction with Wk beam vector, as defined in TR 38.803 [10], be A(Q, $\mathbf{W}_k$)
- For each P UEs, where P is the number of UEs to be simulated:
    - Generate Tx/Rx AWT considering phase and amplitude error per element (if using Model 1):
        - Tx AWT = [$\mathbf{W}_{T1}$ $\mathbf{W}_{T2}$ $\mathbf{W}_{T3}$ … $\mathbf{W}_{TK}$], where K is one of [8, 16, 32]
        - $\mathbf{W}_{TK} = \mathbf{W}_K * \delta_{ak} * \exp(i\ \delta_{pk})$
        - Rx AWT = [$\mathbf{W}_{R1}$ $\mathbf{W}_{R2}$ $\mathbf{W}_{R3}$ … $\mathbf{W}_{RK}$] = [$\mathbf{W}_1$ $\mathbf{W}_2$ $\mathbf{W}_3$ … $\mathbf{W}_K$]
    - Generate Tx/Rx AWT considering phase and amplitude error per beam (if using Model 2):
        - Tx AWT with error = [$\mathbf{W}_{T1}$ $\mathbf{W}_{T2}$ $\mathbf{W}_{T3}$ … $\mathbf{W}_{TK}$], where K is one of [8, 16, 32]
        - Rx AWT = [$\mathbf{W}_{R1}$ $\mathbf{W}_{R2}$ $\mathbf{W}_{R3}$ … $\mathbf{W}_{RK}$] = [$\mathbf{W}_1$ $\mathbf{W}_2$ $\mathbf{W}_3$ … $\mathbf{W}_K$]
        - Relationship between Tx/Rx AWT: $A(Q, \mathbf{W}_k) = A(Q+\delta_{pk}, \mathbf{W}_{Rk}) + \delta_{ak}$
- For given measure point (Q) within EIRP measurement grid (iterate until statistically meaningful measurement values are obtained)

        - Determine UE autonomous DL (Rx) beam selection ($EIRP_1$)
            - Beam Index(k) = index of max($RSRP_1+\Delta_1$, $RSRP_2+\Delta_2$, $RSRP_3+\Delta_3$, … $RSRP_K+\Delta_K$)
            - Beam Index(k) = index of max(A(Q, $\mathbf{W}_{R1}$)+Δ_1, A(Q, $\mathbf{W}_{R2}$)+Δ_2, A(Q, $\mathbf{W}_{R3}$)+Δ_3, … A(Q, $\mathbf{W}_{RK}$)+Δ_K)
            - $EIRP_1$ = A(Q, $\mathbf{W}_{TK}$)
        - Determine UE $EIRP_2$:
            - Size of SRS AWT is restricted by *SRS-resource* of M = 8
                - The common understanding for UL beam sweeping operation is the following:
                    - If UE does not configure the *spatialRelationInfo* from NW, then the UE can consider the UL beam sweeping.
                    - If UE has configure the *spatialRelationInfo* from NW, then the UE consider autonomous beam selection
                    - *spatialRelationInfo* contain the ID of a reference 'ssb-Index' or 'csi-Rs-Index' for SRS resource
            - SRS AWT = [$\mathbf{W}_{SRS\_T1}$ $\mathbf{W}_{SRS\_T2}$ $\mathbf{W}_{SRS\_T3}$ … $\mathbf{W}_{SRS\_TM}$] is a subset of Tx AWT; how to select the subset is up to UE implementation
            - $EIRP_2$ = max(A(Q, $\mathbf{W}_{SRS\_T1}$), …, A(Q, $\mathbf{W}_{SRS\_TM}$)) (beam sweeping and select best)
            - $\Delta EIRP = EIRP_2 - EIRP_1$
    - After calculating ΔEIRP at all measurement grid points, generate CDF of ΔEIRP
        - Correction for the sine of the elevation angle is used when generating the CDF of ΔEIRP (same approach as the EIRP CDF generation)
    - Company should guarantee $EIRP_2$ can fulfill all applicable requirements (Clause 6.6 of TS 38.101-2 [5])
        - The impact on the 50%-tile of the EIRP CDF can be estimated as the average difference in the 50%-tile values between $EIRP_1$ CDF and $EIRP_2$ CDF over the P simulation trials
    - The beam correspondence tolerance value Y is defined as the 85%-tile of the ΔEIRP CDF

The summary of simulation results is provided in Table 7.8.4-2 below.

Table 7.8.4-2: Summary of simulation results

Company / Parameter	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Model type	Model 2	Model 2	Model 1	Model 1	Model 1	Model 1	Model 1
Amplitude error δ_{ak} (dB)	2.0	2.0	2.0		2.0	2.0	2.0
Phase error δ_{pk} (°)	10	10	16	16	16	16	16
RSRP error Δ_k (dB)	2.0	2.0	1.5	2.0	2.0	1.5	
SNR (dB)		High enough	Range of [6.4, 19.4]	10			
BC tolerance (Y dB @ 85%-tile)	6.0	[5.8]	3.5 (n257/n258 /n261) 3.9 (n260)	3.5	3.0	2.5	3.5

7.8.5 Beam correspondence for PC3

8 UE Receiver characteristics (frequency range 2)

8.1 General

8.2 Receiver Sensitivity

8.2.1 MSD (Maximum sensitivity reduction)

8.3 Selectivity

8.4 Blocking performance

8.5 Spurious response

8.6 Intermodulation performance

8.7 Spurious emission

9 UE Transmitter characteristics (NSA and interworking between frequency ranges 1 and 2)

10 UE Receiver characteristics (NSA and interworking between frequency ranges 1 and 2)

Annex A: Environmental conditions

A.1 General

This annex specifies the environmental requirements of the UE. Within these limits the requirements of the present documents shall be fulfilled.

A.2 Environmental

The requirements in this clause apply to all types of UE(s).

A.2.1 Temperature

All RF requirements for UEs operating in FR2 are defined over the air and can only be tested in an OTA chamber.

The UE shall fulfil all the requirements in the temperature range defined in Table A.2.1-1.

Table A.2.1-1: Temperature conditions

+ 25 °C ± [10] °C	For normal (room temperature) conditions

Whether additional temperatures are defined is FFS.

A.2.2 Voltage

Annex B:
Coexistence studies for 55dBm CPE deployment in FR2

B.1 Introduction

In RAN4#84, a WF has been agreed on conducting simulations related to 55dBm CPE in mmWave scenario. This section summarizes the conclusions of the studies.

B.2 Network layout model

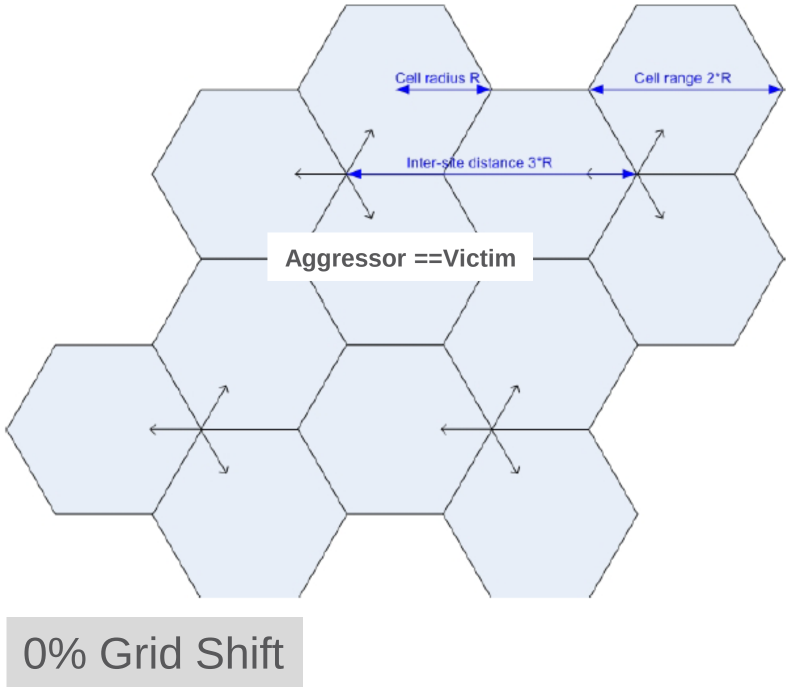
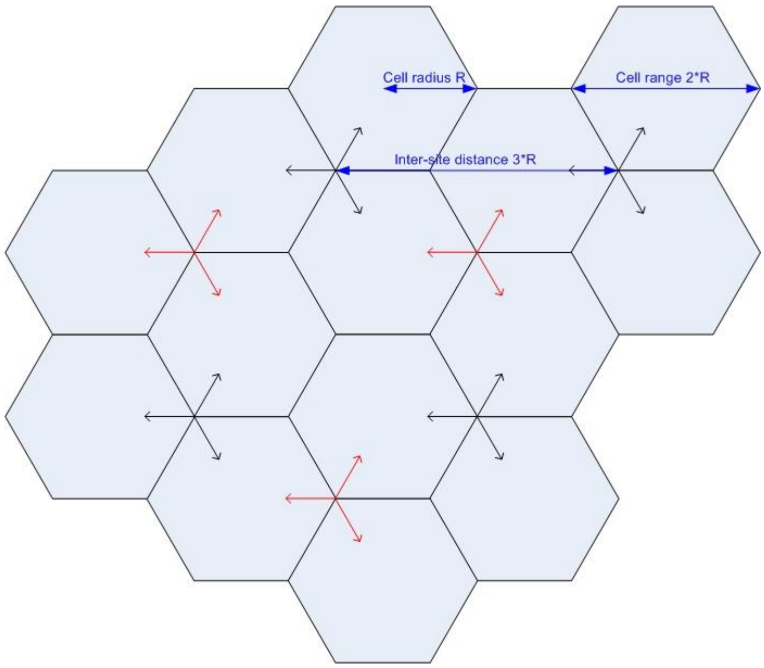
B.2.1 Urban macro

B.2.1.1 Single operator layout

Parameters		Values	Remark
Network layout		hexagonal grid, 19 macro sites, 3 sectors per site with wrap around	
Inter-site distance		300m	Note 1
BS antenna height		25 m	
CPE location	Outdoor/indoor	Outdoor and indoor	
	Indoor CPE ratio	20%	Note 1
	Low/high Penetration loss ratio	50% low loss, 50% high loss	
	LOS/NLOS	LOS and NLOS	Specified in TR 38.803 [10]
	CPE antenna height	Same as 3D-UMa in TR 36.873	Elevation height is 4.5m for both indoor and outdoor scenario
CPE distribution (horizontal)		Uniform	
Minimum BS - CPE distance (2D)		35 m	Note 1
Channel model		UMa	Specified in TR 38.803 [10]
Shadowing correlation		Between cells: 1.0 Between sites: 0.5	
Note: If we find any issue, then we can revisit parameters.			

B.2.1.2 Multi operators layout

Parameters	Values	Remark
Multi operators layout	coordinated operation (0% Grid Shift)	
	uncoordinated operation (100% Grid Shift)	

Coordinated Operation: each network with co-location of sites	
Non-coordinated operation	 **100% grid shift**

B.2.2 Dense urban

Companies can provide simulations results for dense urban micro scenario in both 30GHz and 45GHz. The deployment parameters are same as dense urban scenario as described in TR 38.803 [10] except CPR antenna elevation height is 4.5m.-

B.3 Propagation model

B.3.1 Path loss

Path loss models are based on TR 38.803 [10].

B.3.2 LOS probability

LOS probability models are based on TR 38.803 [10].

B.3.3 O-to-I penetration loss

The pathloss incorporating O-to-I building penetration loss is modelled as in 38.803 [10].

B.4 Transmission power control model

For uplink, TPC model specified in Section 9.1 TR 36.942 [9] is applied with following parameters.

- CL-xile = 100+ 10*log10(200/X)
  - X: UL transmission BW
- Gamma = 1

Note: we need discuss KPI based on simulation results.

B.5 Received signal power model

The following model is applied.

RX_PWR = TX_PWR – pathloss + G_TX + G_RX

where:
RX_PWR is the received signal power
TX_PWR is the transmitted signal power
G_TX is the transmitter antenna gain (directional array gain)
G_RX is the receiver antenna gain (directional array gain).

B.6 Other simulation parameters

Parameters	Urban macro	Dense Urban micro
Channel bandwidth	200MHz	200MHz
Scheduled channel bandwidth per CPE (UL)	200MHz	200MHz
The number of active CPE (UL)	Same as the number of BS beam	Same as the number of BS beam
Traffic model	Full buffer	Full buffer
UL power control	YES	YES
CPE max TX power in dBm	35dBm	35dBm
CPE min TX power in dBm	-40dBm	-40dBm
BS Noise figure in dB	10	10 for 30GHz 12 for 45GHz
Handover margin	3dB	3dB

B.7 Simulation description

Adopt following simulation steps. If companies find issues in the following simulation steps, we can revisit in RAN4#80bis. Note: detailed simulation description is captured in Section 5.1.5 TR25.942.

1) Aggressor and victim network are generated.

2) CPE associations: CPE are associated to base station based on coupling loss.

   - Associations are made assuming a single element at both CPE and BS.

3) Once association is done, round robin scheduling is used. BF weights are adjusted to point to the LOS direction between BS-CPE. This done for both victim and aggressor networks.

4) SINR Throughput are measured in the victim systems without considering ACI, i.e. $Thput_{\mathrm{NO\ ACI}}[bpshz] = f(SINR_{ICI}) = f\left(\frac{S}{N+I_{ICI}}\right)$, where I_{ICI} is the inter-cell interference.

5) SINR and throughput are computed considering ACI: $\mathrm{Thput_{ACI}[bpshz]} = \mathrm{f(SINR_{ICI+ACI})} = \mathrm{f}\left(\frac{\mathrm{S}}{\mathrm{N+I_{ICI}+I_{ACI}}}\right)$, where I_{ACI} is the adjacent channel interference.

6) RF parameters are determined based degradation cause by ACI: $Loss_{ACI} = 1 - \frac{\mathrm{Thput_{ACI}}}{\mathrm{Thput_{SINGLE}}}$.

B.8 Evaluation metric

Assume scaled Shannon's formula specified in TR 36.942 [9] with following parameters.

Parameter	UL	Notes
α, attenuation	0.4	Represents implementation losses
SINRMIN, dB	-10	Based on QPSK, 1/5 rate (UL)
SINRMAX, dB	22	Based on 64QAM 0.93 (UL)

B.9 Antenna configuration

B.9.1 Base station

Assumptions captured in page 8 - 11 of [R4-168794] are assumed as BS antenna configurations. For UMa and UMi base stations, we keep this same antenna model.

B.9.2 CPE

For CPE, we consider the following:

- Baseline: (NV,NH) = (4, 8).
- $(d_V,d_H) = (0.5, 0.5)\lambda$.
- An additional 3dB gain is added to the total beamforming gain to account for the two polarization directions.
- 5dBi element gain, 90 degree HPBW in Azimuth and zenith, Am=25dB, SLAv=25dB

B.10 Evaluated ACIR range

ACIR range: 5 ~ 45dB, with 5dB as step. Note that: we do not have simulation per 1dB step.

B.11 Co-existence scenarios

Evaluate following scenarios for 55dBm CPE:

No.	Aggressor	Victim	Simulation freqCPEncy	Direction	Usage scenario	Deployment Scenario
1	NR, 200MHz	NR, 200MHz	30 GHz	UL to UL	eMBB	Urban macro
2	NR, 200MHz	NR, 200MHz	30 GHz	UL to UL	eMBB	Dense Urban
3	NR, 200MHz	NR, 200MHz	45 GHz	UL to UL	eMBB	Dense Urban

B.12 Summary of co-existence simulations

During RAN4 NR-AH#3 and RAN4#84bis, following contributions provide simulation results based on agreed WF related to 55dBm CPE in mmWave spectrum simulation assumptions, as detailed in this annex:

- R4-1719701, Urban Macro Simulation Results at 30GHz for 55dBm EIRP Transportable Stations, Nokia, Nokia Shanghai Bell
- R4-1719702, Dense Urban Simulation Results at 30GHz for 55dBm EIRP Transportable Stations, Nokia, Nokia Shanghai Bell
- R4-1719703, Dense Urban Simulation Results at 45GHz for 55dBm EIRP Transportable Stations, Nokia, Nokia Shanghai Bell
- R4-1710487, Co-existence study for 55dBm EIRP Transportable Stations for urban macro scenario, Huawei, HiSilicon
- R4-1710488, Co-existence study for 55dBm EIRP Transportable Stations for dense urban scenario, Huawei, HiSilicon
- R4-1710859, Coexistence evaluation results for 55dBm EIRP transportable stations, LG Electronics Inc.
- R4-1711031, Coexistence evaluation results for CPEs with 55 dBm EIRP, Samsung

- R4-1711147, Uncoordinated Urban Macro Simulation Results at 30GHz for 55dBm EIRP Transportable Stations, Nokia, Nokia Shanghai Bell
- R4-1711400, ACIR simulations results for 55dB EIRP transportable stations - Urban Macro deployment at 30GHz, Qualcomm Incorporated
- R4-1711401, ACIR simulations results for 55dBm EIRP transportable stations - Urban Macro deployment at 45GHz, Qualcomm Incorporated
- R4-1711483, Coexistence simulation results for for 55dBm CPE in mmWave FWA scenario, Ericsson
- R4-1711481, Inband receiver blocking for mmWave NR BS with 55dBm CPE FWA deployment, Ericsson
- R4-1712684, Coordinated Urban Macro Simulation Results with Total Fading Correlation at 30GHz for 55dBm EIRP Transportable Stations, Nokia, Nokia Shanghai Bell

Based on these contributions, we summarized the following simulation results.

B.12.1 ACIR simulation results

B.12.1.1 Urban macro (UMa) scenario

Following ACIR simulation results are available:

Company	Collocated	Non-collocated
Huawei		21
Samsung	9	10
Qualcomm	10	15
Ericsson	10	15
Nokia	16	16

B.12.1.2 Dense urban micro (UMi) scenario

Following ACIR simulation results are available:

Company	30GHz	45GHz
Huawei	5dB	5
Samsung	7	5
Qualcomm	-	-
Ericsson	-	-
Nokia	16	15

B.12.1.3 Summary of ACIR simulations

The summary is listed below:

Nokia	The simulation results have shown that 55dBm EIRP transportable stations can be used effectively to extend the coverage of coordinated and uncoordinated urban macro network at 30GHz, as well as dense urban network at 30GHz and 45GHz with minor impacts on the required BS dynamic range and in-band blocking performances, while applying the currently agreed UE ACLR and BS ACS will provide sufficient UL coexistence performance except in the coordinated urban macro network simulated with 0.5 shadowing correlation. The simulation results (total fading) have shown that 55dBm EIRP transportable stations can be used effectively to extend the coverage of coordinated urban macro network at 30GHz, with minor impacts

	on the required BS dynamic range and in-band blocking performances, while applying the currently agreed UE ACLR and BS ACS will provide sufficient UL coexistence performance.
Huawei	Specify the ACLR/ACS requirements for 55dBm EIRP Transportable Stations based on 21dB ACIR value for 30GHz in urban macro scenario
Samsung	Considering CPEs, the simulated ACIR value (10 dB) for urban macro scenario is less than that (16.2 dB) calculated from the agreed ACLR and ACS for 30 GHz. The simulated ACIR value (7 dB) for dense urban scenario is less than the calculated 16.2 dB. Considering CPEs, the simulated ACIR value (5 dB) for dense urban scenario is less than that (15.2 dB) calculated from the agreed ACLR and ACS for 45 GHz.
Qualcomm	The required ACIR for the worst-case scenario is ~15dB. In case of co-located deployment, for UL scenarios the correlation between coupling losses of the adjacent operator wanted link and the coupling loss of cross operator interfering link is very close to 1. In case of co-located deployment the assumption about the correlation between adjacent operator wanted link and cross operator interfering link should be specified. Baseline assumption should be 100% correlation, i.e. same coupling loss for the two links.
Ericsson	The ACIR levels in UL for non-collocated case are around 5dB higher than the collocated case and if we consider the 5% Average throughput loss, the ACIR levels in UL for both collocated and non-collocated case fall in the same range 10dB-15dB as agreed in TR 38.803 [10].

B.12.2 Receiver dynamic range

Nokia	Minor impact in receiver dynamic range when 55dBm CPE is considered.

B.12.3 Inband receiver blocking

Following conclusions are made:

Nokia	Minor impact in receiver in-band blocking when 55dBm CPE is considered.
Ericsson	The “conducted” blocking levels are very similar when array gain is considered, with respect to 23dBm UE.

B.12.4 Conclusions

Based on the above simulation results, following has been agreed:

- Regarding the required AICR, the ACIR levels in UL for non-collocated case are around 5dB higher than the collocated case when different LSF is considered for victim and interfering network and if we consider the 5% Average throughput loss, the ACIR levels in UL for both collocated and non-collocated case fall in the same range 10dB-15dB as agreed in TR 38.803 [10].

- Regarding receiver dynamic range, minor impact in receiver dynamic range when 55dBm CPE is considered.

- Regarding inband receiver blocking, minor impact in receiver in-band blocking when 55dBm CPE is considered.

Annex C: Coexistence studies for 29 dBm UE power class for LTE Band 41 and NR Band n41

C.1 Simulation assumptions

C.1.1 Macro cell propagation model

C.1.1.1 Macro cell propagation model - urban and suburban areas

The propagation model is a derived from TR 36.942 [9].

Considering a carrier frequency of 2.6 GHz and a base station antenna height of 15 m above average rooftop level, the propagation model is given by the following equation:

$$L = 130.5 + 37.6\log_{10}(R)$$

where:

R is the base station-UE separation in kilometres

C.1.1.2 Macro cell propagation model - rural area

The propagation model is a derived from TR 36.942 [9].

For rural area, the Hata model is not applicable for a carrier frequency of 2.6 GHz, while the modified Hata model can be used:

Case 1: $d \leq 0.6$ km

$$L = 100.7 + 10\log\left(d^2 + 0.00189225\right)$$

Case 2: $d > 0.6$ km

$$L = 103.9 + 34.1\log\left(d\right)$$

where: d is the base station-UE separation in kilometres

C.1.2 Power control simulation parameters

Table C.1.2-1: CLx-ile parameters for +23 dBm UE

(a) CLx-ile parameters for +23 dBm UE using 0.75 km inter-site distance and 2.6 GHz carrier frequency

Parameter set	Gamma	CLx-ile	
		20 MHz bandwidth	10 MHz bandwidth
Set 1	1	109	112
Set 1'	1	117	120
Set 2	0,8	133	137

(b) CLx-ile parameters for +23 dBm UE using 2.8 km inter-site distance and 2.6 GHz carrier frequency

Parameter set	Gamma	CLx-ile	
		20 MHz bandwidth	10 MHz bandwidth
Set 1	1	133	136
Set 2	0,8	149	153

(c) CLx-ile parameters for +23 dBm UE using 6 km inter-site distance and 2.6 GHz carrier frequency

Parameter set	Gamma	CLx-ile	
		20 MHz bandwidth	10 MHz bandwidth
Set 1	1	117	120
Set 2	0,8	132	136

(d) CLx-ile parameters for +23 dBm UE using 8 km inter-site distance and 2.6 GHz carrier frequency

Parameter set	Gamma	CLx-ile	
		20 MHz bandwidth	10 MHz bandwidth
Set 1	1	122	124
Set 2	0,8	136	140

Table C.1.2-2: CLx-ile power control algorithm parameters for +29 dBm UE

(a) CLx-ile power control algorithm parameters for +29 dBm UE using 0.75 km inter-site distance and 2.6 GHz carrier frequency

Parameter set	Gamma	CLx-ile	
		20 MHz bandwidth	10 MHz bandwidth
Set 1	1	115	118
Set 1'	1	123	126
Set 2	0,8	141	145

(b) CLx-ile power control algorithm parameters for +29 dBm UE using 2.8 km inter-site distance and 2.6 GHz carrier frequency

Parameter set	Gamma	Modified CLx-ile	
		20 MHz bandwidth	10 MHz bandwidth
Set 1	1	139	142
Set 2	0,8	157	161

(c) CLx-ile power control algorithm parameters for +29 dBm UE using 6 km inter-site distance and 2.6 GHz carrier frequency

Parameter set	Gamma	Modified CLx-ile	
		20 MHz bandwidth	10 MHz bandwidth
Set 1	1	123	126
Set 2	0,8	140	144

(d) CLx-ile power control algorithm parameters for +29 dBm UE using 8 km inter-site distance and 2.6 GHz carrier frequency

Parameter set	Gamma	Modified CLx-ile	
		20 MHz bandwidth	10 MHz bandwidth
Set 1	1	128	130
Set 2	0,8	144	148

C.1.3 Cell layout

Base stations with 3 sectors per site are placed on a hexagonal grid with distance of 3*R, where R is the cell radius (see Figure C.1.3-1), with wrap around. The number of sites shall be equal to or higher than 19. Uncoordinated macro cellular deployment is assumed, where interfering UE may be at cell edge of the serving base station but close to the victim base station (hence transmitting with highest power and causing highest interference).

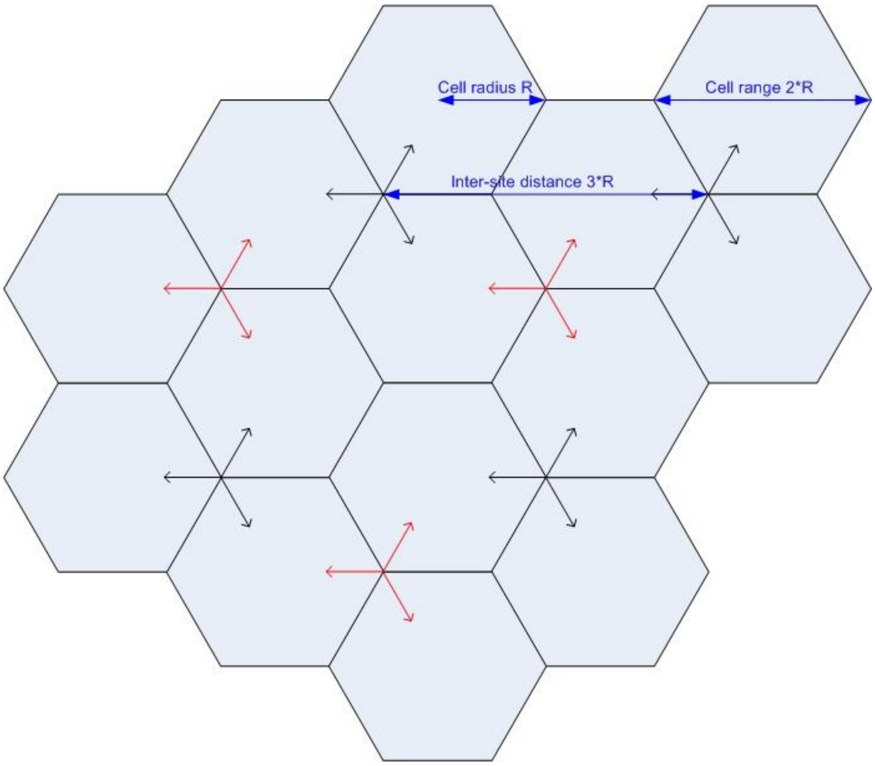


Figure C.1.3-1: Uncoordinated macro cellular deployment

The inter-site distances considered in the present document are provided in Table C.1.3-1 below.

Table C.1.3-1: Inter-site distances and Propagation model

Environment	ISD (km)	ISD (miles)
Urban	.75	.47
Suburban	2.8	1.74
Rural	6	3.73
Rural	8	5

C.1.4 Other simulation assumptions

Other simulation assumptions are summarized in Tables C.1.4-1 and C.1.4-2 below:

Table C.1.4-1: Simulation parameters for Band 41 system with 23 dBm UE

	Base Station	UE
Carrier frequency	2600 MHz	
Channel bandwidth	20 MHz, 10 MHz	
Inter-site distance	Use Table C.1.3-1	
Cell layout	Wrap-around 19 tri-sector cells, uncoordinated	
Frequency reuse	1x3x1	
Lognormal fading	10 dB	
Shadowing correlation	Between cells: 0.5, between sites: 1.0	
MCL (including antenna gain)	70 dB (urban and suburban areas) 80 dB (rural area)	
Antenna gain and horizontal antenna pattern	17 dBi, θ_{3dB} = 65 degrees, $A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ Am = 20 dB	Omni-directional antenna with -3.5 dBi.
Noise figure	5 dB	9 dB
Transmit power	46 dBm	23 dBm
Antenna height	45 m	1.5 m
ACLR	45 dB	Use Table 5.2 in TR 36.942 ACLR1: 30+X, ACLR2: 43+X Where X is 1 dB
ACS	45 dB	27 dB

Table C.1.4-2: Simulation parameters for Band 41 system with 29 dBm UE

	Base Station	HPUE
Carrier frequency	2600 MHz	
Channel bandwidth	20 MHz, 10 MHz	
Inter-site distance	Use Table C.1.3-1	
Cell layout	Wrap-around 19 tri-sector cells, uncoordinated	
Frequency reuse	1x3x1	
Lognormal fading	10 dB	
Shadowing correlation	Between cells: 0.5, between sites: 1.0	
MCL (including antenna gain)	70 dB (urban and suburban areas) 80 dB (rural area)	
Antenna gain and horizontal antenna pattern	17 dBi, θ_{3dB} = 65 degrees, $A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ Am = 20 dB	Omni-directional antenna with -3.5 dBi.
Noise figure	5 dB	9 dB
Transmit power	46 dBm	29 dBm
Antenna height	45 m	1.5 m
ACLR	45 dB	Use Table 5.2 in TR 36.942 ACLR1: 30+X, ACLR2: 43+X Where X is 1 dB
ACS	45 dB	27 dB

Simulations should assume the worst case of 100 % HPUEs in the scenarios with HPUEs.

C.1.5 Simulation procedure

For the co-existence study, the following procedure shall be performed:

1) Run the Band 41 UL to UL coexistence study, assuming parameters of both systems are according Table C.1.4-1. Power control parameters in Table C.1.2-1 are used. This corresponds to the coexistence of two commercial networks operating in adjacent channel and with similar deployment parameters. This is used as the reference. Band 41 victim system performance degradation results in this scenario are used as the baseline. Provide a CDF plot of UE transmit power.

2) Run the Band 41 UL to UL coexistence study, assuming +29 dBm power class UE is deployed in Band 41 interfering system only, and obtain the victim system performance degradation results. The simulation parameters in Tables C.1.4-1 and C.1.4-2 are used for the victim and interfering system, respectively. And the power control parameters in Tables C.1.2-1 and C.1.2-2 are used for the victim and interfering system, respectively. Provide a CDF plot of UE transmit power.

3) Compare the Band 41 victim system performance degradation obtaining in steps 1) and 2), choose the 29 dBm UE ACLR value so that the victim system performance degradation due to 29 dBm UE in 2) is the same as 1).

C.2 Simulation results

C.2.1 UE ACLR

The summary of the ACLR simulation results is shown in the Table C.2.1-1 below.

Table C.2.1-1: Summary of ACLR simulation results (additional ACLR needed)

	20 MHz (R4-1901489, R4-1901490)		10 MHz (R4-1903115, R4-1903116)		10 MHz (R4-1904020, R4-1904021)	
ISD	**Avg**	**5th percentile**	**Avg**	**5th percentile**	**Avg**	**5th percentile**
0.75 km	0.56	0.57	0.53	0.24	0.08	0.38
2.8 km	0.23	0.31	0.08	0.11		
6 km	0.33	0.37	0.13	0.20	0.30	0.14
8 km	0.29	0.18	0.07	0.07	0.20	0

The simulation results have shown that when the UL power control parameters are adjusted according to the UE maximum output power, the ACLR of the 29 dBm UE need to be improved (~1 dB) so that the victim system performance degradation due to 29 dBm interfering UE is the same as that due to 23 dBm interfering UE. Therefore, a value of 31 dB for ACLR is needed for 29 dBm UE.

C.2.2 BS receiver blocking

The summary of the 99.99%-tile victim BS received signal power from 29 dBm UE for the simulated cases is shown in the Table C.2.2-1 below.

Table C.2.2-1: Summary of 99.99%-tile victim BS received signal power from 29 dBm UE

	Scenario	Power control parameters	20 MHz (R4-1901489, R4-1901490)	10 MHz (R4-1903115, R4-1903116)	10 MHz (R4-1905987)
29 dBm UE	**Urban: ISD = 0.75 km**	1	-42.3112	-45.3109	-44.7
		1'	-50.3107	-53.3107	-52.7
		2	-62.8175	-66.0175	-63.5
	Suburban: ISD = 2.8 km	1	-48.8596	-51.8596	
		2	-62.4909	-65.6909	
	Rural: ISD = 6 km	1	-52.1831	-55.0907	-54.6
		2	-65.4718	-68.6718	-65.1
	Rural: ISD = 8 km	1	-53.5211	-55.5211	-60.5
		2	-65.8158	-69.0158	-67.0

The simulation results have shown that the 99.99%-tile received signal power in all simulated cases, except with the more aggressive Set 1 for 0.75 km inter-site distance, are lower than the current -43 dBm in-band blocking requirements specified in RAN4 specifications for wide-area BS. Although the 99.99%-tile received signal power with the more aggressive Set 1 for 0.75 km inter-site distance with 20 MHz channel bandwidth is slightly (< 0.7 dB) higher than -43 dBm, this should not be an issue for typical BS implementation with reasonable margin over the standards requirements. Therefore, the current BS in-band blocking requirements can also be applied for the 29 dBm UE case, and there is no need to specify new BS in-band blocking requirements.

C.3 Conclusions

The simulation results have shown that when the UL power control parameters are adjusted according to the UE maximum output power, the ACLR of the 29 dBm UE need to be improved (~1 dB) so that the victim system performance degradation due to 29 dBm interfering UE is the same as that due to 23 dBm interfering UE. Therefore, a value of 31 dB for ACLR is needed for 29 dBm UE.

Moreover, the simulation results have shown that the current BS in-band blocking requirements can also be applied for the 29 dBm UE case when the UL power control parameters are adjusted according to the UE maximum output power, and there is no need to specify new BS in-band blocking requirements.

Annex D: Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2017-09	RAN4-NR#3	R4-1709767				Report skeleton	0.0.1
2017-10	RAN4-#84bis	R4-1711049				Approved TPs at RAN4 #84 R4-1708965, TP to TR 38.xxx (NR WI TR): NR band numbering Approved at RAN4 NR#3 R4-1709871, TP for TR 38.xxx Update of NR bands R4-1710078, TP to TR 38.xxx (UE TR): Subcarrier Spacing options for non SS channels R4-1709941, TP for TR General aspects for UE RF for NR: Range 1 UE power class R4-1709541, TP for UE RF TR 38.xxx: sub-6GHz minimum output power R4-1709949, TP to TR General aspects for UE RF for NR: NR range 1 IQ Image and Carrier leakage R4-1709485, TP for TR General aspects for UE RF for NR: Range 1 UE EVM R4-1709477, TP for TR General aspects for UE RF for NR: Range 1 general SEM R4-1709950, TP for TR General aspects for UE RF for NR: Range 1 ACLR	0.1.0
2017-11	RAN4-#85	R4-1712893				Approved TPs at RAN4 #84bis R4-1711852 TP to TR 38.817-1 to add the subclause for UE general RF requirements for SUL and LTE-NR co-existence R4-1711729 TP for TR 38.817-01: mixed numerology FDM requirements R4-1711863 TP for TR 38.817-01 Further update of NR bands R4-1711741 TP to TR 38.817-1: Basestation and UE bandwidth allocation R4-1711555 TP to TR38.817-1 Environmental conditions for FR2 R4-1710960 TP to TR 38.817-01: Applicability of bandwithd combination sets to NR R4-1711562 TP to TR General Aspects for UE RF for NR Sub-6 GHz - MPR table and inner allocation a R4-1711621 TP to TR General Aspects for UE RF for NR Sub-6 GHz - NR Sub-6 GHz SU, SCS Allocation Alignment, TXBW and Guard-band R4-1711604 TP to TR 38.817-02 v0.1.0: Transient time for NR UE R4-1710959 TP to TR 38.817-01: In-band emissions R4-1710957 TP to TR 38.817-01: Futher ACLR agreements R4-1710556 TP for TR38.817-01:Conducted UE Tx spurious emission for FR1(section 5.5.4) R4-1710555 TP for TR 38.817-01 on conducted UE transmitter intermodulation for FR1 (setion 5.6) R4-1711967 UE RF requirements for UL sharing R4-1711568 TP to TR 38.xxx - UE minimum transmit power for range 2	0.2.0
2018-01	RAN4-AH-1801	R4-1800782				Approved TPs R4-1712460 TP to TR 38.817-01: Furher discussion on bandwidth support for NR bands in LTE-NR DC Nokia, Nokia Shanghai Bell R4-1712934 TP for UE RF TR 38.817-01: mmWave EIRP spherical coverage requirement Sumitomo Elec. Industries, Ltd R4-1714002 TP for UE RF TR 38.817-01: mmWave power class Sumitomo Elec. Industries, Ltd R4-1714099 TP for TR 38.817-01: UE RF requriements for SUL Huawei, HiSilicon R4-1714168 TP for TS 38.817-01: NR CA bandwidth class Huawei, HiSilicon R4-1714305 TP to 38.817-01 on ¡°Summary of simulation results on Coexistence Studies for 55dBm CPE¡± Ericsson, Nokia, Nokia Shanghai Bell R4-1714370 TP for TR 38.817-01: UE Power Class for UL-MIMO Huawei, HiSilicon, CMCC	0.3.0

						R4-1714452 TP to TR 38.817-01: UE REFSENS for NR bands below 6GHz Huawei, HiSilicon R4-1714479 TP for TR 38.817-01 NR channel bandwidth Huawei, HiSilicon	
2018-02	RAN4-#86	R4-1802136				Approved TPs R4-1800440 TP for TR 38.817-01 NR channel bandwidth CMCC R4-1800938 TP for TR 38.817-01v0.3.0 addition of n25 including refsens Sprint Corporation R4-1800999 TP for TR 38.817-01 Further update of NR bands Huawei, HiSilicon R4-1801009 pCR to UE TR 38.817-01: Spectrum utilization release 15 requirement Ericsson R4-1801103 TP for TR 38.817-01 addition of 26 including refsens Sprint Corporation R4-1801178 TP for TR 38.817-01v0.3.0 n41 refsens corrections Sprint Corporation R4-1801324 pCR to TR 38.817-01: Spectrum utilization for multiple numerologies Ericsson	0.4.0
2018-03	RAN #79	RP-180332				Approved TPs R4-1801431 TP for TR 38.817-01 NR UE power classes CMCC R4-1801480 TP for TR38.817-01:Channel spacing for NR ZTE R4-1801555 TP to TR 38.817-01 update of NR CBWs Huawei, HiSilicon R4-1801556 TP to TR 38.817-01 update of NR REFSENS and UL configurations Huawei, HiSilicon R4-1802144 TP to TR 38.817-01: NR channel and sync raster Ericsson R4-1802145 TP to TR 38.817-01: Sync raster calculations Ericsson R4-1802202 TP for TR 38.817-01: n41 correction Sprint Corporation R4-1803526 TP to TR 38.817-01: Spectrum Utilization for multiple numerologies Ericsson	1.0.0
2018-06	RAN #80	RP-180949				Approved TPs RAN4 #86bis R4-1804224 TP for TR 37.817-01: n41 correction and addtion SPRINT Corporation R4-1804225 TP for TR 38.817-01: n41 SEM and additional spurious emissions SPRINT Corporation R4-1805452 TP for TR 38.817-01 on US 28 GHz band number Qualcomm Incorporated R4-1805662 TP for TR 38.817-01 – Using BCS concept in NR ZTE Corporation R4-1805781 TP for TR38.817-01:Power class and REFSENSE for Bands n34,n39 and n40 ZTE Corporation,CMCC R4-1805901 TP for TS 38.817-01 Some corrections for SUL bands Huawei, HiSilicon R4-1805984 TP to TR 38.817-01: Sync raster open issues (4.3.1) Ericsson R4-1806006 UE RF requirements for EN-DC with UL sharing from UE perpective Huawei, HiSilicon RAN4 #87 R4-1806804 TP for TR 38.817-01 Notations on NR CA, EN-DC & NR DC ZTE Corporation R4-1806806 TP for TR 38.817-01 Introduction of BCS for intra-band EN-DC ZTE Corporation R4-1807815 TP for TR 38.817-01 correction to DFT-S-OFDM table for n41 SEM Sprint Corporation R4-1807823 TP for TR 37.817-01 Addition of intra-band EN-DC BCS text Sprint Corporation R4-1808123 TP for TS 38-817-01 n41 -25 dBm/MHz spurious emissions with NS_04 Sprint Corporation R4-1808267 TP for TR 38.817-01 Corrections on sync raster description in section 4.3.1 ZTE Corporation v2.0.0 submitted for plenary approval	2.0.0
2018-06	RAN#80					Approved by plenary – Rel-15 spec under change control	15.0.0
2018-09	RAN#81	RP-181896	0001		F	CR on TRx RF test metrics for mmWave	15.1.0
2018-09	RAN#81	RP-181896	0002	1	D	CR for 38.817-01: Formulas for the GSCN calculation	15.1.0
2018-12	RAN#82	RP-182359	0003	1	F	CR to TR 38.817-01 on Correction of calculations of GSCN per operating band	15.2.0
2018-12	RAN#82	RP-182359	0004		F	CR for the definition of mmWave power class	15.2.0
2019-03	RAN#83	RP-190401	0008		F	CR to TS 38.817-01: Corrections on ACLR simulation result and annex heading	15.3.0
2019-03	RAN#83	RP-190401	0010	2	F	CR to TR 38.817-01 on GSCN raster ranges	15.3.0

2019-03	RAN#83	RP-190402	0011	1	F	CR to TR 38.817-01: FR1 upper frequency limit extension	15.3.0
2019-06	RAN#84	RP-191237	0012	1	F	CR to TR 38.817-01 on GSCN raster ranges	15.4.0
2019-06	RAN#84	RP-191237	0013	2	F	CR to 38.817-01: FR2 CA MPR explained	15.4.0
2019-06	RAN#84	RP-191237	0015		F	CR to 38.817-01 to align system level simulation assumptions with MPR definition	15.4.0
2019-06	RAN#84	RP-191237	0016	1	F	CR to 38.817-01 to capture outcome of beam correspondence	15.4.0
2019-06	RAN#84	RP-191253	0014	1	B	CR to TS 38.817-01: Coexistence study on 29dBm UE Power Class for LTE Band 41 and NR Band n41	16.0.0
2019-09	RAN#85	RP-192033	0017		F	CR to TS 38.817-01: Correction on coexistence study on 29dBm UE Power Class for LTE Band 41 and NR Band n41 with 20MHz channel bandwidth	16.1.0
2019-09	RAN#85	RP-192048	0019		A	CR to TR 38.817-01 on FR1 inner RB allocation range	16.1.0