



NR Radio Frequency and co-existence

3GPP TSG RAN WG4 Chairman (Samsung)

Introduction | 3GPP RAN4 5G specifications



A GLOBAL INITIATIVE

RF Requirements

- | RF specification for UE (**38.101-1/2/3**) and BS (**38.104**)
 - Operating bands and Channel arrangement
 - Transmitter RF requirements
 - Receiver RF requirements
- | EMC specification for UE (**38.124**) and BS (**38.113**)
 - EMC emission
 - EMC Immunity
- | MSR BS RF requirements (**37.104**)
 - RF requirements for Multi-Standard Radio BS

Baseband Requirements

- | Radio Resource Management (**38.133**)
 - Mobility
 - Timing
 - Measurement
- | UE (**38.101-4**) Demod/CSI and BS (**38.104**) Demod
 - PDSCH/PDCCH/SDR
 - PUSCH/PUCCH/PRACH
 - CSI/PMI/RI
 - CRI
 - Other PHY channel
 - Other channel state information

Test

- | BS conformance Test
 - Conducted Test (**38.141-1**)
 - Radiated Test (**38.141-2**)
- | NR test method (**38.810**)
 - RF testing method
 - RRM testing method
 - Demodulation Testing method

3GPP TS 38.101-1 V0.2.0 2017.10

3rd Generation Partnership Project;
Technical Specification Group Radio
Access Network;
NR;
User Equipment (UE) radio
transmission and reception Part 1:
Rang 1 standalone
(Release 15)

3GPP TS 38.104 V0.3.0 2017.10

3rd Generation Partnership Project;
Technical Specification Group Radio
Access Network;
NR;
Base Station (BS) radio
transmission and reception
(Release 15)








3GPP TS 38.133 V0.3.0 2017.10

3rd Generation Partnership Project;
Technical Specification Group Radio
Access Network;
NR;
Requirements for support of radio
resource management
(Release 15)

3GPP TS 38.141-1 V0.3.0 2017.10

3rd Generation Partnership Project;
Technical Specification Group Radio Access
Network;
NR;
Base Station (BS) conformance testing;
Part1: Conducted conformance testing
(Release-15)

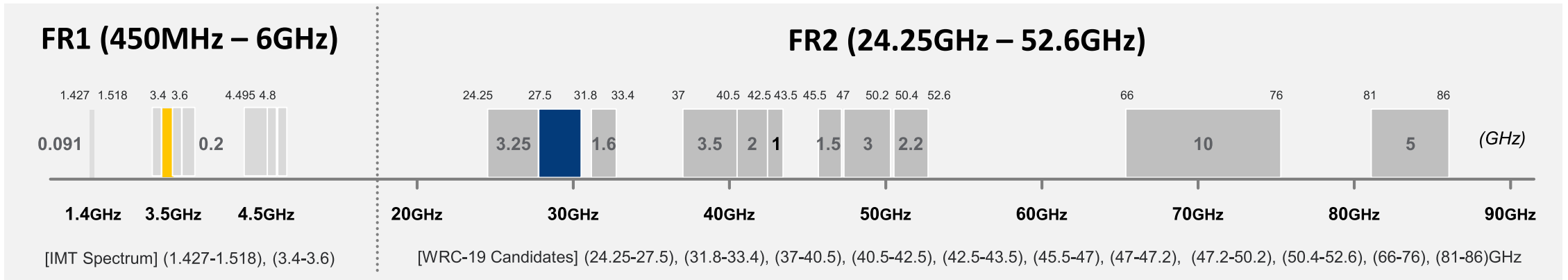
Content

-  NR System Parameters
 -  Spectrum/NR bands
 -  Channel Bandwidth
 -  Spectrum Utilization
 -  Guardband and Channel spacing
 -  Channel Raster
-  NR Radio Frequency Parameters

System Parameters | Spectrum



5G Candidate frequency bands for ITU-R WRC-19 (Nov. 2019)



New 5G frequency allocation status



USA

- 27.5 - 28.35GHz
- 37 - 38.6GHz
- 38.6 - 40GHz
- 37 - 43.5 GHz



Europe

- 3.4 - 3.8GHz
- 24.25 - 27.5GHz



China

- 3.3 - 3.6GHz
- 4.8 - 5.0GHz
- 24.25 - 27.5GHz
- 37 - 42.5GHz



Japan

- 3.6 - 4.2GHz
- 4.4 - 4.9GHz
- 27.5 - 29.5GHz



Korea

- 3.4 - 3.7GHz
- 26.5 - 29.5GHz

n77	3.3 - 4.2 GHz
n78	3.3 - 3.8 GHz
n79	4.4 - 5.0 GHz
n257	26.5 - 29.5 GHz
n258	24.25 - 27.5 GHz
n260	37 - 40 GHz
n261	27.5 - 28.35 GHz

System Parameters | NR Band Numbering



- Use prefix “n” to differentiate from E-UTRA bands and UTRA bands
- New bands for NR are assigned band numbers on a “first come first served” basis in reserved ranges regardless of duplex mode
- Reserved range is 65-256 for NR FR1 bands, 257-512 for NR FR2 bands

NR operating Band	Uplink (UL) operating band	Downlink (DL) operating band	Duplex Mode	
n1	1920MHz – 1980MHz	2110MHz-2170MHz	FDD] LTE Refarming Bands
:	:	:	:	
n77	3300MHz-4200MHz	3300MHz-4200MHz	TDD] NR FR1 new bands
:	:	:	:	
n257	26.5GHz – 29.5GHz	26.5GHz – 29.5GHz	TDD] NR FR2 new bands
:	:	:	:	
n512	:	:	:	

System Parameters | Channel Bandwidth



- 🌿 Fixed 15KHz SCS in LTE → Flexible SCS in NR
- 📶 Channel bandwidths depends on data subcarrier spacing (SCS) and frequency ranges
- 📶 Maximum Channel BW is specified assuming not over 3300 SC carriers and 4K FFT
- 📶 All channel bandwidth specified are mandatory except 90MHz in FR1 and 400MHz in FR2
- 📶 UE capability of supporting channel bandwidth is per band per SCS
- 📶 Separated capability for DL and UL. UE can operate with asymmetric UL and DL bandwidths
- 📶 New channel bandwidth can be added in the future release

NR band / SCS / UE Channel bandwidth													
LTE Refarming bands	SCS kHz	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90MHz	100 MHz
n1	15	Yes	Yes	Yes	Yes								
	30		Yes	Yes	Yes								
	60		Yes	Yes	Yes								
n41	15		Yes	Yes	Yes			Yes	Yes				
	30		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes

NR band / SCS / UE Channel bandwidth													
NR Band in FR1	SCS kHz	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	80 MHz	90 MHz	100 MHz
n77	15		Yes	Yes	Yes			Yes	Yes				
	30		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
n78	15		Yes	Yes	Yes			Yes	Yes				
	30		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes			Yes	Yes	Yes	Yes	Yes	Yes
n79	15							Yes	Yes				
	30							Yes	Yes	Yes	Yes	Yes	Yes
	60							Yes	Yes	Yes	Yes	Yes	Yes

Additional 30MHz and 70MHz Channel BW supported for N77,N78 in BS side ; 90MHz bandwidth supported in UE side is optional in Rel-15 for N77,N78 and N41

NR band / SCS / BS channel bandwidth					
NR Band in FR2	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
n261	60	Yes	Yes	Yes	
	120	Yes	Yes	Yes	Yes

System Parameters | Spectrum Utilization



- Spectrum Utilization (SU) is specified as Transmission Resource Block (RB) configuration in RAN4 specifications
- Spectrum utilization is specified as per combination of {CHBW, SCS}
- No specific waveform confinement technologies assumed (filtering, windowing, hybrid of them) for evaluating feasible SU
- Overall >90% SU achieved, maximum achieved SU are **98.3%** for FR1 and **95%** for FR2
- Spectrum Utilization is specified considering the forward compatibility
 - 📶 RAN4 defines a single set spectrum utilization (SU) values in Rel-15 for DL and UL
 - 📶 All the requirements defined in RAN4 based on Rel-15 SU
 - 📶 Meanwhile allow flexibility with higher values than RAN4 in RAN1/RAN2 protocol design

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}	N _{RB}
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

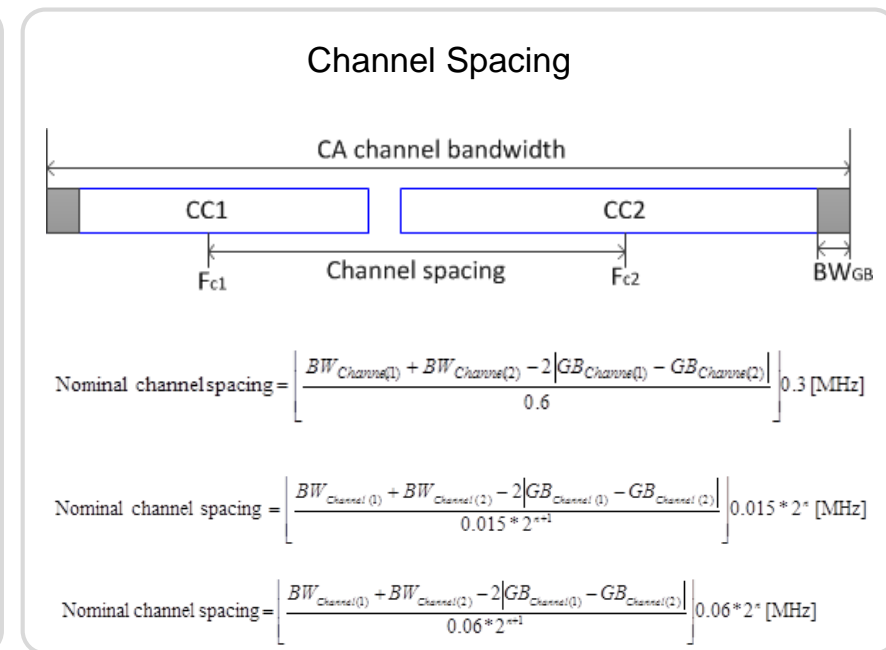
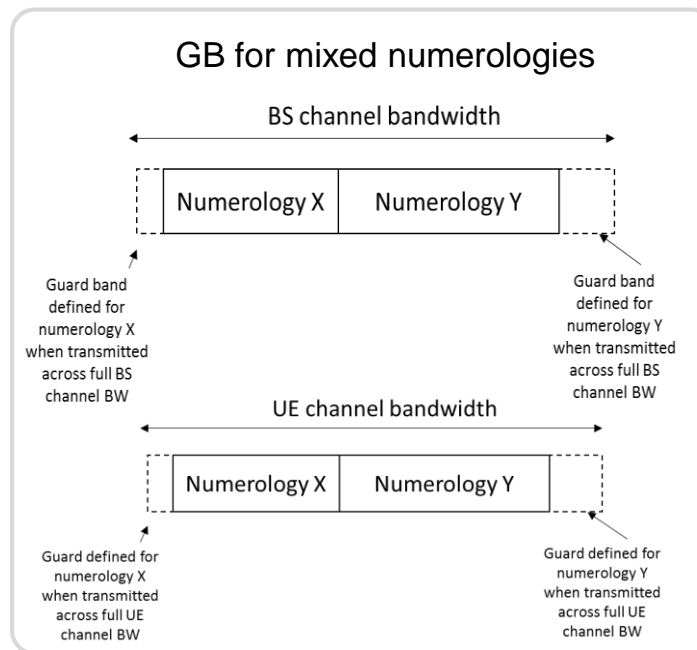
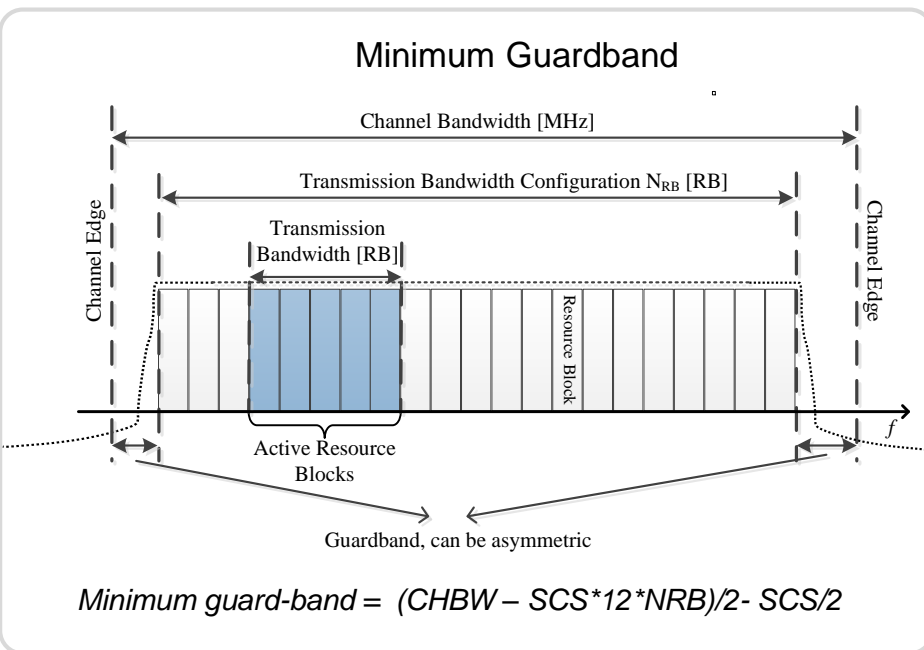
SCS (kHz)	50 MHz	100 MHz	200 MHz	400 MHz
	NRB	NRB	NRB	NRB
60	66	132	264	N.A
120	32	66	132	264

System Parameters | Guardband and Channel Spacing



A GLOBAL INITIATIVE

- Minimum guardband is specified based on channel bandwidth and transmission bandwidth configuration
- Minimum guardband for mixed numerologies is also specified
- Nominal Channel spacing for CA are also specified for different channel raster (100KHz, 15KHz, 60KHz)



System Parameters | Channel Raster



- The channel raster defines RF reference frequencies to identify channel position for both DL and UL
- A global frequency raster is defined between 0 -100GHz as NR-ARFCN
- The granularity of the global frequency raster is ΔF_{Global} :
 - 📶 For FR1 below 3GHz: 5kHz
 - 📶 For FR1 above 3GHz: 15kHz
 - 📶 For FR2: 60kHz
- The RF channel positions on the channel raster in each NR operating band are given through the applicable NR-ARFCN
- Band specific raster granularity ΔF_{Raster} , which may be equal to or larger than ΔF_{Global} :
 - 📶 FR1: LTE reframing bands except band 41, 100kHz aligned with LTE
 - 📶 FR1: New frequency ranges above 3GHz and band 41: SC based 15kHz, 30kHz
 - 📶 FR2: SC based 60kHz, 120kHz
- Similar global raster and band specific raster concept is also used to define Sync Raster

Content



- NR System Parameters
- NR RF Parameters
 - Transmitter Power
 - Unwanted Emission
 - REFSENS
 - ACS

Transmitter Power | UE FR1(38.101-1)



Power class (PC)

- Power class 3: 23dBm
- Power class 2: 26dBm
- Power class 3 is default power class



Maximum Power Reduction (MPR)

- UE is allowed to reduce the maximum output power due to higher order modulations and transmit bandwidth configurations
- For certain waveform and modulation scheme combination, MPR is defined according to RB allocation range, i.e., outer RB allocation and inner RB allocation



Additional Maximum Power Reduction (A-MPR)

- Additional maximum power reduction (A-MPR) is allowed to meet additional emission requirements which can be signalled by the network (NS value)



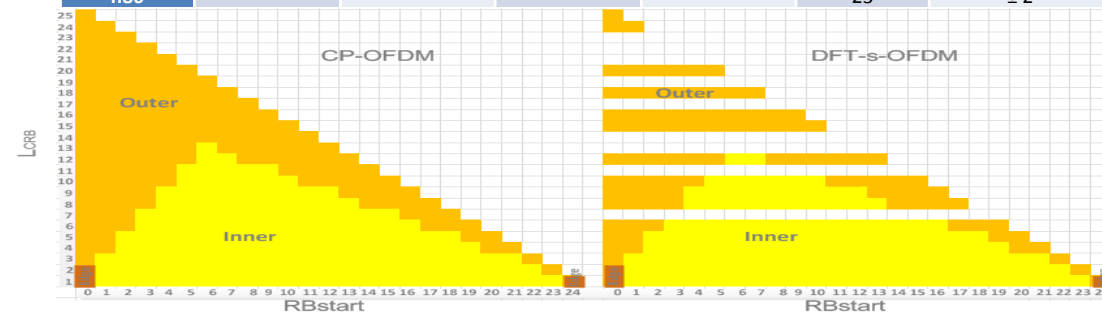
Configured transmitted power (Pcmax)

- The UE is allowed to set its configured maximum output power within the bounds, i.e., range of Pcmax











MPR, A-MPR and Pcmax are also specified for CA, DC, SUL and UL-MIMO

NR band	Class 1 (dBm)	Tolerance (dB)	Class 2 (dBm)	Tolerance (dB)	Class 3 (dBm)	Tolerance (dB)
n1					23	± 2
n2					23	± 2 ³
n3					23	± 2 ³
n5					23	± 2
n7					23	± 2 ³
n8					23	± 2 ³
n12					23	± 2 ³
n20					23	± 2 ³
n25					23	± 2
n28					23	+2 / - 2.5
n34					23	± 2
n38					23	± 2
n39					23	± 2
n40					23	± 2
n41			26	+2/-3 ³	23	± 2 ³
n50					23	± 2
n51					23	± 2
n66					23	± 2
n70					23	± 2
n71					23	+2 / - 2.5
n74					23	± 2
n77			26	+2/-3	23	+2/-3
n78			26	+2/-3	23	+2/-3
n79			26	+2/-3	23	+2/-3
n80					23	± 2
n81					23	± 2
n82					23	± 2
n83					23	± 2/-2.5
n84					23	± 2
n86					23	± 2



Transmitter Power | FR2 UE and EN-DC (38.101-2 and 38.101-3)



-  Power class definition package for FR2 UE
 -  Minimum peak EIRP-> UL coverage for network link budget
 -  Maximum TRP-> UL interference restriction
 -  Maximum EIRP-> Regulatory requirement
 -  EIRP at certain % of CDF-> Spatial coverage
-  MPR, A-MPR and P_{cm} are specified for each power class for FR2 UE
-  MPR, A-MPR and P_{cm} are also specified for CA and UL-MIMO
-  Transmitter power including Power class, MPR, A-MPR and P_{cm} are also defined for EN-DC UE

PC#	Min Peak EIRP (dBm)		Spherical coverage		Max. EIRP (dBm)		Max. TRP (dBm)		UE type
	28GHz	39GHz	28GHz	39GHz	28GHz	39GHz	28GHz	39GHz	
1	40.0	38.0	32.0dBm@85%	30.0dBm@85%	55	55	35	35	Fixed Wireless Access (FWA) on fixed platform
2	29.0	N/A	18.0dBm@60%	N/A	43	N/A	23	N/A	Vehicle mounted UE (fixed on moving platform)
3	22.4	20.6	11.5dBm@50%	8.0dBm@50%	43	43	23	23	Handheld UE
4	34.0	31.0	25.0dBm@20%	19.0dBm@20%	43	43	23	23	Higher power mobile UE

Note: The spherical coverage requirements in this table are only applicable for UE which supports single band in FR2

Output Power | BS



- Output power is specified per BS class (Wide area, Medium Range, Local area) and per BS type (BS 1-C, BS 1-H and BS 1-O)
- No upper limit is defined for Wide Area BS output power
- $10\log(N_{\text{TXU, counted}})$ is used to derive rated carrier output power from output power per TAB connector for BS 1-H
- No upper limits for output power is specified for BS type 2-O in Rel-15

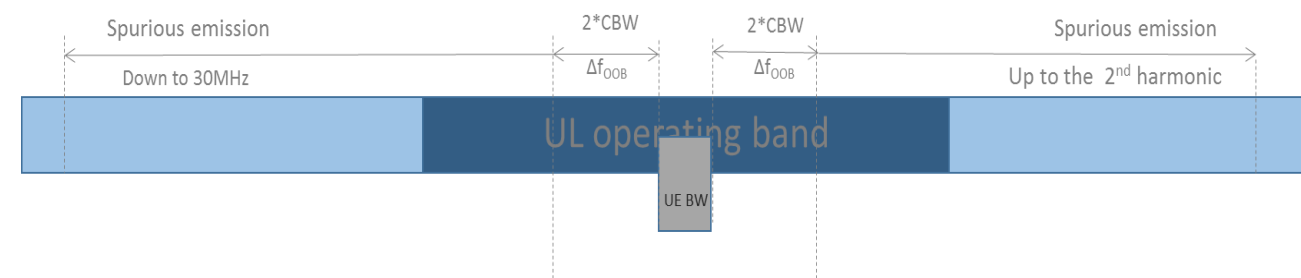
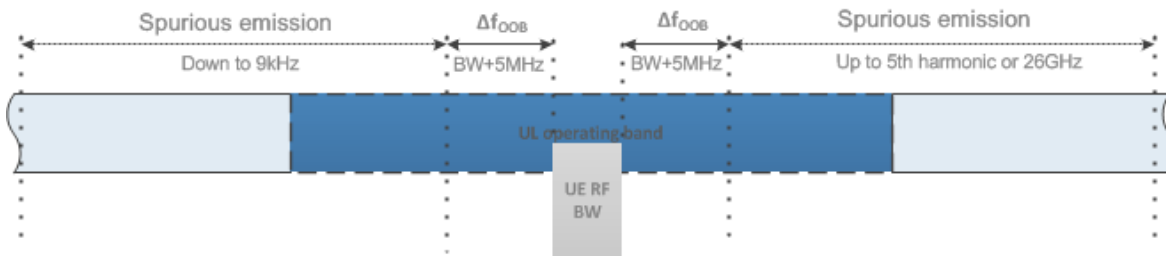
	BS 1-C	BS 1-H		BS 1-O
	The rated carrier output power per antenna connector	The sum of rated carrier output power for all TAB connectors for a single carrier	The rated carrier output power per TAB connector	Rated carrier TRP output power declared per RIB
Wide Area BS	No upper limit for Wide Area Base Station			
Medium Range BS	≤ 38 dBm	≤ 38 dBm + $10\log(N_{\text{TXU, counted}})$	≤ 38 dBm	$\leq + 47$ dBm
Local Area BS	≤ 24 dBm	≤ 24 dBm + $10\log(N_{\text{TXU, counted}})$	≤ 24 dBm	$\leq + 33$ dBm

Unwanted emission | UE output RF spectrum emission



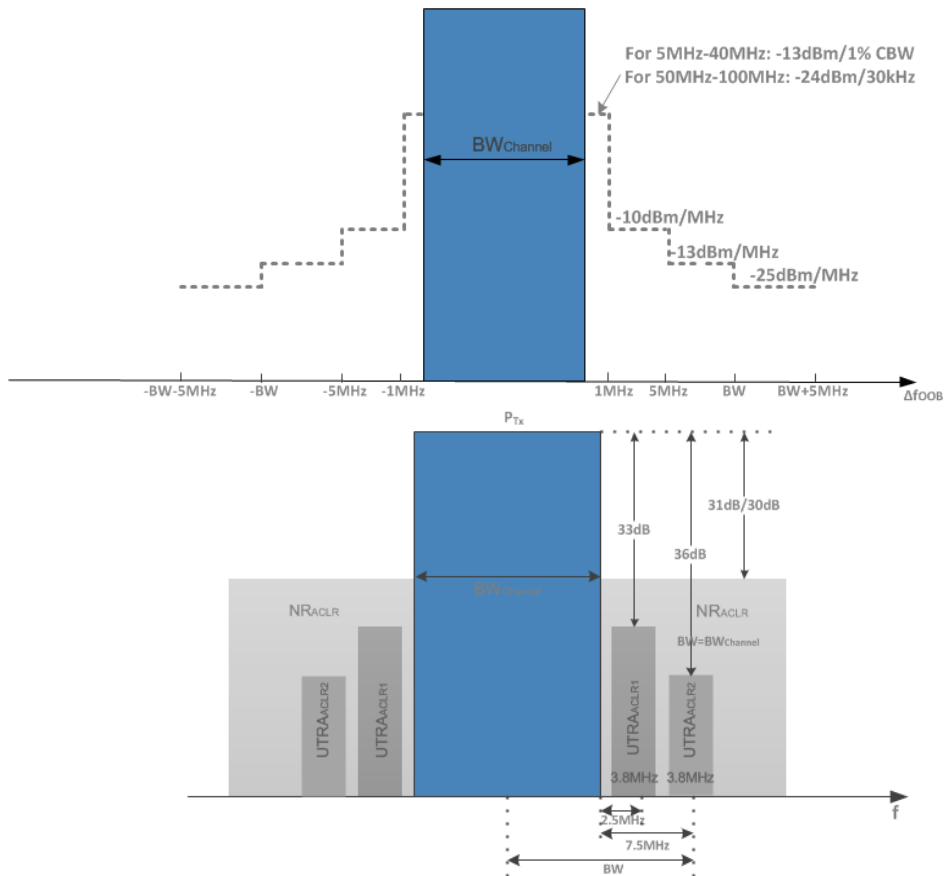
UE output RF spectrum emission consists of

- 📶 **Out-of-band (OOB) emission**: unwanted emissions immediately outside the assigned channel bandwidth resulting from the modulation process and non-linearity in the transmitter. OOB emission is specified in terms of
 - 📶 **Spectrum Emission Mask (SEM)**
 - Starting from each edge of the assigned NR channel bandwidth to $\pm(BW_{\text{channel}} + 5\text{MHz})$ for FR1
 - Starting from each edge of the assigned NR channel bandwidth to $\pm 2 * BW_{\text{channel}}$ for FR2
 - 📶 **Adjacent Channel Leakage Ratio (ACLR)**
 - NR ACLR and UTRA ACLR for FR1
 - NR ACLR for FR2
- 📶 **Spurious emission**: caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products
 - 📶 Frequency range up to 5th harmonic or 26GHz for FR1
 - 📶 Frequency range up to 2nd harmonic range of UL operating band for FR2



Unwanted emission | UE OOB emission

FR1 OOB Emission



FR2 OOB Emission

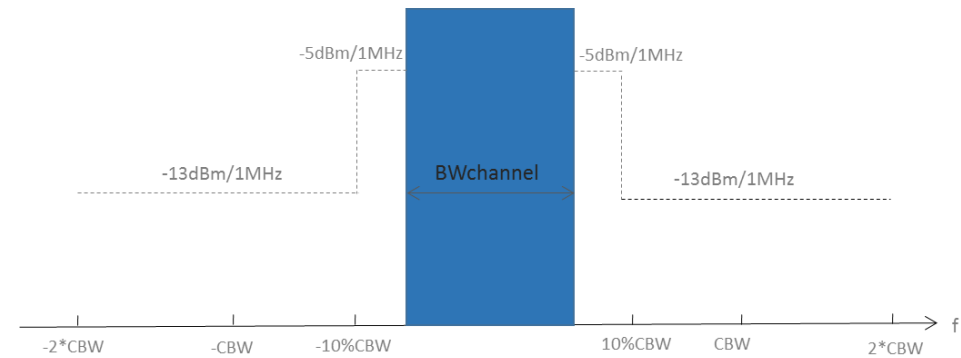


Figure 1: General NR spectrum emission mask

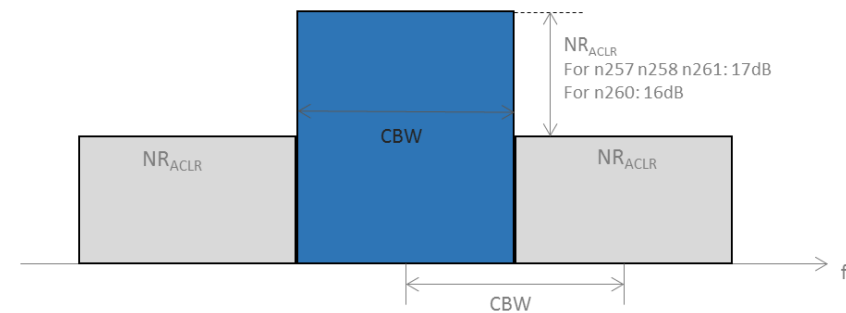


Figure 1: NR_{ACLR} requirement

Unwanted emission | BS unwanted emissions



Basic limit and scaling

- Basic limit is applied for each antenna connector as emission requirements for BS 1-C
- Emission requirements are scaled by $10\log_{10}(N_{\text{TXU, counted per cell}})$ for 1-H and 9dB for 1-O except co-location requirements
- No scaling is applied for FR2



BS unwanted emission consists of

Out-of-band (OOB) emission:

Operating band unwanted emissions (OBUE)

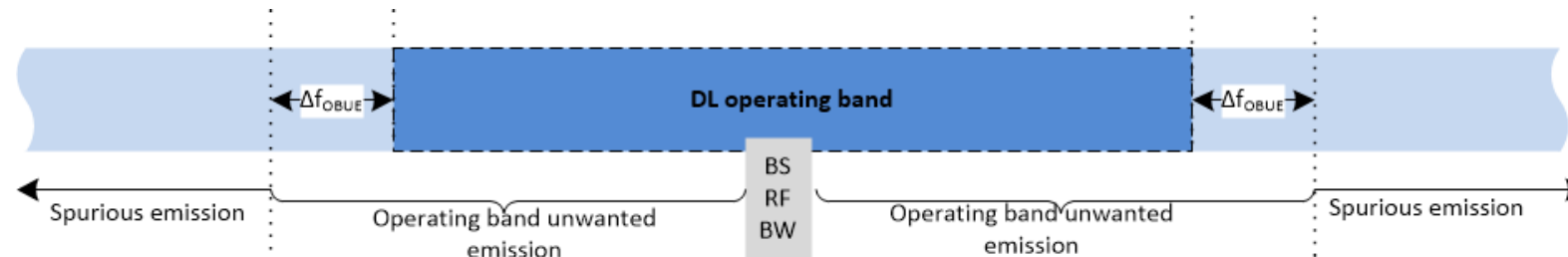
- OBUE is specified as band centric manner with offset Δf_{OBUE}
- Both Category A and Category B limits are specified for FR1

Adjacent Channel Leakage Ratio (ACLR)

- NR ACLR1/ACLR2 are specified for FR1. LTE ACLR1/ACLR2 are specified for FR1 band also operating as E-UTRA or UTRA
- Only NR ACLR1 is specified for FR2
- Absolute ACLR limit or relative ACLR is applied, which is less stringent.

Spurious emission

- From 9 kHz to 12.75GHz (up to 5th harmonic limit of the downlink operating band for certain bands) for FR1 (excluding OBUE region)
- From 30MHz to 2nd harmonic of the upper frequency edge of the DL operating band for FR2 (excluding OBUE region)
- Both Category A and Category B limits are specified for NR BS spurious emission for FR1



- For FR1, REFSENS power level is defined as

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

Where RAN4 assume

- SNR = -1dB, IM (Implementation Margin) = 2.5dB, Diversity Gain = 3dB for 2Rx
- Noise Figure: 9dB for LTE refarming band; 10dB for n77 (3.3GHz – 3.8GHz), n78, n79; 10.5dB for n77 (3.8GHz- 4.2GHz)

- For FR1, both 2Rx REFSENS (for all bands) and 4Rx REFSENS (for n7, n38, n41, n77, n78, n79) are defined.
- For FR2, REFSENS power level is the EIS level in the RX beam peak direction.
- For CA and EN-DC, additional relaxation are defined for below cases.
 - Band combination specific Δ RIB for FR1 inter-band CA
 - Aggregated Channel BW specific Δ RIB for FR2 intra-band continuous CA, i.e., 0.5dB for aggregated CHBW >800MHz
 - Band combination specific MSD for the band impacted by harmonic interference and intermodulation interference for CA and EN-DC.

For BS 1-C and BS 1-H, REFSENS power level is defined as

$$Sensitivity = -174dBm(kT) + 10*\log(R_x BW) + NF + SNR + IM$$

Where RAN4 assume

- SNR = BW specific value, IM (Implementation Margin) = 2dB
- Noise Figure: 5 dB for Wide Area BS, 10 dB for Medium Range BS and 13 dB for Local Area BS

For BS type 1-O, OTA Reference sensitivity level is a directional requirement specified as an EIS level over declared OTA REFSENS RoAoA.

For BS type 2-O, a range of OTA reference sensitivity is defined for vendor to declare specific value for each BS class.

- The declared reference sensitivity value is per polarization
- 2dB antenna gain difference between 28GHz and 39GHz assumed to maintain the UL same coverage

BS channel bandwidth [MHz]	Subcarrier spacing [kHz]	FRC for REFSENS as example
5, 10, 15	15	G-FR1-A1-1
10, 15	30	G- FR1-A1-2
10, 15	60	G- FR1-A1-3
20, 25, 30, 40, 50	15	G- FR1-A1-4
20, 25, 30, 40, 50, 60, 70, 80, 90, 100	30	G- FR1-A1-5
20, 25, 30, 40, 50, 60, 70, 80, 90, 100	60	G- FR1-A1-6

BS class	G	
	30 GHz (24.25 – 33.4 GHz)	45GHz (37 – 52.6 GHz)
WA	10 to 33 dBi	12 to 35 dBi
MR	5 to 28 dBi	7 to 30 dBi
LA	0 to 23 dBi	2 to 25 dBi

Frequency range	30 GHz (24.25 – 33.4 GHz)	45GHz (37 – 52.6 GHz)
BS	10 dB	12 dB

- For FR1, different ACS minimum requirement are specified for bands below 2.7GHz and bands above 3.3GHz
 - 📶 For bands below 2.7GHz, ACS is scaled for channel BW larger than 10MHz to keep the same 33dB ACS as LTE
 - 📶 For bands above 3.3GHz, 33dB ACS is specified for all channel bandwidth
- For FR2, the ACS requirement is verified with the test metric of EIS.
 - 📶 28GHz band: 23dB ACS
 - 📶 39GHz band: 22 dB ACS
- It is not possible to directly measure ACS, instead the lower and upper range of test parameters are chosen to verify ACS



- For BS 1-C and BS 1-H, same conductive ACS requirements as LTE is specified for all NR BS classes
- For BS 1-O, ACS is applied when AoA of wanted signal and interference signal are within the minSENS RoAoA.
- For BS 2-O ACS is applied when AoA of wanted signal and interference signal are within FR2 OTA REFSENS RoAoA. Requirements are derived based on co-existence study
 - 📶 24dBc for 24.24 – 33.4 GHz frequency range.
 - 📶 23dBc for 37 – 52.6 GHz frequency range.

For more Information:



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