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TECHNICAL SPECIFICATION

LTE;
Evolved Universal Terrestrial Radio Access (E-UTRA);
User Equipment (UE) radio transmission and reception for satellite access
(3GPP TS 36.102 version 19.3.0 Release 19)

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Contents

Foreword

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

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In the present document, modal verbs have the following meanings:

shall indicates a mandatory requirement to do something

shall not indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

should indicates a recommendation to do something

should not indicates a recommendation not to do something

may indicates permission to do something

need not indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

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will indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

will not indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

might indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

might not indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

is (or any other verb in the indicative mood) indicates a statement of fact

is not (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

1 Scope

The present document establishes the minimum RF characteristics and minimum performance requirements for E-UTRA User Equipment (UE) operating satellite access.

2 References

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

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

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

[2] 3GPP TS 36.108: "Evolved Universal Terrestrial Radio Access (E-UTRA); Satellite Access Node (SAN) radio transmission and reception".

[3] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation".

[4] ITU-R Recommendation M.1545: "Measurement uncertainty as it applies to test limits for the terrestrial component of International Mobile Telecommunications-2000".

[5] 3GPP TS 36.307: "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements on User Equipments (UEs) supporting a release-independent frequency band".

[6] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification".

[7] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception"

[8] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2".

[9] ITU-R Recommendation SM.329, "Unwanted emissions in the spurious domain"

[10] [ANSI C63.26-2015, American National standard for Compliance Testing of Transmitters Used in Licensed Radio Services, Accredited Standards Committee C63 – Electromagnetic compatibility]

[11] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".

[12] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".

[13] 3GPP TR 38.811: "Study on New Radio (NR) to support non-terrestrial networks"

[14] 3GPP TS 36.508: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); Common test environments for User Equipment (UE) conformance testing".

[15] 3GPP TS 36.212: " Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".

[16] 3GPP TS 38.101-5: "NR; User Equipment (UE) radio transmission and reception; Part 5: Satellite access Radio Frequency (RF) and performance requirements”

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in 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 TR 21.905 [1].

5G Broadcast over Geosynchronous Satellite: LTE-based 5G Broadcast utilizing a geosynchronous satellite.

Channel edge: The lowest and highest frequency of the carrier, separated by the channel bandwidth.

Channel bandwidth: The RF bandwidth supporting a single E-UTRA 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.

Category NB1/NB2 stand-alone operation: category NB1/NB2 is operating standalone when it utilizes its own spectrum, for example the spectrum used by GERAN systems as a replacement of one or more GSM carriers, as well as scattered spectrum for potential IoT deployment.

Category NB1/NB2 guard band operation: category NB1/NB2 is operating in guard band when it utilizes the unused resource block(s) within a E-UTRA carrier's guard-band.

Category NB1/NB2 in-band operation: category NB1/NB2 is operating in-band when it utilizes the resource block(s) within a normal E-UTRA carrier or within a normal NR carrier plus 15 kHz at each edge (and not within NR minimum guard band).

Geosynchronous Earth Orbit: Earth-centred orbit at approximately 35786 kilometres above Earth's surface and synchronised with Earth's rotation. A geostationary orbit is a non-inclined geosynchronous orbit, i.e. in the Earth's equator plane.

Low Earth Orbit: Orbit around the Earth with an altitude between 300 km, and 1500 km.

Satellite: A space-borne vehicle embarking a bent pipe payload or a regenerative payload telecommunication transmitter, placed into Low-Earth Orbit (LEO), Medium-Earth Orbit (MEO), or Geosynchronous Earth Orbit (GEO).

Satellite Access Node: see definition in TS 36.108 [2].

sTTI: A transmission time interval (TTI) of either one slot or one subslot as defined in TS 36.211 [3] on either uplink or downlink.

3.2 Symbols

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

ΔF_{Raster}	Band dependent channel raster granularity
$BW_{Channel}$	Channel bandwidth
F	Frequency
$F_{Interferer}$ (offset)	Frequency offset of the interferer (between the center frequency of the interferer and the carrier frequency of the carrier measured)
$F_{Interferer}$	Frequency of the interferer
$F_{Ioffset}$	Frequency offset of the interferer (between the center frequency of the interferer and the closest edge of the carrier measured)
F_C	Frequency of the carrier centre frequency
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
F_{OOB}	The boundary between the E-UTRA out of band emission and spurious emission domains.

L_{Ctone}	Transmission bandwidth which represents the length of a contiguous sub-carrier allocation expressed in units of tones
N_{DL}	Downlink EARFCN
$N_{Offs\text{-}DL}$	Offset used for calculating downlink EARFCN
$N_{Offs\text{-}UL}$	Offset used for calculating uplink EARFCN
N_{RB}	Transmission bandwidth configuration, expressed in units of resource blocks
N_{RB_alloc}	Total number of simultaneously transmitted resource blocks in Channel bandwidth or Aggregated Channel Bandwidth.
N_{tone}	Transmission bandwidth configuration for category NB1 and NB2, expressed in units of tones.
$N_{tone\ 3.75kHz}$	Transmission bandwidth configuration for category NB1 and NB2 with 3.75 kHz sub-carrier spacing, expressed in units of tones.
$N_{tone\ 15kHz}$	Transmission bandwidth configuration for category NB1 and NB2 with 15 kHz sub-carrier spacing, expressed in units of tones.
N_{UL}	Uplink EARFCN.
P_{CMAX}	The configured maximum UE output power.
$P_{Interferer}$	Modulated mean power of the interferer
$P_{PowerClass}$	$P_{PowerClass}$ is the nominal UE power (i.e., no tolerance).
$P_{PowerClass\_Default}$	$P_{PowerClass\_Default}$ is the default nominal UE power (i.e., no tolerance) for the band.
P_{UMAX}	The measured configured maximum UE output power.
Puw	Power of an unwanted DL signal
Pw	Power of a wanted DL signal
Δf_{OOB}	Δ Frequency of Out Of Band emission

3.3 Abbreviations

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

ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
A-MPR	Additional Maximum Power Reduction
AWGN	Additive White Gaussian Noise
BOG	LTE-based 5G Broadcast over Geosynchronous Satellite
BW	Bandwidth
CW	Continuous Wave
DL	Downlink
EARFCN	E-UTRA Absolute Radio Frequency Channel Number
E-UTRA	Evolved UMTS Terrestrial Radio Access
EUTRAN	Evolved UMTS Terrestrial Radio Access Network
EVM	Error Vector Magnitude
FDD	Frequency Division Duplex
GEO	Geostationary Earth Orbit
GSO	Geosynchronous Orbit
ITU-R	Radiocommunication Sector of the International Telecommunication Union
LEO	Low Earth Orbit
HD-FDD	Half- Duplex FDD
MEO	Medium Earth Orbit
MPR	Maximum Power Reduction
NGSO	Non-Geosynchronous Orbit
OCNG	OFDMA Channel Noise Generator
OFDMA	Orthogonal Frequency Division Multiple Access
OOB	Out-of-band
QAM	Quadrature Amplitude Modulation
RAN	Radio Access Network
RE	Resource Element
REFSENS	Reference Sensitivity power level
RF	Radio Frequency
SDO	Standalone Downlink Only
UE	User Equipment
UL	Uplink

UMTS	Universal Mobile Telecommunications System
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network

4 General

4.1 Relationship between minimum requirements and test requirements

The present document is a Single-RAT specification for satellite NR UE, covering RF characteristics and minimum performance requirements.

The Minimum Requirements given in this specification make no allowance for measurement uncertainty.

The measurement results returned by the test system are compared - without any modification - against the test requirements as defined by the shared risk principle.

The shared risk principle is defined in Recommendation ITU-R M.1545 [4].

4.2 Applicability of minimum requirements

a) Minimum requirements are mandated to be met in all scenarios by UEs supporting the applicable UE category(ies) for which that requirement is specified. In the present document, only minimum requirements for UE categories of M1, NB1, and NB2 and UE BOG are specified.

b) For UE category M1, the applicable minimum requirements in clauses 5, 6 or 7 are specified in the suffix A subclause where they differ from the requirements in the main subclause. Where suffix A does not exist for a requirement, the minimum requirement in the main subclause shall apply.

c) For UE category NB1 and NB2, the applicable minimum requirements in clauses 5, 6 or 7 are specified in the Suffix B subclause, where they differ from the requirements in the main subclause. Where suffix B does not exist for a requirement, the minimum requirement in the main subclause shall apply.

d) For UE BOG, the applicable minimum requirements in clauses 5 or 7 are specified in the Suffix C subclause, where they differ from the requirements in the main subclause. Where suffix C does not exist for a requirement, the minimum requirement in the main subclause shall apply.

e) NOTE: Receiver sensitivity degradation may occur when:

    1) The UE simultaneously transmits and receives with bandwidth allocations less than the transmission bandwidth configuration (see Figure 5.3A-1 and Figure 5.3B-1), and

    2) Any part of the downlink transmission bandwidth is within an uplink transmission bandwidth from the downlink center subcarrier.

f) The spurious emissions power requirements are for the long-term average of the power. For the purpose of reducing measurement uncertainty it is acceptable to average the measured power over a period of time sufficient to reduce the uncertainty due to the statistical nature of the signal.

g) The requirements related to subslot TTI and/or slot TTI shall apply only if UE supports multiple TTI patterns. And these requirements only apply to subslot and/or slot TTI configurations

h) TS36.307 [5] specifies which minimum requirements in the present document are applicable to UEs that conform to an earlier specification Release, and from which Release those requirements apply.

4.3 Specification Suffix Information

The following suffixes are defined at 2nd level for clauses 5, 6 and 7, as shown in Table 4.3-1.

Table 4.3-1: Definition of suffixes

Clause suffix	Variant
A	Cat-M1
B	NB1, NB2
C	BOG

The suffixes shall apply as defined in clause 4.2.

5 Operating bands and channel arrangement

5.1 General

The channel arrangements presented in this clause are based on the operating bands and channel bandwidths defined in the present release of specifications.

NOTE: Other operating bands and channel bandwidths may be considered in future releases.

5.2 Operating bands

E-UTRA satellite access is designed to operate in the operating bands defined in Table 5.2-1.

Table 5.2-1 E-UTRA operating bands for satellite access

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit			Downlink (DL) operating band BS transmit UE receive			Duplex Mode
	F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}	
256	1980 MHz	–	2010 MHz	2170 MHz	–	2200 MHz	FDD
255	1626.5 MHz	–	1660.5 MHz	1525 MHz	–	1559 MHz	FDD
254	1610 MHz	–	1626.5 MHz	2483.5 MHz	–	2500 MHz	FDD
253[2]	1668 MHz	–	1675 MHz	1518 MHz	–	1525 MHz	FDD
252	2000 MHz	–	2020 MHz	2180 MHz	–	2200 MHz	FDD
249[4]	1616 MHz	–	1626.5 MHz	1616 MHz	–	1626.5 MHz	TDD
246[3]	N/A			1467 MHz	–	1492 MHz	SDO

NOTE 1: Satellite bands are numbered in descending order from 256
NOTE 2: UE assigned to channels and allocated frequency resources in the lower portion of Band 253 may experience blocking or harmful interference from terrestrial networks in adjacent or nearby frequencies when operating in the proximity with terrestrial base stations.
NOTE3: Band 246 only applies for LTE-based 5G Broadcast over Geosynchronous Satellite in region 3.
NOTE 4: Band 249 is defined only for NB-IoT operation.

5.2A Operating bands for UE category M1

UE category M1 is designed to operate in the E-UTRA satellite access operating bands defined in Table 5.2-1 in both half duplex FDD mode and full-duplex FDD mode.

5.2B Operating bands for category NB1 and NB2

Category NB1 and NB2 UE are designed to operate in the E-UTRA satellite access operating bands defined in Table 5.2-1.

Category NB1 and NB2 UE operate in HD-FDD duplex mode.

Category NB1 and NB2 UE operate in TDD duplex mode for 249 band.

For operation in Band 255, only channels positions which guarantee at least 190 kHz guard band from RF channel edge to the lower limit of the band shall be used.

For operation in Band 255 when NS_02N is signalled, only channels positions which guarantee at least 90 kHz guard band from RF channel edge to the lower and upper limit of the band shall be used.

For operation in Band 254 when NS_03N is signalled, only channels positions which guarantee at least 90 kHz guard band from RF channel edge to the lower and upper limit of the band shall be used.

For operation in Band 252 when NS_06N, NS_07N or NS_08N is signalled, only channels positions which guarantee at least 90 kHz guard band from RF channel edge to the lower and upper limit of the band shall be used.

5.2C Operating bands for BOG

UE BOG is designed to operate in the E-UTRA satellite access operating bands defined in Table 5.2-1 in SDO mode.

5.3 Channel bandwidth

This clause is reserved.

5.3A Channel bandwidth for category M1

The requirements in present document are specified for the channel bandwidth listed in Table 5.3A-1.

Table 5.3A-1: Transmission bandwidth configuration N_{RB} in E-UTRA channel bandwidths

Channel bandwidth $BW_{Channel}$ [MHz]	**1.4**
Transmission bandwidth configuration N_{RB}	6

Figure 5.3A-1 shows the relation between the Channel bandwidth ($BW_{Channel}$) and the Transmission bandwidth configuration (N_{RB}). The channel edges are defined as the lowest and highest frequencies of the carrier separated by the channel bandwidth, i.e. at F_C +/- $BW_{Channel}$ /2.

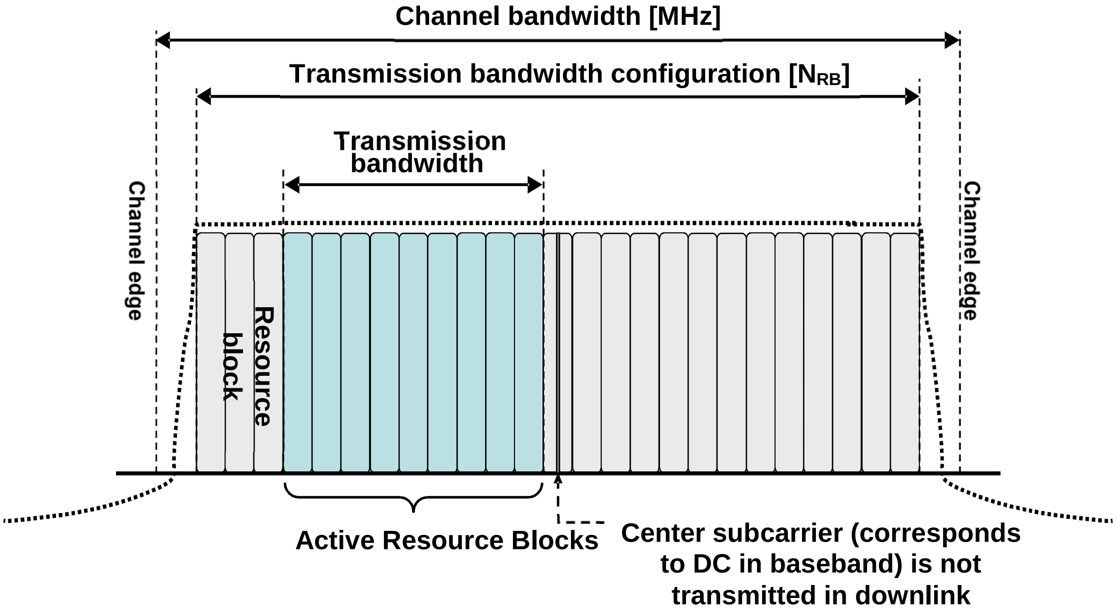

Figure 5.3A-1: Definition of channel bandwidth and transmission bandwidth configuration for one E-UTRA carrier

5.3B Channel bandwidth for category NB1 and NB2

For category NB1 and NB2, requirements in present document are specified for the channel bandwidth listed in Table 5.3B-1.

Table 5.3B-1: Transmission bandwidth configuration N_{RB}, $N_{tone\ 15kHz}$ and $N_{tone\ 3.75kHz}$ in NB1 and NB2 channel bandwidth

Channel bandwidth $BW_{Channel}$ [kHz]	200
Transmission bandwidth configuration N_{RB}	1
Transmission bandwidth configuration $N_{tone\ 15kHz}$	12
Transmission bandwidth configuration $N_{tone\ 3.75kHz}$	48

Figure 5.3B-1 shows the relation between the Category NB1/NB2 channel bandwidth ($BW_{Channel}$) and the Category NB1 /NB2 transmission bandwidth configuration (N_{tone}). The channel edges are defined as the lowest and highest frequencies of the carrier separated by the channel bandwidth, i.e. at F_C +/- $BW_{Channel}$ /2.

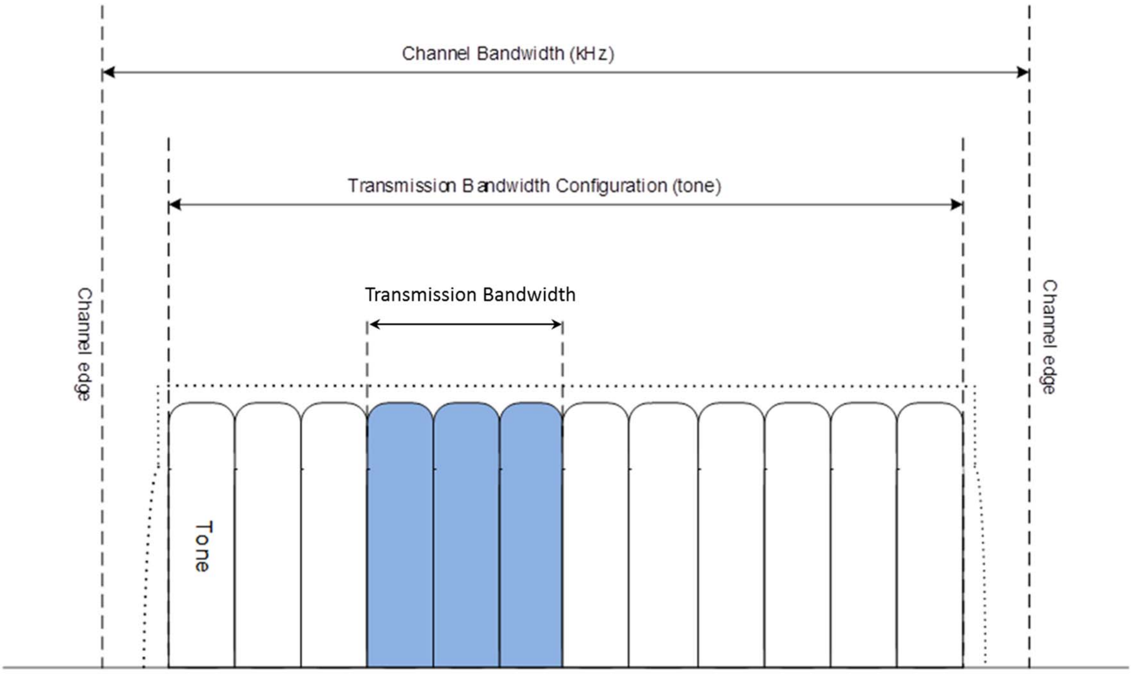

Figure 5.3B-1 Definition of Channel Bandwidth and Transmission Bandwidth configuration

5.3C Channel bandwidth for BOG

The requirements in present document are specified for the channel bandwidth listed in Table 5.3C-1.

Table 5.3C-1: Transmission bandwidth configuration N_{RB} in BOG channel bandwidth

PMCH bandwidth [MHz]	10
Transmission bandwidth configuration N_{RB}^{PMCH}	50
Note: SCS is 15kHz	

Table 5.3C-2: PMCH bandwidths for BOG in operating band

Operating Band	PMCH bandwidth
	10MHz
246	Yes

5.4 Channel arrangement

This clause is reserved.

5.4A Channel arrangement for category M1

5.4A.1 Channel spacing

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 E-UTRA carriers is defined as following:

$$\text{Nominal Channel spacing} = (BW_{Channel(1)} + BW_{Channel(2)})/2$$

where $BW_{Channel(1)}$ and $BW_{Channel(2)}$ are the channel bandwidths of the two respective E-UTRA carriers. The channel spacing can be adjusted to optimize performance in a particular deployment scenario.

5.4A.2 Channel raster, carrier frequency and EARFCN

The global frequency raster is defined for all frequencies. The granularity of the global frequency raster is 100 kHz, which means that the carrier centre frequency must be an integer multiple of 100 kHz. For each operating band, a subset of frequencies from the global frequency raster are applicable and forms a channel raster with a granularity ΔF_{Raster}.

The carrier frequency in the uplink and downlink is designated by the E-UTRA Absolute Radio Frequency Channel Number (EARFCN) in the range 0 – 262143. The relation between EARFCN and the carrier frequency in MHz for the downlink is given by the following equation, where F_{DL_low} and $N_{Offs\text{-}DL}$ are given in Table 5.4A.2-1 and N_{DL} is the downlink EARFCN.

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

The relation between EARFCN and the carrier frequency in MHz for the uplink is given by the following equation where F_{UL_low} and $N_{Offs\text{-}UL}$ are given in Table 5.4.2-1 and N_{UL} is the uplink EARFCN.

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

The applicable channel raster and EARFCNs for each operating band are specified in Table 5.4A.2-1.

For operating bands with a channel raster of 100 kHz, every EARFCN within the operating band shall be applicable for the channel raster, and the step size for the channel raster in Table 5.4A.2-1 is given as <1>. The broadcast parameter *earfcn-LSB* defined in TS36.331 [6] may be used to assist the UE in synchronizing to the cell.

Table 5.4A.2-1: E-UTRA channel numbers

E-UTRA Operating Band	ΔF_{Raster} (kHz)	Downlink			Uplink		
		F_{DL_low} (MHz)	$N_{Offs\text{-}DL}$	Range of N_{DL} (First – <Step size> – Last)	F_{UL_low} (MHz)	$N_{Offs\text{-}UL}$	Range of N_{UL} (First – <Step size> – Last)
256	100	2170	229076	229076 –<1>- 229375	1980	261844	261844 –<1>- 262143
255	100	1525	228736	228736 –<1>- 229075	1626.5	261504	261504 –<1>- 261843
254	100	2483.5	228571	228571 –<1>- 228735	1610	261339	261339 –<1>- 261503
253	100	1518	228501	228501-<1>- 228570	1668	261269	261269-<1>- 261338
252	100	2180	228301	228301 –<1>- 228500	2000	261069	261069 –<1>- 261268
249	100	1616	196607	196607-<1>- 196711	1616	196607	196607-<1>- 196711
NOTE 1: The channel numbers that designate carrier frequencies so close to the operating band edges that the carrier extends beyond the operating band edge shall not be used. This implies that the first 7 channel numbers at the lower operating band edge and the last 6 channel numbers at the upper operating band edge shall not be used for channel bandwidth of 1.4 MHz.							

5.4A.3 TX–RX frequency separation

a) The default E-UTRA TX channel (carrier centre frequency) to RX channel (carrier centre frequency) separation is specified in Table 5.4A.3-1 for the TX and RX channel bandwidth defined in Table 5.3A-1.

Table 5.4A.3-1: Default UE TX-RX frequency separation

E-UTRA Operating Band	TX – RX carrier centre frequency separation
256	190 MHz[1] 161.4 to 218.6 MHz[2]
255	-101.5 MHz[1] -68.9 to -134.1 MHz[2]
254	873.5 MHz[1] 858.4 to 888.6 MHz[2]
253	-150 MHz[1] -144.4 to -155.6 MHz[2]
252	180 MHz[1] 161.4 to 198.6 MHz[2]
NOTE 1: Default TX-RX separation. NOTE 2: The verification of flexible TX-RX frequency separation within this range is limited to reference sensitivity. Further details are specified in clause 7.3A.	

5.4B Channel arrangement for category NB1 and NB2

5.4B.1 Channel spacing

Nominal channel spacing for UE category NB1 and NB2 in stand-alone mode is 200 kHz. For in-band operation, the nominal channel spacing between two adjacent category NB1 or NB2 carriers is 180 kHz.

5.4B.2 Channel raster, carrier frequency and EARFCN

5.4B.2.1 General

The channel raster of UE category NB1/NB2 shall be as defined in clause 5.4A.2, and the channel raster per-frequency band shall be as defined in table 5.4A.2-1.

The carrier frequency of UE category NB1/NB2 in the downlink is designated by the E-UTRA Absolute Radio Frequency Channel Number (EARFCN) as defined in Table 5.4A.2-1, and the Offset of category NB1/NB2 Channel Number to EARFCN in the range of {-10, -9, -8, -7, -6, -5, -4, -3, -2, -1, -0.5, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9} for FDD and TDD band 249.

The carrier frequency of UE category NB1/NB2 in the uplink is designated by the E-UTRA Absolute Radio Frequency Channel Number (EARFCN) as defined in Table 5.4A.2-1, and the Offset of category NB1/NB2 Channel Number to EARFCN in the range of {-10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9} for FDD and TDD band 249.

5.4B.2.2 Stand-alone operation

The relation between EARFCN, Offset of category NB1/NB2 Channel Number to EARFCN and the carrier frequency in MHz for the downlink is given by the following equation, where F_{DL} is the downlink carrier frequency of category NB1/NB2, F_{DL_low} and $N_{Offs\text{-}DL}$ are given in table 5.4A.2-1, N_{DL} is the downlink EARFCN, M_{DL} is the Offset of category NB1/NB2 Channel Number to downlink EARFCN.

$$F_{DL} = F_{DL\_low} + 0.1(N_{DL} – N_{Offs\text{-}DL}) + 0.0025*(2M_{DL})$$

The relation between EARFCN, Offset of category NB1/NB2 Channel Number to EARFCN and the carrier frequency in MHz for the uplink is given by the following equation, where F_{UL} is the uplink carrier frequency of category NB1/NB2, F_{UL_low} and $N_{Offs\text{-}UL}$ are given in table 5.4A.2-1, N_{UL} is the uplink EARFCN, M_{UL} is the Offset of category NB1/NB2 Channel Number to uplink EARFCN.

$$F_{UL} = F_{UL\_low} + 0.1(N_{UL} – N_{Offs\text{-}UL}) + 0.0025*(2M_{UL})$$

For the carrier including NPSS/NSSS for stand-alone operation, the $M_{DL} = 0$ is used.

In Rel-18, UE is only required to support the same operation mode for anchor and non-anchor carriers.

5.4B.2.3 In-band operation

In the current release, NTN NB-IoT UEs shall support in-band operation with NR NTN.

The relation between EARFCN, Offset of category NB1/NB2 Channel Number to EARFCN and the carrier frequency in MHz for the downlink is given by the following equation, where F_{DL} is the downlink carrier frequency of category NB1/NB2, F_{DL_low} and $N_{Offs\text{-}DL}$ are given in table 5.4A.2-1, N_{DL} is the downlink EARFCN, M_{DL} is the Offset of category NB1/NB2 Channel Number to downlink EARFCN.

$$F_{DL} = F_{DL\_low} + 0.1(N_{DL} - N_{Offs\text{-}DL}) + 0.0025*(2M_{DL}+1)$$

The relation between EARFCN, Offset of category NB1/NB2 Channel Number to EARFCN and the carrier frequency in MHz for the uplink is given by the following equation, where F_{UL} is the uplink carrier frequency of category NB1/NB2, F_{UL_low} and $N_{Offs\text{-}UL}$ are given in table 5.4A.2-1, N_{UL} is the uplink EARFCN, M_{UL} is the Offset of category NB1/NB2 Channel Number to uplink EARFCN.

$$F_{UL} = F_{UL\_low} + 0.1(N_{UL} - N_{Offs\text{-}UL}) + 0.0025*(2M_{UL})$$

For the carrier including NPSS/NSSS, M_{DL} is selected from {-2,-1,0,1}. For in-band operations, M_{DL} = -0.5 is not applicable.

In the current release, UE is only required to support the same operation mode for anchor and non-anchor carriers.

NOTE 1: For in-band operation, RRC signalling should indicate guardband-r13 in operationModeInfo IE in MasterInformationBlock-NB during UE conformance tests.

NOTE 2: In the current release, for in-band operation, UE is not expected to access a cell indicating inband-SamePCI or inband-DifferentPCI in operationMode IE in MasterInformationBlock-NB.

NOTE 3: UE is not expected to be aware of where the configured NB-IoT UL carrier is within the NTN NR carrier. It is presumed that operators will ensure, through network configuration during deployment, that there is sufficient guardband between NB-IoT carrier and operating band and/or spectrum block edges to meet emission requirements of clause 6.5B outside its allocated spectrum block.

5.4B.3 TX–RX frequency separation

For UE category NB1/NB2 operation in stand-alone mode, the default TX-RX frequency separation shall be as specified in Table 5.4B.3-1 for the NB-IoT TX and RX channel bandwidth defined in Table 5.3B-1.

For in-band operation, the category NB1 and NB2 TX-RX frequency separation is flexible within the assigned channel bandwidth of NR NTN carrier with the TX-RX frequency separation of the NR NTN carriers as specified in TS 38.101-5 [16].

Table 5.4B.3-1: Default UE TX-RX frequency separation

E-UTRA Operating Band	TX – RX carrier centre frequency separation
256	190 MHz[1] 160.2 to 219.8 MHz[2]
255	-101.5 MHz[1] -67.7 to -135.3 MHz[2]
254	873.5 MHz[1] 857.2 to 889.8 MHz[2]
253	-150 MHz[1] -143.2 to -156.8 MHz[2]
252	180 MHz[1] 160.2 to -199.8 MHz[2]
NOTE 1: Default Tx-Rx separation. NOTE 2: The verification of flexible TX-RX frequency separation within this range is limited to reference sensitivity. Further details are specified in clause 7.3B.	

5.4C Channel arrangement for BOG

5.4C.1 Channel spacing

Nominal channel spacing between adjacent broadcast channels is defined as follows

Nominal Channel spacing = PMCH bandwidth

where PMCH bandwidth is the broadcast bandwidth indicated by upper layer signalling *dl-Bandwidth-MBMS* in the MBSFN area (see TS 36.331 [7]).

5.4C.2 Channel raster, carrier frequency and EARFCN

The channel raster is 100 kHz for all bands, which means that the carrier centre frequency must be an integer multiple of 100 kHz.

The EARFCN for applicable bands designated for BOG according to Table 5.2-1 are specified in Table 5.4C.2-1.

Table 5.4C.2-1: E-UTRA channel numbers E-UTRA Operating Band	ΔF_{Raster} (kHz)	Downlink			Uplink		
		F_{DL_low} (MHz)	$N_{Offs\text{-}DL}$	Range of N_{DL} (First – <Step size> – Last)	F_{UL_low} (MHz)	$N_{Offs\text{-}UL}$	Range of N_{UL} (First – <Step size> – Last)
246	100	1467	228051	228051 -<1>- 228300	N/A		

6 Transmitter characteristics

6.1 General

Unless otherwise stated, the transmitter characteristics are specified at the antenna connector of the UE with a single or multiple transmit antenna(s). For UE with integral antenna only, a reference antenna with a gain of 0 dBi is assumed.

All requirements in this section are applicable to devices supporting GSO and/or NGSO satellites.

6.2 Transmit power

This clause is reserved.

6.2A Transmit power for category M1

6.2A.1 UE maximum output power for category M1

The following UE Power Classes define the maximum output power for any transmission bandwidth within the channel bandwidth. The period of measurement shall be at least one sub frame (1ms).

Table 6.2A.1-1: UE Power Class

E-UTRA band	Class 2 (dBm)	Tolerance (dB)	Class 3 (dBm)	Tolerance (dB)	Class 5 (dBm)	Tolerance (dB)
256	26	+/-2	23	+/-2	20	+/-2
255	26	+/-2	23	+/-2	20	+/-2
254			23	+/-2	20	+/-2
253			23	+/-2	20	+/-2
252			23	+/-2	20	+/-2
NOTE 1: $P_{PowerClass}$ is the maximum UE power specified without taking into account the tolerance.						

The default power class $P_{PowerClass\_Default}$ for an operating band is Power Class 3 unless otherwise stated.

The UE shall meet the following additional requirements for maximum transmission power density specified in Table 6.2A.1-2 when NS is signalled and when the configured channel overlaps with any portion of the specified frequency range.

Table 6.2A.1-2: Additional requirements for transmit power density

E-UTRA Band	NS value	Channel bandwidth (MHz)	Frequency range (MHz)	Maximum power density	Measurement method
254	NS_04N	1.4	1610 - 1618.25	27dBm/4kHz	Mean spectral limit (note 2)
	NS_05N	1.4	1618.25 - 1626.5		
	NS_11N	1.4	1610 - 1618.25	15dBm/4kHz	Peak spectral limit (note 2)
	NS_12N	1.4	1618.25 - 1626.5		
NOTE 1: The EIRP requirement in regulation is converted to conducted requirement using a 0 dBi antenna. NOTE 2: Indicated limit is applied to any frequency of the 1610-1626.5MHz band.					

6.2A.2 UE maximum output power reduction for category M1

For category M1 UE, the allowed Maximum Power Reduction (MPR) for the maximum output power specified in Table 6.2A.1-1 due to higher order modulation and transmit bandwidth configuration (resource blocks) is specified in Table 6.2A.2-1.

For subPRB allocation of category M1 UE of PC3 and PC2, no MPR applies.

Table 6.2A.2-1: Maximum Power Reduction (MPR) for category M1 UE for Power Class 2, 3 and 5

Modulation	Channel bandwidth / Transmission bandwidth (N_{RB})	MPR (dB)
	1.4 MHz	

QPSK	> 2	≤ 1
QPSK	> 5	≤ 2
16 QAM	≤ 2	≤ 1
16 QAM	>2	≤ 2
NOTE: MPR only applicable for N_{RB} ≥ 1		

For PRACH, PUCCH and SRS transmissions, the allowed MPR is according to that specified for PUSCH QPSK modulation for the corresponding transmission bandwidth.

For each subframe, the MPR is evaluated per slot and given by the maximum value taken over the transmission(s) within the slot; the maximum MPR over the two slots is then applied for the entire subframe.

For the UE maximum output power modified by MPR, the power limits specified in subclause 6.2A.4 apply.

6.2A.3 UE additional maximum output power reduction for category M1 UE

Additional ACLR and spectrum emission requirements can be signalled by the network to indicate that the UE shall also meet additional requirements in a specific deployment scenario. To meet these additional requirements, Additional Maximum Power Reduction (A-MPR) is allowed for the output power as specified in Table 6.2A.1-1. Unless stated otherwise, an A-MPR of 0 dB shall be used.

The specific requirements and identified subclauses are specified in Table 6.2A.3-1 and Table 6.2A.3-1a along with the allowed A-MPR values that may be used to meet these requirements. The allowed A-MPR values specified below in Table 6.2A.3-1 are in addition to the allowed MPR requirements specified in subclause 6.2A.2.

Table 6.2A.3-1: Additional Maximum Power Reduction (A-MPR) for category M1 UE for PC3 and PC5

<table>
<tr><th>Network Signalling value</th><th>Requirements (subclause)</th><th>E-UTRA Band</th><th>Resources Blocks (NRB)</th><th colspan="2">A-MPR (dB)</th></tr>
<tr><td>NS_01</td><td>6.5A.4.2</td><td>Table 5.2-1</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
<tr><td rowspan="2">NS_24N</td><td rowspan="2">6.5A.4.4.3</td><td rowspan="2">256</td><td rowspan="2">Table 5.3A-1</td><td>PC3</td><td>PC5</td></tr>
<tr><td>≤ 3.5</td><td>≤ 0.5</td></tr>
<tr><td>NS_02N</td><td>6.5A.3.3.1, 6.5A.4.4.2</td><td>255</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
<tr><td>NS_03N</td><td>6.5A.3.3.1, 6.5A.4.4.4</td><td>254</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
<tr><td>NS_04N</td><td>6.5A.3.3.2, 6.5A.4.4.5</td><td>254</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
<tr><td>NS_05N</td><td>6.5A.3.3.3, 6.5A.4.4.5</td><td>254</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
<tr><td>NS_06N</td><td>6.5A.4.4.7
6.5A.3.3.1</td><td>252</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
<tr><td>NS_07N</td><td>6.5A.4.4.8
6.5A.3.3.1</td><td>252</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
<tr><td>NS_08N</td><td>6.5A.4.4.9
6.5A.3.3.1</td><td>252</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
<tr><td>NS_11N</td><td>6.5A.3.3.2, 6.5A.4.4.5</td><td>254</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
<tr><td>NS_12N</td><td>6.5A.3.3.3, 6.5A.4.4.5</td><td>254</td><td>Table 5.3A-1</td><td colspan="2">N/A</td></tr>
</table>

Table 6.2A.3-1a: Additional Maximum Power Reduction (A-MPR) for category M1 UE for PC2

Network Signalling value	Requirements (subclause)	E-UTRA Band	Resources Blocks (N_{RB})	A-MPR (dB)
NS_01	6.5A.4.2	Table 5.2-1	Table 5.3A-1	N/A
NS_24N	6.5A.4.4.3	256	Table 5.3A-1	≤ 6.5
NS_02N	6.5A.4.4.2	255	Table 5.3A-1	N/A

For subPRB allocation, the allowed A-MPR values specified below in Table 6.2A.3-2 and Table 6.2A.3-3 for category M1 UE are in addition to the allowed MPR requirements specified in subclause 6.2A.2.

Table 6.2A.3-2: Additional Maximum Power Reduction (A-MPR) for category M1 UE for subPRB allocation for PC3 and PC5

Network Signalling value	Requirements (subclause)	E-UTRA Band	A-MPR (dB)	
NS_01	6.5A.4.2	Table 5.2-1	N/A	
NS_24N	6.5A.4.4.3	256	PC3	PC5
			≤ 3.5	≤ 0.5
NS_02N	6.5A.3.3.1, 6.5A.4.4.2	255	N/A	
NS_03N	6.5A.3.3.1, 6.5A.4.4.4	254	N/A	
NS_04N	6.5A.3.3.2, 6.5A.4.4.5	254	N/A	
NS_05N	6.5A.3.3.3, 6.5A.4.4.5	254	N/A	
NS_06N	6.5A.4.4.7 6.5A.3.3.1	252	N/A	
NS_07N	6.5A.4.4.8 6.5A.3.3.1	252	N/A	
NS_08N	6.5A.4.4.9 6.5A.3.3.1	252	N/A	
NS_11N	6.5A.3.3.2, 6.5A.4.4.5	254	PC3	PC5
			≤ 3	0
NS_12N	6.5A.3.3.3, 6.5A.4.4.5	254	PC3	PC5
			≤ 3	0

Table 6.2A.3-3: Additional Maximum Power Reduction (A-MPR) for category M1 UE for subPRB allocation for PC2

Network Signalling value	Requirements (subclause)	E-UTRA Band	A-MPR (dB)
NS_01	6.5A.4.2	Table 5.2-1	N/A
NS_24N	6.5A.4.4.3	256	≤ 6.5
NS_02N	6.5A.4.4.2	255	N/A

6.2A.4 Configured transmitted Power for category M1

The configured transmitted power requirements in clause 6.2.5 of TS 36.101 [7] shall apply, wherein

- $P_{PowerClass}$ is the maximum UE power specified in Table 6.2A.1-1 without taking into account the tolerance specified in the Table 6.2A.1-1
- The MPR requirements are specified in subclause 6.2A.2
- The A-MPR requirements are specified in subclause 6.2A.3.
- $\Delta T_{C,c}$, $\Delta T_{IB,c}$, ΔT_{RxSRS} , ΔT_{ProSe} are not applicable.

6.2B Transmit power for category NB1 and NB2

6.2B.1 UE maximum output power for category NB1 and NB2

Category NB1 and NB2 UE Power Classes are specified in Table 6.2B.1-1 and define the maximum output power for any transmission bandwidth within the category NB1 and NB2 channel bandwidth. For 3.75 kHz sub-carrier spacing the maximum output power is defined as mean power of measurement which period is at least one slot (2ms) excluding the 2304Ts gap when UE is not transmitting. For 15 kHz sub-carrier spacing the maximum output power is defined as mean power of measurement which period is at least one sub-frame (1ms).

Table 6.2B.1-1: UE Power Class

EUTRA band	Class 1 (dBm)	Tolerance (dB)	Class 2 (dBm)	Tolerance (dB)	Class 3 (dBm)	Tolerance (dB)	Class 5 (dBm)	Tolerance (dB)
256	31	+2/-3	26	+/-2	23	+/-2	20	+/-2
255	31	+2/-3	26	+/-2	23	+/-2	20	+/-2
254					23	+/-2	20	+/-2
253					23	+/-2	20	+/-2
252					23	+/-2	20	+/-2
249					23	+/-2	20	+/-2

The default power class $P_{PowerClass\_Default}$ for an operating band is Power Class 3 unless otherwise stated.

The UE shall meet the following additional requirements for maximum transmission power density specified in Table 6.2B.1-2 when NS is signalled and when the configured channel overlaps with any portion of the specified frequency range.

Table 6.2B.1-2: Additional requirements for transmit power density

E-UTRA Band	NS value	Channel bandwidth (MHz)	Frequency range (MHz)	Maximum power density	Measurement method
254	NS_04N	0.2	1610 - 1618.25	27dBm/4kHz	Mean spectral limit (note 2)
	NS_05N	0.2	1618.25 - 1626.5		
	NS_11N	0.2	1610 - 1618.25	15dBm/4kHz	Peak spectral limit (note 2)
	NS_12N	0.2	1618.25 - 1626.5		
NOTE 1: The EIRP requirement in regulation is converted to conducted requirement using a 0 dBi antenna. NOTE 2: Indicated limit is applied to any frequency of the 1610-1626.5MHz band.					

6.2B.2 UE maximum output power reduction for category NB1 and NB2

For UE category NB1 and NB2, the allowed Maximum Power Reduction (MPR) for the maximum output power are specified in following tables.

Table 6.2B.2-0: Maximum Power Reduction (MPR) for UE category NB1 and NB2 Power Class 3 and 5, Single-Tone

Modulation	π/2 BPSK, π/4 QPSK	π/2 BPSK, π/4 QPSK
SCS	15KHz	3.75kHz
Tone positions for 1 Tone allocation	0-11	0-47
MPR	0 dB	0 dB
Note 1: For single-tone allocation, the listed modulation and SCS are supported.		

Table 6.2B.2-1: Maximum Power Reduction (MPR) for UE category NB1 and NB2 Power Class 3 and 5, Multi-Tone

Modulation	**QPSK**		
SCS	15KHz		
Tone positions for 3 Tones allocation	0-2	3-5 and 6-8	9-11
MPR	≤ 0.5 dB	0 dB	≤ 0.5 dB
Tone positions for 6 Tones allocation	0-5 and 6-11		
MPR	≤ 1 dB	≤ 1 dB	
Tone positions for 12 Tones allocation	0-11		
MPR	≤ 2 dB		
Note 1: For multi-tone allocation, the listed modulation and SCS are supported.			

Table 6.2B.2-2: Maximum Power Reduction (MPR) for UE category NB1 and NB2 Power Class 2, Single-Tone

Modulation	π/2 BPSK, π/4 QPSK			π/2 BPSK, π/4 QPSK		
SCS	15 kHz			3.75 kHz		
Tone positions for 1 Tone allocation	0	1-10	11	0-3	4-43	44-47
MPR	≤ 0.5 dB	0 dB[Note 2]	≤ 0.5 dB	≤ 0.5 dB	0 dB[Note 2]	≤ 0.5 dB
Note 1: For single-tone allocation, the listed modulations and SCS are supported. Note 2: For tone positions 3 to 8 for 15kHz SCS and 8 to 39 for 3.75 kHz, 1dB MPR applies when UE indicates support for UE capability [*powerBoosting-NBIotNTN-r19*] and IE [*powerBoostNBIotNTN-r19*] is set to 1.						

Table 6.2B.2-3: Maximum Power Reduction (MPR) for UE category NB1 and NB2 Power Class 2, Multi-Tone

Modulation	QPSK		
SCS	15 kHz		
Tone positions for 3 Tones allocation	0-2	3-5 and 6-8	9-11
MPR	≤ 0.5 dB	0 dB	≤ 0.5 dB
Tone positions for 6 Tones allocation	0-5 and 6-11		
MPR	≤ 1 dB	≤ 1 dB	
Tone positions for 12 Tones allocation	0-11		
MPR	≤ 2 dB		
Note 1: For multi-tone allocation, the listed modulation and SCS are supported.			

Table 6.2B.2-4: Maximum Power Reduction (MPR) for UE category NB1 and NB2 Power Class 1, Single-Tone

Modulation	π/2 BPSK, π/4 QPSK			π/2 BPSK, π/4 QPSK		
SCS	15 kHz			3.75 kHz		
Tone positions for 1 Tone allocation	0-1	2-9	10-11	0-5	6-41	42-47
MPR	≤ 2 dB	0 dB	≤ 2 dB	≤ 3.5 dB	0 dB	≤ 3.5 dB
Note 1: For single-tone allocation, the listed modulations and SCS are supported.						

Table 6.2B.2-5: Maximum Power Reduction (MPR) for UE category NB1 and NB2 Power Class 1, Multi-Tone

Modulation	QPSK		
SCS	15 kHz		
Tone positions for 3 Tones allocation	0-2	3-5 and 6-8	9-11
MPR	≤ 2 dB	≤ 1 dB	≤ 2 dB
Tone positions for 6 Tones allocation	0-5 and 6-11		
MPR	≤ 2.5dB	≤ 2.5dB	
Tone positions for 12 Tones allocation	0-11		
MPR	≤ 4 dB		
Note 1: For multi-tone allocation, the listed modulation and SCS are supported.			

For the UE maximum output power modified by MPR, the power limits specified in sub-clause 6.2B.4 apply.

6.2B.3 UE additional maximum output power reduction for category NB1 and NB2 UE

6.2B.3.0 General

Additional ACLR and spectrum emission requirements can be signalled by the network to indicate that the UE shall also meet additional requirements in a specific deployment scenario. To meet these additional requirements, Additional Maximum Power Reduction (A-MPR) is allowed for the output power as specified in Table 6.2B.1-1. For the agreed E-UTRA bands for category NB1 and NB2 UE an A-MPR of 0 dB shall be allowed unless specified otherwise.

For UE PC3/PC5 and PC1/PC2, the specific requirements and identified subclauses are specified in Table 6.2B.3.0-1 and 6.2B.3.0-2 along with the allowed A-MPR values that may be used to meet these requirements. The allowed A-MPR values specified below in Table 6.2B.3.0-1 are in addition to the allowed MPR requirements specified in subclause 6.2B.2.

Table 6.2B.3.0-1: Additional Maximum Power Reduction (A-MPR) for category NB1 and NB2 UE

Network Signalling value	Requirements (subclause)	E-UTRA Band	A-MPR (dB)	
NS_01	6.5B.4.2	Table 5.2-1	N/A	
NS_24N	6.5B.4.4.3	256	PC3	PC5
			≤ 3.5	≤ 0.5
NS_02N	6.5B.3.3.1, 6.5B.4.4.2	255	N/A	
NS_03N	6.5B.3.3.2, 6.5B.4.4.4	249, 254	N/A	
NS_04N	6.5B.3.3.3, 6.5B.4.4.5	249, 254	6.2B.3.1	
NS_05N	6.5B.3.3.4, 6.5B.4.4.5	249, 254	6.2B.3.2	
NS_06N	6.5B.4.4.7 6.5B.3.3.1	252	N/A	
NS_07N	6.5B.4.4.8 6.5B.3.3.1	252	N/A	
NS_08N	6.5B.4.4.9 6.5B.3.3.1	252	N/A	
NS_11N	6.5B.3.3.3, 6.5B.4.4.5	249, 254	6.2B.3.3	
NS_12N	6.5B.3.3.4, 6.5B.4.4.5	249, 254	6.2B.3.4	

Table 6.2B.3.0-2: Additional Maximum Power Reduction (A-MPR) for category NB1 and NB2 UE for PC1 and PC2

Network Signalling value	Requirements (subclause)	E-UTRA Band	A-MPR (dB)	
NS_01	6.5B.4.2	Table 5.2-1	N/A	
NS_24N	6.5B.4.4.3	256	PC1	PC2
			≤ 10	≤ 5.5
NS_02N	6.5B.4.4.2	255	N/A	

6.2B.3.1 A-MPR for NS_04N

Table 6.2B.3.1-1: A-MPR for "NS_04N" with 3.75 kHz SCS for Power Class 3

Modulation	QPSK						
Tone positions for 3.75 kHz single tone allocation	0-3	4-6	7-9	10-38	39-41	42-44	45-47
A-MPR (dB)	≤ 10.5	≤ 5.5	≤ 3	≤ 0	≤ 3	≤ 5.5	≤ 10.5

Table 6.2B.3.1-2: A-MPR for "NS_04N" with 15kHz SCS for Power Class 3

Modulation	QPSK											
Tone positions for single tone allocation	0	1	2	3	4	5	6	7	8	9	10	11
A-MPR (dB)	≤12		≤8.5	≤6.5	≤1	≤0.5	≤0.5	≤1	≤6.5	≤8.5	≤12	
Tone positions for 3 Tones allocation	0-2				3-5 and 6-8				9-11			
A-MPR (dB)	≤ 8.5				≤ 2				≤ 8.5			
Tone positions for 6 Tones allocation	0-5 and 6-11											
A-MPR (dB)	≤ 6						≤ 6					
Tone positions for 12 Tones allocation	0-11											
A-MPR (dB)	≤ 2											

6.2B.3.2 A-MPR for NS_05N

Table 6.2B.3.2-1: A-MPR for "NS_05N" with 3.75 kHz SCS for Power Class 3

Modulation	QPSK						
Tone positions for 3.75 kHz single tone allocation	0-3	4-6	7-10	11-37	38-41	42-44	45-47
A-MPR (dB)	≤ 13.5	≤ 8	≤ 5	0	≤ 3	≤ 5.5	≤ 13.5

Table 6.2B.3.2-2: A-MPR for "NS_05N" with 15kHz SCS for Power Class 3

Modulation	QPSK											
Tone positions for single tone allocation	0	1	2	3	4	5	6	7	8	9	10	11
A-MPR (dB)	≤15		≤10.5	≤8	≤2	≤1.5	≤1.5	≤2	≤8	≤10.5	≤15	
Tone positions for 3 Tones allocation	0-2				3-5 and 6-8				9-11			
A-MPR (dB)	≤ 11				≤ 3.5				≤ 11			
Tone positions for 6 Tones allocation	0-5 and 6-11											
A-MPR (dB)	≤ 8.5						≤ 8.5					
Tone positions for 12 Tones allocation	0-11											
A-MPR (dB)	≤ 4.5											

6.2B.3.3 A-MPR for NS_11N

Table 6.2B.3.3-1: A-MPR for "NS_11N" for Power Class 3

SCS and number of tones	3.75kHz	15 kHz 1-tone	15 kHz 3-tone	15 kHz 6-tone	15 kHz 12-tone
A-MPR (dB)	≤ 18.0	≤ 15	≤ 11	≤ 8.5	≤ 4.5

6.2B.3.4 A-MPR for NS_12N

Table 6.2B.3.4-1: A-MPR for "NS_12N" for Power Class 3

SCS and number of tones	3.75kHz	15 kHz 1-tone	15 kHz 3-tone	15 kHz 6-tone	15 kHz 12-tone
A-MPR (dB)	≤ 18.0	≤ 15	≤ 11	≤ 8.5	≤ 4.5

6.2B.4 Configured transmitted Power for category NB1 and NB2

For category NB1 and NB2 UE, the configured transmitted power requirements in clause 6.2.5F of TS 36.101 [7] shall apply except for:

The definition of $P_{CMAX\_L,c}$ and $P_{CMAX\_H,c}$ which would be substituted by:

– $P_{CMAX\_L,c} = \text{MIN} \{ P_{EMAX,c}, \ P_{PowerClass} – \text{MAX}(MPR_c + A\text{-}MPR_c, P\text{-}MPR_c) + \Delta P_{NBBoost} \}$

– $P_{CMAX\_H,c} = \text{MIN} \{ P_{EMAX,c}, \ P_{PowerClass} + \Delta P_{NBBoost} \}$

, wherein

- $P_{PowerClass}$ is the maximum UE power specified in Table 6.2B.1-1 without taking into account the tolerance specified in the Table 6.2B.1-1
- $\Delta P_{NBBoost}$ is defined as

  2dB for single tone positions 3 to 8 for 15kHz SCS and 8 to 39 for 3.75kHz

  1dB for other single tone positions and all multi-tone cases,

  when all of the following conditions are met:

  if the UE indicates support for UE capability [*powerBoosting-NBIotNTN-r19*]

  if IE [*powerBoostNBIotNTN-r19*] is set to 1

  if UE indicates support for power class 2.

- The Maximum output power requirements are specified in subclause 6.2B.1
- The MPR requirements are specified in subclause 6.2B.2
- The A-MPR requirements are specified in subclause 6.2B.3.
- $P_{EMAX,c}$ and $P\text{-}MPR_c$ are specified in subclause 6.2.5 of TS 36.101 [7]

The measured maximum output power $P_{UMAX,c}$ shall be within the following bounds:

$$P_{CMAX\_L,c} – \text{MAX}\{T_{L,c}, T(P_{CMAX\_L,c})\} \le P_{UMAX,c} \le P_{CMAX\_H,c} + \text{MAX}\{T(P_{CMAX\_H,c})\}$$

where T(P_{CMAX}) is defined by the tolerance table in Table 6.2B.4-1 and applies to $P_{CMAX\_L,c}$ and $P_{CMAX\_H,c}$ separately. The tolerance $T_{L,c}$ is the absolute value of the lower tolerance for the applicable operating band as specified in Table 6.2B.1-1.

Table 6.2B.4-1: P_{CMAX} tolerance

$P_{CMAX,c}$ (dBm)	Tolerance T($P_{CMAX,c}$) (dB)
23 < $P_{CMAX,c}$ ≤ 33	2.0
21 ≤ $P_{CMAX,c}$ ≤ 23	2.0
20 ≤ $P_{CMAX,c}$ < 21	2.5
19 ≤ $P_{CMAX,c}$ < 20	3.5
18 ≤ $P_{CMAX,c}$ < 19	4.0
13 ≤ $P_{CMAX,c}$ < 18	5.0
8 ≤ $P_{CMAX,c}$ < 13	6.0
-40 ≤ $P_{CMAX,c}$ < 8	7.0

6.3 Output power dynamics

This clause is reserved.

6.3A Output power dynamics for category M1

6.3A.1 UE Minimum output power for category M1

The minimum controlled output power of the UE is defined as the broadband transmit power of the UE, i.e. the power in the channel bandwidth for all transmit bandwidth configurations (resource blocks), when the power is set to a minimum value.

The minimum output power is defined as the mean power in one sub-frame (1ms). The minimum output power shall not exceed the values specified in Table 6.3.2.1-1 of TS 36.101 [7].

6.3A.2 Transmit OFF power for category M1

Transmit OFF power is defined as the mean power when the transmitter is OFF. The transmitter is considered to be OFF when the UE is not allowed to transmit or during periods when the UE is not transmitting a sub-frame. During DTX and measurements gaps, the UE is not considered to be OFF.

The transmit OFF power is defined as the mean power in a duration of at least one sub-frame (1ms) excluding any transient periods. The transmit OFF power shall not exceed the values specified in Table 6.3.3.1-1 of TS 36.101 [7].

6.3A.3 ON/OFF time mask for category M1

The requirements for transmit ON/OFF time mask defined in clause 6.3.4 of TS 36.101 [7] shall apply.

6.3A.4 Power control for category M1

For category M1 UE, the requirements in clause 6.3.5E of TS 36.101 [7] shall apply, wherein

- The Maximum output power requirements are specified in subclause 6.2A.1
- The Minimum output power requirements are specified in subclause 6.3A.1.
- The requirements for configured transmitted power are specified in subclause 6.2A.4.

6.3B Output power dynamics for category NB1 and NB2

6.3B.1 UE Minimum output power for category NB1 and NB2

For category NB1 and NB2 UE, the requirements in clause 6.3.2F of TS 36.101 [7] shall apply.

6.3B.2 Transmit OFF power for category NB1 and NB2

For category NB1 and NB2 UE, the requirements in clause 6.3.3F of TS 36.101 [7] shall apply.

6.3B.3 ON/OFF time mask for category NB1 and NB2

For category NB1 and NB2 UE, the requirements in clause 6.3.4F of TS 36.101 [7] shall apply.

6.3B.4 Power Control for category NB1 and NB2

For category NB1 and NB2 UE, the requirements in clause 6.3.5F of TS 36.101 [7] shall apply, wherein

- The Maximum output power requirements are specified in subclause 6.2B.1
- The Minimum output power requirements are specified in subclause 6.3B.1
- The requirements for configured transmitted power are specified in subclause 6.2B.4.

6.4 Transmit signal quality

This clause is reserved.

6.4A Transmit signal quality for category M1

6.4A.1 Frequency error for UE category M1

For category M1 UE, the basic measurement interval of modulated carrier frequency is 1 UL timeslot (0.5ms). The UE pre-compensates the uplink modulated carrier frequency by the estimated Doppler shift based on received ephemeris information of the SAN in IE EphemerisInfo (TS 36.331 [6]), its own location and UL carrier frequency signalled to the UE by the SAN (according to TS36.300 [8] clause 16.14.2).

For category M1 FD-FDD UEs and for category M1 HD-FDD UEs with continuous uplink transmissions of duration ≤ 64 ms, the mean value of basic measurements of UE pre-compensated modulated carrier frequency shall be accurate to within ± 0.1 PPM observed over a period of one time slot (0.5 ms) compared with the ideally pre-compensated UL carrier frequency.

For category M1 HD-FDD UEs with continuous uplink transmissions of duration > 64 ms, the mean value of basic measurements of UE pre-compensated modulated carrier frequency shall be accurate within the limits in Table 6.4A.1-1 observed over a period of one time slot (0.5 ms) compared with ideally pre-compensated UL carrier frequency.

When a repetition period is configured on the uplink for which repetition period (R) >1, the UE shall not change Doppler pre-compensation during an ongoing repetition period, except in the transmission gaps as defined in clause 10.1.3.6 of TS 36.211[3]. When segmentation is applied, then the UE shall update pre-compensation at the beginning of each segment prior to segment transmission.

NOTE: The ideally pre-compensated reference uplink carrier frequency consists of the UL carrier frequency signalled to the UE by SAN and UL pre-compensated Doppler frequency shift corresponding to the estimated Doppler frequency at the beginning of the transmission.]

Table 6.4A.1-1: Frequency error requirement for HD-FDD UE category M1

Carrier frequency [GHz]	Frequency error [ppm]
≤1	±0.2
>1	±0.1

6.4A.2 Transmit modulation quality for category M1

Transmit modulation quality defines the modulation quality for expected in-channel RF transmissions from the UE. The transmit modulation quality is specified in terms of:

- Error Vector Magnitude (EVM) for the allocated resource blocks (RBs)
- EVM equalizer spectrum flatness derived from the equalizer coefficients generated by the EVM measurement process
- Carrier leakage
- In-band emissions for the non-allocated RB

All the parameters defined in subclause 6.4A.2 are defined using the measurement methodology specified in clause Annex F of TS 36.101 [7].

For category M1 UE, the requirements in clause 6.5.2E of TS 36.101 [7] shall apply, and only QPSK and 16QAM in UL shall be applicable.

6.4B Transmit signal quality for category NB1 and NB2

6.4B.1 Frequency error for UE category NB1 and NB2

For UE category NB1 and NB2, the UE pre-compensates the uplink modulated carrier frequency by the estimated Doppler shift based on received ephemeris information of the SAN in IE *EphemerisInfo* (TS 36.331 [6]), its own location and UL carrier frequency signalled to the UE by the SAN (according to TS36.300 [8] clause 23.21.2.2).

The UE pre-compensated modulated carrier frequency shall be accurate to within the limits in Table 6.4B.1-1, observed over a period of one time slot (0.5 ms for 15 kHz sub-carrier spacing and 2 ms excluding the 2304Ts gap for 3.75 kHz sub-carrier spacing) and averaged over $72/L_{Ctone}$ slots (where L_{Ctone} = {1, 3, 6, 12} is the number of sub-carriers used for the transmission), compared to the ideally pre-compensated reference uplink carrier frequency.

When a repetition period is configured on the uplink for which repetition period (R) >1, the UE shall not change Doppler pre-compensation during an ongoing repetition period, except in the transmission gaps as defined in clause 10.1.3.6 of TS 36.211[3] or except for band 249 in which UE is allowed to perform pre-compensation at the beginning of the uplink burst of 8 consecutive transmitted subframes, pre-compensation gap is not applicable for band 249. When segmentation is applied, then the UE shall update pre-compensation at the beginning of each segment prior to segment transmission, except for band 249 in which segmented pre-compensation is not supported.

[NOTE: The ideally pre-compensated reference uplink carrier frequency consists of the UL carrier frequency signalled to the UE by SAN and UL pre-compensated Doppler frequency shift corresponding to the estimated Doppler frequency at the beginning of the transmission.]

Table 6.4B.1-1: Frequency error requirement for UE category NB1 and NB2

Carrier frequency [GHz]	Frequency error [ppm]
≤1	±0.2
>1	±0.1

6.4B.2 Transmit modulation quality for Category NB1 and NB2

Transmit modulation quality requirements for Category NB1 and NB2 UEs for BPSK and QPSK modulation as specified in clause 6.5.2F of 36.101 [7] are applicable.

6.5 Output RF spectrum emissions

The output UE transmitter spectrum consists of the three components; the emission within the occupied bandwidth (channel bandwidth), the Out Of Band (OOB) emissions and the far out spurious emission domain.

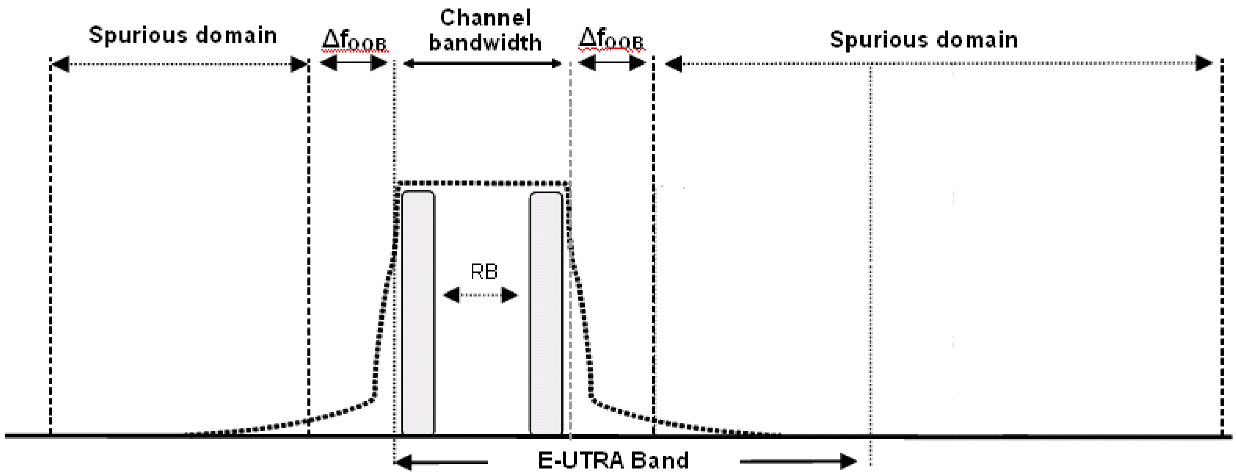

Figure 6.5-1: Transmitter RF spectrum

6.5A Output RF spectrum emissions for category M1

6.5A.1 General

The definitions in clause 6.5 shall apply.

When the UE is operating in an NGSO deployment, to support coexistence, it is assumed that a guardband at least equivalent to the maximum doppler shift expected for the NGSO constellation between the channel edge of the channel bandwidth operated by the UE and the spectrum block edge has been accounted for as part of system deployment configuration by the operator.

6.5A.2 Occupied bandwidth for category M1

Occupied bandwidth is defined as the bandwidth containing 99 % of the total integrated mean power of the transmitted spectrum on the assigned channel. The occupied bandwidth for all transmission bandwidth configurations (Resources Blocks) shall be less than the 1.4MHz channel bandwidth specified in Table 6.6.1-1 of TS 36.101 [7].

6.5A.3 Out of band emission for category M1

6.5A.3.1 General

The out of band emissions are unwanted emissions immediately outside the assigned channel bandwidth resulting from the modulation process and non-linearity in the transmitter but excluding spurious emissions. This out of band emission limit is specified in terms of a spectrum emission mask and an Adjacent Channel Leakage power Ratio.

6.5A.3.2 Spectrum emission mask

The spectrum emission mask of the UE applies to frequencies (Δf_{OOB}) starting from the ± edge of the assigned E-UTRA channel bandwidth. For frequencies offset greater than Δf_{OOB} as specified in Table 6.5A.3.2-1 the spurious requirements in subclause 6.5A.4 are applicable.

The power of any UE emission shall not exceed the levels specified in Table 6.5A.3.2-1 for the specified channel bandwidth.

Table 6.5A.3.2-1: Category M1 spectrum emission mask

Spectrum emission limit (dBm)/ Channel bandwidth		
Δf_{OOB} (MHz)	1.4 MHz	Measurement bandwidth
± 0-1	-10	30 kHz
± 1-2.5	-10	1 MHz
± 2.5-2.8	-25	1 MHz

NOTE1: As a general rule, the resolution bandwidth of the measuring equipment should be equal to the measurement bandwidth. However, to improve measurement accuracy, sensitivity and efficiency, the resolution bandwidth may be smaller than the measurement bandwidth. When the resolution bandwidth is smaller than the measurement bandwidth, the result should be integrated over the measurement bandwidth in order to obtain the equivalent noise bandwidth of the measurement bandwidth.

6.5A.3.3 Additional Spectrum Emission Mask for category M1

6.5A.3.3.1 Requirements for network signalling value "NS_02N", “NS_03N”, “NS_06N”, “NS_07N” and “NS_08N”

When "NS_02N", "NS_03N", “NS_06N”, “NS_07N” or “NS_08N” is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.3.3.1-1 or Table 6.5A.3.3.1-2.

Table 6.5A.3.3.1-1: Additional requirements for "NS_02N", “NS_06N”, “NS_07N” and “NS_08N”

Δf_{OOB} (MHz)	Spectrum Emission Limit (dBm)	Measurement bandwidth
±0 – 0.7	1 for PC2 -2 for PC3 -5 for PC5	4 kHz
±0.7 – 2.8	-9 for PC2 -12 for PC3 -15 for PC5	4 kHz
±>2.8	-13 for PC2, PC3 and PC5	4 kHz

Table 6.5A.3.3.1-2: Additional requirements for "NS_03N"

Δf_{OOB} (MHz)	Spectrum Emission Limit (dBm)	Measurement bandwidth
±0 – 0.7	-2 for PC3 -5 for PC5	4 kHz
±0.7 – 2.8	-12 for PC3 -15 for PC5	4 kHz
±>2.8	-13 for PC3 and PC5	4 kHz

6.5A.3.3.2 Requirements for network signalling value "NS_04N" and "NS_11N"

When "NS_04N" or "NS_11N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.3.3.2-1 for any channel bandwidth configured within 1610-1618.25MHz.

Table 6.5A.3.3.2-1: Additional requirements for "NS_04N" and "NS_11N"

Δf_{OOB} (kHz)	Spectrum emission limit (dBm)	Measurement bandwidth	Measurement method
± 0-160	-2	30kHz	Average
± 160-2300	-2 to -26		
± 2300-18500	-26		
NOTE 1: Spectrum emissions are linearly interpolated in dBm versus frequency offset. NOTE 2: The EIRP requirement in regulation is converted to conducted requirement using a 0dBi antenna.			

6.5A.3.3.3 Requirements for network signalling value “NS_05N" and "NS_12N"

When "NS_05N" or "NS_12N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.3.3.3-1 for any channel bandwidth configured within 1618.25-1626.5MHz.

Table 6.5A.3.3.3-1: Additional requirements for "NS_05N" and "NS_12N"

Δf_{OOB} (kHz)	Spectrum emission limit (dBm)	Measurement bandwidth	Measurement method
± 0-160	-5	30kHz	Average
± 160-225	-5 to -8.5		
± 225-650	-8.5 to -15		
± 650-1365	-15		
± 1365-1800	-23 to -26		
± 1800-16500	-26		
NOTE 1: Spectrum emissions are linearly interpolated in dBm versus frequency offset. NOTE 2: The EIRP requirement in regulation is converted to conducted requirement using a 0dBi antenna.			

6.5A.3.4 Adjacent Channel Leakage Ratio for category M1

E-UTRA category M1 Adjacent Channel Leakage power Ratio (E-$UTRA_{ACLR}$) is the ratio of the filtered mean power centred on the assigned channel frequency to the filtered mean power centred on an adjacent channel frequency at nominal channel spacing. The assigned E-UTRA category M1 channel power and adjacent E-UTRA category M1 channel power are measured with rectangular filters with measurement bandwidths specified in Table 6.5A.3.4-1 and Table 6.5A.3.4-2. If the measured adjacent channel power is greater than –50dBm then the E-$UTRA_{ACLR}$ shall be higher than the value specified in Table 6.5A.3.4-1 and Table 6.5A.3.4-2.

Table 6.5A.3.4-1: Category M1 ACLR requirements for Power Class 3 and Power Class 5

	Channel bandwidth / E-$UTRA_{ACLR}$ / Measurement bandwidth
	1.4 MHz
E-$UTRA_{ACLR}$	30 dB
E-UTRA channel Measurement bandwidth	1.08 MHz
Adjacent channel centre frequency offset [MHz]	+1.4/-1.4

Table 6.5A.3.4-2: Additional category M1 ACLR requirements for Power Class 2

	Channel bandwidth / E-$UTRA_{ACLR}$ / Measurement bandwidth
	1.4 MHz

E-UTRA$_{ACLR}$	31 dB
E-UTRA channel Measurement bandwidth	1.08 MHz
Adjacent channel centre frequency offset [MHz]	+1.4/-1.4

6.5A.4 Spurious emission for category M1

6.5A.4.1 General

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. The spurious emission limits are specified in terms of general requirements inline with SM.329 [9] and E-UTRA operating band requirement to address UE co-existence.

To improve measurement accuracy, sensitivity and efficiency, the resolution bandwidth may be smaller than the measurement bandwidth. When the resolution bandwidth is smaller than the measurement bandwidth, the result should be integrated over the measurement bandwidth in order to obtain the equivalent noise bandwidth of the measurement bandwidth.

6.5A.4.2 Minimum requirements

Unless otherwise stated, the spurious emission limits apply for the frequency ranges that are more than F_{OOB} (MHz) in Table 6.5A.4.2-1 from the edge of the channel bandwidth. The spurious emission limits in Table 6.5A.4.2-2 apply for all transmitter band configurations (N_{RB}) and channel bandwidths.

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.

Table 6.5A.4.2-1: Boundary between E-UTRA out of band and spurious emission domain

Channel bandwidth	1.4 MHz
OOB boundary F_{OOB} (MHz)	2.8

Table 6.5A.4.2-2: 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 < 5th harmonic of the upper frequency edge of the UL operating band in GHz	-30 dBm	1 MHz	

6.5A.4.3 Spurious emission band UE co-existence

This clause specifies the requirements for E-UTRA satellite bands for UE coexistence with protected bands.

Table 6.5A.4.3-1: Requirements for spurious emissions for UE co-existence

E-UTRA Band	Spurious emission						
	Protected band	Frequency range (MHz)			Maximum Level (dBm)	MBW (MHz)	NOTE
253	E-UTRA Band 5, 26, 31, 41, 48, 72 NR Band n1, n3, n7, n8, n18, n20, n28, n34, n38, n39, n40, n50, n51, n65, n67, n74, n75, n76, n79, n91, n92, n93, n94, n105, n109	F_{DL_low}	-	F_{DL_high}	-50	1	
	NR Band n77, n78	F_{DL_low}	-	F_{DL_high}	-50	1	2
254	E-UTRA Band 2, 4, 5, 12, 13, 14, 17, 24, 25, 26, 29, 30, 31, 41, 48, 54, 66, 70, 71, 72, 85, 87, 88, 103 NR Band n1, n3, n7, n8, n18, n20, n28, n34, n38, n39, n40, n50, n51, n53, n65, n67, n74, n75, n76, n77, n78, n90, n91, n92, n93, n94, n105, n106, n109	F_{DL_low}	-	F_{DL_high}	-50	1	
	NR Band n79	F_{DL_low}	-	F_{DL_high}	-50	1	2
255	E-UTRA Band 2, 4, 5, 12, 13, 14, 17, 24, 25, 26, 29, 30, 31, 41, 48, 66, 70, 71, 72, 85, 103 NR Band n1, n3, n7, n8, n18, n20, n28, n34, n38, n39, n40, n50, n51, n53, n65, n67, n74, n75, n76, n90, n91, n92, n93, n94, n105, n106, n109	F_{DL_low}	-	F_{DL_high}	-50	1	
	NR Band n77, n78, n79	F_{DL_low}	-	F_{DL_high}	-50	1	2
	Frequency range	1621.5	-	1624.5	-30	0.03	5
	Frequency range	1624.5	-	1625	-30 to -27.5	0.03	4, 5
	Frequency range	1625	-	1625.125	-27.5 to -27.2	0.03	4, 5
	Frequency range	1625.125	-	1625.8	-27.2 to -20	0.03	4, 5
	Frequency range	1625.8	-	1626	-20 to -17	0.03	4, 5
	Frequency range	1626	-	1626.2	-17 to -10	0.03	4, 5
	Frequency range	1626.2	-	1626.5	-10	0.03	5
256	E-UTRA Band 1, 3, 5, 7, 8, 11, 18, 19, 20, 21, 22, 26, 27, 28, 31, 33, 32, 35, 38, 40, 41, 42, 43, 50, 51, 54, 65, 68, 69, 72, 74, 75, 76, 87, 88 NR Band n12, n13, n14, n24, n29, n30, n39, n48, n53, n66, n67, n71, n78, n79, n85, n90, n91, n92, n93, n94, n101, n105, n106, n109	F_{DL_low}	-	F_{DL_high}	-50	1	
	NR Band n77	F_{DL_low}	-	F_{DL_high}	-50	1	2
	NR Band n2, n25, n70	F_{DL_low}	-	F_{DL_high}	NA	NA	3
252	E-UTRA Band 1, 3, 5, 7, 8, 11, 18, 19, 20, 21, 22, 26, 27, 28, 31, 33, 32, 35, 38, 40, 41, 42, 43, 50, 51, 54, 65, 68, 69, 72, 74, 75, 76, 87, 88 NR Band n12, n13, n14, n24, n29, n30, n39, n48, n53, n66, n67, n68, n71, n78, n79, n85, n87, n88, n90, n91, n92, n93, n94, n101, n105, n106, n109, n110	F_{DL_low}	-	F_{DL_high}	-50	1	
	NR Band n77	F_{DL_low}	-	F_{DL_high}	-50	1	2

NOTE 1: F_{DL_low} and F_{DL_high} refer to each E-UTRA frequency band specified in Table 5.4A.2-1

NOTE 2: As exceptions, measurements with a level up to the applicable requirements defined in Table 6.5A.4.2-2 are permitted for each assigned E-UTRA carrier used in the measurement due to 2nd, 3rd, 4th [or 5th] harmonic spurious emissions. Due to spreading of the harmonic emission the exception is also allowed for the first 1 MHz frequency range immediately outside the harmonic emission on both sides of the harmonic emission. This results in an overall exception interval centred at the harmonic emission of (2MHz + N x L_{CRB} x 180kHz), where N is 2, 3, 4, [5] for the 2nd, 3rd, 4th [or 5th] harmonic respectively. The exception is allowed if the measurement bandwidth (MBW) totally or partially overlaps the overall exception interval.

NOTE 3: The co-existence between 256 and band 2, 25 and 70 is subject to regional/national regulation.

NOTE 4: Linearly interpolated in dBm vs. frequency.

NOTE 5: Requirement is a regional regulatory requirement.

NOTE: To simplify Table 6.5A.4.3-1, E-UTRA band numbers are listed for bands which are specified only for E-UTRA operation or both E-UTRA and NR operation. NR band numbers are listed for bands which are specified only for NR operation.

6.5A.4.4 Additional spurious emissions

6.5A.4.4.1 General

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. The value used in IE *AdditionalSpectrumEmission* only includes the digits of the NS-value, e.g., 2 for NS_02N.

NOTE: In addition to the requirements below, additional UE region-specific emissions requirements for European are expected to be added once more information becomes available.

6.5A.4.4.2 Minimum requirement (network signalled value "NS_02N")

When "NS_02N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.4.4.2-1. This requirement also applies for the frequency ranges that are less than F_{OOB} (MHz) in Table 6.5A.4.2-1 from the edge of the channel bandwidth.

Table 6.5A.4.4.2-1: Additional requirements for "NS_02N"

Frequency band (MHz)	Channel bandwidth / Spectrum emission limit[1] (dBm)	Measurement bandwidth	NOTE
	1.4MHz		
1559≤ f ≤ 1605	-50	700 Hz	Averaged over any 2 millisecond active transmission interval
1605≤ f ≤ 1610	-50 + 24/5 (f-1605)	700Hz	
1559 ≤ f ≤ 1605	-40	1MHz	Averaged over any 2 millisecond active transmission interval
1605≤ f ≤ 1610	-40 + 24/5 (f-1605)	1MHz	
NOTE: The EIRP requirement in regulation is converted to conducted requirement using a 0 dBi antenna.			

6.5A.4.4.3 Minimum requirement (network signalled value "NS_24N")

When "NS_24N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.4.4.3-1.

Table 6.5A.4.4.3-1: Additional requirements for "NS_24N"

Frequency band (MHz)	Channel bandwidth / Spectrum emission limit (dBm)	Measurement bandwidth
	1.4MHz	
Band 34	-50	MHz
NOTE 1: This requirement applies at a frequency offset equal or larger than 5 MHz from the upper edge of the channel bandwidth, whenever these frequencies overlap with the specified frequency band 256.		

6.5A.4.4.4 Minimum requirement (network signalled value "NS_03N")

When "NS_03N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.4.4.4-1 where BWchannel equals to 1.4MHz. This requirement also applies for the frequency ranges that are less than F_{OOB} (MHz) in Table 6.5A.4.2-1 from the edge of the channel bandwidth.

Table 6.5.4.4.4-1: Additional out-of-band requirements for "NS_03N"

Frequency band (MHz)	Channel bandwidth / Spectrum emission limit[1] (dBm)	Measurement bandwidth	NOTE
	BWchannel		
1559 ≤ f ≤ 1605	-50	700 Hz	Discreet emissions averaged over any 2 millisecond active transmission interval
1605 ≤ f ≤ 1610	-50 + 60/5 (f-1605)	700 Hz	
1559 ≤ f ≤ 1605	-40	1MHz	Averaged over any 2 millisecond active transmission interval
1605 ≤ f ≤ 1610	-40 + 60/5 (f-1605)	1MHz	
NOTE: The EIRP requirement in regulation is converted to conducted requirement using a 0dBi antenna.			

6.5A.4.4.5 Minimum requirement (network signalled value "NS_04N", "NS_05N", "NS_11N" and "NS_12N")

When "NS_04N" or "NS_05N" or "NS_11N" or "NS_12N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.4.4.5-1 where BWchannel equals to 1.4MHz. This requirement also applies for the frequency ranges that are less than F_{OOB} (MHz) in Table 6.5A.4.2-1 from the edge of the channel bandwidth.

Table 6.5A.4.4.5-1: Additional out-of-band requirements for "NS_04N", "NS_05N", "NS_11N" and "NS_12N"

Frequency band (MHz)	Channel bandwidth / Spectrum emission limit[1] (dBm)	Measurement bandwidth	Measurement method
	BWchannel		
1559 ≤ f ≤ 1605	-40	1MHz	Average (note 2)
1605 ≤ f ≤ 1610	-40 + 60/5 (f-1605)	1MHz	
			Average
1628.5 ≤ f ≤ 1631.5	-30	30kHz	
1631.5 ≤ f ≤ 1636.5	-30	100kHz	
1636.5 ≤ f ≤ 1646.5	-30	300kHz	
1646.5 ≤ f ≤ 1666.5	-30	1MHz	
1666.5 ≤ f ≤ 2200	-30	3MHz	
NOTE 1: The EIRP requirement in regulation is converted to conducted requirement using a 0dBi antenna. NOTE 2: In the sub-band 1573.42MHz to 1580.42 MHz the average measurement time is 20ms.			

6.5A.4.4.6 Void

6.5A.4.4.7 Minimum requirement (network signalled value "NS_06N")

When "NS_06" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.4.4.7-1.

Table 6.5A.4.4.7-1: Additional requirements for "NS_06"

Frequency range (MHz)	Channel bandwidth / Spectrum emission limit (dBm)	Measurement bandwidth	NOTE
	1.4MHz		
1559 ≤ f < 1610	-50	700 Hz	Averaged over any 2 millisecond active transmission interval
1559 ≤ f < 1610	-40	1MHz	

6.5A.4.4.8 Minimum requirement (network signalled value "NS_07N")

When "NS_07N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.4.4.8-1.

Table 6.5A.4.4.8-1: Additional requirements for "NS_07N"

Frequency range (MHz)	Channel bandwidth / Spectrum emission limit (dBm)	Measurement bandwidth	NOTE
	1.4MHz		
1559 ≤ f < 1610	-50	700 Hz	Averaged over any 2 millisecond active transmission interval
1559 ≤ f < 1610	-40	1MHz	
1930 ≤ f ≤1995	-40	1MHz	

6.5A.4.4.9 Minimum requirement (network signalled value "NS_08N")

When "NS_08N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.4.4.9-1.

Table 6.5A.4.4.9-1: Additional requirements for "NS_08N"

Frequency range (MHz)	Channel bandwidth / Spectrum emission limit (dBm)	Measurement bandwidth	NOTE
	1.4MHz		
1559 ≤ f < 1610	-50	700 Hz	Averaged over any 2 millisecond active transmission interval
1559 ≤ f < 1610	-40	1MHz	
1930 ≤ f ≤1995	-30	1MHz	

6.5B Output RF spectrum emissions for category NB1 and NB2

6.5B.1 General

The definitions in clause 6.5 shall apply.

6.5B.2 Occupied bandwidth for category NB1 and NB2

For category NB1 and NB2 UE, the requirements in clause 6.6.1F of TS 36.101 [7] shall apply.

6.5B.3 Out of band emission for category NB1 and NB2

6.5B.3.1 General

The out of band emissions are unwanted emissions immediately outside the assigned channel bandwidth resulting from the modulation process and non-linearity in the transmitter but excluding spurious emissions. This out of band emission limit is specified in terms of a spectrum emission mask and an Adjacent Channel Leakage power Ratio.

6.5B.3.2 Spectrum emission mask

The spectrum emission mask of the category NB1 and NB2 UE applies to frequencies (Δf_{OOB}) starting from the ± edge of the assigned category NB1 or NB2 channel bandwidth. For frequencies greater than (Δf_{OOB}) as specified in Table 6.5B.3.2-1 the spurious requirements in subclause 6.5B.4 are applicable.

The power of any category NB1 or NB2 UE emission shall not exceed the levels specified in Table 6.5B.3.2-1. The spectrum emission limit between each Δf_{OOB} is linearly interpolated.

Table 6.5B.3.2-1: Category NB1 and NB2 UE spectrum emission mask

Δf_{OOB} (kHz)	Emission limit (dBm)	Measurement bandwidth
± 0	26	30 kHz
± 100	-5	30 kHz
± 150	-8	30 kHz
± 300	-29	30 kHz
± 500-1700	-35	30 kHz

NOTE1: As a general rule, the resolution bandwidth of the measuring equipment should be equal to the measurement bandwidth. However, to improve measurement accuracy, sensitivity and efficiency, the resolution bandwidth may be smaller than the measurement bandwidth. When the resolution bandwidth is smaller than the measurement bandwidth, the result should be integrated over the measurement bandwidth in order to obtain the equivalent noise bandwidth of the measurement bandwidth.

[NOTE2: When the UE is operating in an NGSO deployment, to support coexistence, it is assumed that a guardband at least equivalent to the maximum doppler shift expected for the NGSO constellation between the channel edge of the channel bandwidth operated by the UE and the spectrum block edge has been accounted for as part of system deployment configuration by the operator.]

6.5B.3.3 Additional Spectrum Emission Mask for category NB1 and NB2

6.5B.3.3.1 Requirements for network signalling value "NS_02N", “NS_06N”, “NS_07N” and “NS_08N”

When "NS_02N", “NS_06N”, “NS_07N” or “NS_08N” is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5B.3.3.1-1.

Table 6.5B.3.3.1-1: Additional requirements for "NS_02N", “NS_06N”, “NS_07N” and “NS_08N”

Δf_{OOB} (MHz)	Spectrum Emission Limit (dBm)	Measurement bandwidth
± 0.09–0.28	6 for PC1 1 for PC2 -2 for PC3 -5 for PC5	4 kHz
± 0.28–0.85	-4 for PC1 -9 for PC2 -12 for PC3 -15 for PC5	4 kHz
± >0.85	-13 for PC1, PC2, PC3 and PC5	4 kHz

NOTE: Δf_{OOB} = 0.09 MHz corresponds to an authorized bandwidth, as defined in C63.26-2015 [10], of 0.38 MHz.

6.5B.3.3.2 Requirements for network signalling value "NS_03N"

When "NS_03N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5B.3.3.2-1.

Table 6.5B.3.3.2-1: Additional requirements for "NS_03N"

Δf_{OOB} (MHz)	Spectrum Emission Limit (dBm)	Measurement bandwidth
± 0.09–0.28	-2 for PC3 -5 for PC5	4 kHz
± 0.28–0.85	-12 for PC3 -15 for PC5	4 kHz
± 0.85–1.7	-13 for PC3 and PC5	4 kHz

NOTE: Δf_{OOB} = 0.09 MHz corresponds to an authorized bandwidth, as defined in C63.26-2015 [10], of 0.38 MHz.

6.5B.3.3.3 Requirements for network signalling value "NS_04N" and "NS_11N"

As specified in 6.5A.3.3.2.

6.5B.3.3.4 Requirements for network signalling value “NS_05N" and "NS_12N"

As specified in 6.5A.3.3.3.

6.5B.3.4 Adjacent Channel Leakage Ratio for category NB1 and NB2

Adjacent Channel Leakage power Ratio is the ratio of the filtered mean power centred on the assigned channel frequency to the filtered mean power centred on an adjacent channel frequency. The assigned category NB1or NB2 channel power and adjacent channel power are measured with filters and measurement bandwidths specified in Table 6.5B.3.4-1. If the measured adjacent channel power is greater than –50dBm then the category NB1 or NB2 UE ACLR shall be higher than the value specified in Table 6.5B.3.4-1. $UTRA_{ACLR}$ requirement is intended for protection of UTRA and E-UTRA systems.

Table 6.5B.3.4-1: Category NB1 and NB2 UE ACLR requirements

	$UTRA_{ACLR}$
ACLR	37 dB
Adjacent channel center frequency offset from category NB1 or NB2 Channel edge	±2.5 MHz
Adjacent channel measurement bandwidth	3.84 MHz
Measurement filter	RRC-filter α=0.22
Category NB1 and NB2 channel measurement bandwidth	180 kHz
Category NB1 and NB2 channel Measurement filter	Rectangular

6.5B.4 Spurious emission for category NB1 and NB2

6.5B.4.1 General

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. The spurious emission limits are specified in terms of general requirements inline with SM.329 [9] and E-UTRA operating band requirement to address UE co-existence.

To improve measurement accuracy, sensitivity and efficiency, the resolution bandwidth may be smaller than the measurement bandwidth. When the resolution bandwidth is smaller than the measurement bandwidth, the result should be integrated over the measurement bandwidth in order to obtain the equivalent noise bandwidth of the measurement bandwidth.

6.5B.4.2 Minimum requirements

When UE is configured for category NB1 or NB2 uplink transmissions the requirements in subclause 6.5A.4.2 apply with an exception that boundary between category NB1 or NB2 out of band and spurious emission domain shall be F_{OOB} = 1.7 MHz.

6.5B.4.3 Spurious emission band UE co-existence

The spurious emission band UE coexistence requirement in sub-clause 6.5A.4.3 is also applicable for NB1 and NB2 UE.

6.5B.4.4 Additional spurious emissions

6.5B.4.4.1 General

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. The value used in IE *AdditionalSpectrumEmission* only includes the digits of the NS-value, e.g., 2 for NS_02N.

NOTE: In addition to the requirements below, additional UE region-specific emissions requirements for European are expected to be added once more information becomes available.

6.5B.4.4.2 Minimum requirement (network signalled value "NS_02N")

When "NS_02N" is indicated in the cell, the power of any UE spurious emission shall not exceed the levels specified in Table 6.5B.4.4.2-1. This requirement also applies for the frequency ranges that are less than F_{OOB} (MHz) specified in 6.5B.4.2 from the edge of the channel bandwidth.

Table 6.5B.4.4.2-1: Additional requirements for "NS_02N"

<table>
<tr><th rowspan="2">Frequency band (MHz)</th><th>Channel bandwidth / Spectrum emission limit[1] (dBm)</th><th rowspan="2">Measurement bandwidth</th><th rowspan="2">NOTE</th></tr>
<tr><th>200kHz</th></tr>
<tr><td>1559≤ f ≤ 1605</td><td>-50</td><td>700 Hz</td><td rowspan="2">Averaged over any 2 millisecond active transmission interval</td></tr>
<tr><td>1605≤ f ≤ 1610</td><td>-50 + 24/5 (f-1605)</td><td>700Hz</td></tr>
<tr><td>1559 ≤ f ≤ 1605</td><td>-40</td><td>1MHz</td><td rowspan="2">Averaged over any 2 millisecond active transmission interval</td></tr>
<tr><td>1605≤ f ≤ 1610</td><td>-40 + 24/5 (f-1605)</td><td>1MHz</td></tr>
<tr><td colspan="4">NOTE: The EIRP requirement in regulation is converted to conducted requirement using a 0 dBi antenna.</td></tr>
</table>

6.5B.4.4.3 Minimum requirement (network signalled value "NS_24N")

When "NS_24N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5B.4.4.3-1.

Table 6.5B.4.4.3-1: Additional requirements for "NS_24N"

Frequency band (MHz)	Channel bandwidth / Spectrum emission limit (dBm)	Measurement bandwidth
	200kHz	
Band 34	-50	MHz
NOTE 1: This requirement applies at a frequency offset equal or larger than 5 MHz from the upper edge of the channel bandwidth, whenever these frequencies overlap with the specified frequency band 256.		

6.5B.4.4.4 Minimum requirement (network signalled value "NS_03N")

When "NS_03N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.4.4.4-1 where BWchannel is replaced with 200 kHz, and F_{OOB} (MHz) is replaced with 1.7MHz.

6.5B.4.4.5 Minimum requirement (network signalled value "NS_04N", "NS_05N", "NS_11N" and "NS_12N")

When "NS_04N" or "NS_05N" or "NS_11N" or "NS_12N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5A.4.4.5-1 where BWchannel is replaced with 200 kHz, and F_{OOB} (MHz) is replaced with 1.7MHz.

6.5B.4.4.6 Void

6.5B.4.4.7 Minimum requirement (network signalled value "NS_06N")

When "NS_06N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5B.4.4.7-1.

Table 6.5B.4.4.7-1: Additional requirements for "NS_06N"

Frequency range (MHz)	Channel bandwidth / Spectrum emission limit (dBm)	Measurement bandwidth	NOTE
	200kHz		
1559 ≤ f < 1610	-50	700 Hz	Averaged over any 2 millisecond active transmission interval
1559 ≤ f < 1610	-40	1MHz	

6.5B.4.4.8 Minimum requirement (network signalled value "NS_07N")

When "NS_07N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5B.4.4.8-1.

Table 6.5B.4.4.8-1: Additional requirements for "NS_07N"

Frequency range (MHz)	Channel bandwidth / Spectrum emission limit (dBm)	Measurement bandwidth	NOTE
	200kHz		

1559 ≤ f < 1610	-50	700 Hz	Averaged over any 2 millisecond active transmission interval
1559 ≤ f < 1610	-40	1MHz	
1930 ≤ f ≤1995	-40	1MHz	Frequency range covers DL of B2/n2 and B25/n25

6.5B.4.4.9 Minimum requirement (network signalled value "NS_08N")

When "NS_08N" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5B.4.4.9-1.

Table 6.5B.4.4.9-1: Additional requirements for "NS_08N"

Frequency range (MHz)	Channel bandwidth / Spectrum emission limit (dBm)	Measurement bandwidth	NOTE
	200kHz		
1559 ≤ f < 1610	-50	700 Hz	Averaged over any 2 millisecond active transmission interval
1559 ≤ f < 1610	-40	1MHz	
1930 ≤ f ≤1995	-30	1MHz	Frequency range covers DL of B2/n2 and B25/n25

6.6 Transmit intermodulation

This clause is reserved.

6.6A Transmit intermodulation for category M1

For category M1 UE, Tx intermodulation requirements are not applicable.

6.6B Transmit intermodulation for category NB1 and NB2

For category NB1 and NB2 UE, the Tx intermodulation requirements in clause 6.7.1F of TS 36.101 [7] shall apply.

7 Receiver characteristics

7.1 General

The requirements in clause 7.1 of TS 36.101 [7] shall apply.

All requirements in this section are applicable to devices supporting GSO and/or NGSO satellites.

All RX requirements are verified with default TX-RX frequency separation specified in Table 5.4A.3-1. Additional TX-RX frequency separations specified in clauses 7.3A and 7.3B do not apply to other requirements.

7.2 Diversity characteristics

The requirements in clause 7 assume that the receiver is equipped with single Rx port.

7.3 Reference sensitivity power level

This clause is reserved.

7.3A Reference sensitivity power level for UE category M1

The reference sensitivity power level REFSENS is the minimum mean power applied to the single antenna port for UE category M1, at which the throughput shall meet or exceed the requirements for the specified reference measurement channel.

The throughput for the REFSENS test is measured based on the Transmission Mode 1 unless specified otherwise.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annexes A.2.2 and A.3.2 (with one sided dynamic OCNG Pattern OP.1 FDD/TDD for the DL-signal as described in Annex A.5.1.1) with parameters specified in Table 7.3A-1 and Table 7.3A-2 for category M1.

Table 7.3A-1: Reference sensitivity for FDD UE category M1 QPSK $P_{REFSENS}$

NTN Band	REFSENS (dBm)	Duplex Mode
256	-102.2	FDD
255	-102.7	FDD
254	-102.2	FDD
253	-102.7	FDD
252	-102.2	FDD
NOTE 1: The transmitter shall be set to P_{UMAX} as defined in subclause 6.2.5- in TS 36.101 [7].		

Table 7.3A-2: Reference sensitivity for HD-FDD UE category M1 QPSK $P_{REFSENS}$

NTN Band	REFSENS (dBm)	Duplex Mode
256	-103	HD-FDD
255	-103.5	HD-FDD
254	-103.1	HD-FDD
253	-103.5	HD-FDD
252	-103	HD-FDD
NOTE 1: The transmitter shall be set to P_{UMAX} as defined in subclause 6.2.5 in TS 36.101 [7].		

For power class 2 FDD UE category M1, certain degradation of the reference sensitivity in Table 7.3A-1 is allowed. The maximum amount of degradation is specified in Table 7.3A-2a.

Table 7.3A-2a Reference Sensitivity Degradation from PC3 to PC2 for FDD UE category M1

NTN Band	Reference Sensitivity Degradation (dB)	Duplex Mode
256	0.5	FDD
255	1	FDD
254	0	FDD

The reference sensitivity (REFSENS) requirement specified in Table 7.3A-1, Table 7.3A-2 and 7.3A-2a shall be met for an uplink transmission bandwidth less than or equal to that specified in Table 7.3A-3 and with default TX-RX carrier center frequency separation except for cases specified in Table 7.3A-4.

NOTE: Table 7.3A-3 is intended for conformance tests and does not necessarily reflect the operational conditions of the network, where the number of uplink and downlink allocated resource blocks will be practically constrained by other factors. Typical receiver sensitivity performance with HARQ retransmission enabled and using a residual BLER metric relevant for e.g. Speech Services is given in the Annex [G] (informative).

Table 7.3A-3: FDD UE category M1 Uplink configuration for reference sensitivity

E-UTRA Band	N_{RB}	Duplex Mode
256	6[1]	FDD and HD-FDD
255	6[1]	FDD and HD-FDD
254	6[1]	FDD and HD-FDD
253	6[1]	FDD and HD-FDD
252	6[1]	FDD and HD-FDD
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 (Table 5.3A-1).		

Table 7.3A-4: TX – RX carrier centre frequency separation for REFSENS verification

E-UTRA Operating Band	Channel bandwidth	TX – RX carrier centre frequency separation for REFSENS verification
256	1.4 MHz	161.4 MHz, 218.6 MHz
255	1.4 MHz	-68.9 MHz, -134.1 MHz
254	1.4 MHz	858.4 MHz, 888.6 MHz
253	1.4 MHz	-144.4 MHz, -155.6 MHz
252	1.4 MHz	161.4 MHz, 198.6 MHz

7.3B Reference sensitivity power level for UE category NB1 and NB2

The reference sensitivity power level REFSENS is the minimum mean power applied to the single antenna port for UE category NB1 and category NB2, at which the throughput shall meet or exceed the requirements for the specified reference measurement channel.

The throughput for the REFSENS test is measured based on the Transmission Mode 1 unless specified otherwise.

The category NB1 and NB2 UE throughput shall be ≥ 95% of the maximum throughput of the reference measurement channel as specified in TS 36.101 [7] Annex A.3.2 with received signal level as specified in Table 7.3B-1. Requirement in Table 7.3B-1 applies for any uplink configuration and with default TX-RX carrier center frequency separation except for cases specified in Table 7.3B-2.

Table 7.3B-1: Reference sensitivity for UE category NB1 and NB2

Operating band	REFSENS [dBm]
According to subclause 5.2B	- 108.2

Table 7.3B-2: TX – RX carrier centre frequency separation for REFSENS verification

E-UTRA Operating Band	Channel bandwidth	TX – RX carrier centre frequency separation for REFSENS verification
256	0.2 MHz	160.2 MHz, 219.8 MHz
255	0.2 MHz	-67.7 MHz, -135.3 MHz
254	0.2 MHz	857.2 MHz, 889.8 MHz
253	0.2 MHz	-143.2 MHz, -156.8 MHz
252	0.2 MHz	160.2 MHz, 199.8 MHz

7.3C Minimum requirements for BOG

The throughput shall be ≥ 95% of the maximum throughput as represented by a reported BLER of <5% for the reference measurement channels as specified in Annexes A.1.3 with parameters specified in Table 7.3C.

Table 7.3C: Reference sensitivity for BOG

Operating Band	PMCH bandwidth	Duplex Mode
	10 MHz (dBm)	
246	-97	SDO
NOTE1: The signal power is specified per port		

7.4 Maximum input level

This clause is reserved.

7.4A Maximum input level for category M1

This is defined as the maximum mean power received at the UE antenna port, at which the specified relative throughput shall meet or exceed the minimum requirements for the specified reference measurement channel.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in TS 36.101 [7] Annexes A.2.2, A.2.3 and A.3.2 (with one sided dynamic OCNG Pattern OP.1 FDD as described in TS 36.101 [7] Annex A.5.1.1) with parameters specified in Table 7.4A-1.

Table 7.4A-1: Maximum input level

Rx Parameter	Units	Channel bandwidth
		1.4 MHz
Power in Transmission Bandwidth Configuration	dBm	-40[2]
NOTE 1: The transmitter shall be set to 4dB below P_{CMAX_L} at the minimum uplink configuration specified in Table 7.3A-3 with P_{CMAX_L} as defined in subclause 6.2.5 of TS 36.101 [7]. NOTE 2: Reference measurement channel is TS 36.101 [7] Annex A.3.2: 64QAM, R=3/4 variant with one sided dynamic OCNG Pattern OP.1 FDD as described in Annex A.5.1.1 of TS 36.101 [7].		

7.4B Maximum input level for category NB1 and NB2

This is defined as the maximum mean power received at the UE antenna port, at which the specified relative throughput shall meet or exceed the minimum requirements for the specified reference measurement channel.

Category NB1 and NB2 UE maximum input level requirement is -40 dBm. For this input level the throughput shall be ≥ 95% of the maximum throughput of the reference measurement channel as specified in Annex A.3.2 of TS 36.101 [7].

7.4C Maximum input level for BOG

This is defined as the maximum mean power received at the UE antenna port, at which the specified relative throughput shall meet or exceed the minimum requirements for the specified reference measurement channel.

The throughput shall be ≥ 95% of the maximum throughput as represented by a reported BLER of <5% for the reference measurement channels as specified in Annexes A.1.3 with parameters specified in Table 7.4C -1.

Table 7.4C-1: Maximum input level for BOG

Rx Parameter	Units	PMCH bandwidth
		10 MHz
Power in Transmission Bandwidth Configuration	dBm	-40
NOTE: Reference measurement channel is Annex A.1.3 16QAM, R=1/2 variant		

7.5 Adjacent Channel Selectivity (ACS)

This clause is reserved.

7.5A Adjacent Channel Selectivity for category M1

Adjacent Channel Selectivity (ACS) is a measure of a receiver's ability to receive a E-UTRA signal at its assigned channel frequency in the presence of an adjacent channel signal at a given frequency offset from the centre frequency of the assigned channel. ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channel(s).

The UE shall fulfil the minimum requirement specified in Table 7.5A-1 for all values of an adjacent channel interferer up to –40 dBm. However it is not possible to directly measure the ACS, instead the lower and upper range of test parameters are chosen in Table 7.5A-2 and Table 7.5A-3 where the throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in TS 36.101 [7] Annexes A.2.2, A.2.3 and A.3.2 (with one sided dynamic OCNG Pattern OP.1 FDD for the DL-signal as described in TS 36.101 [7] Annex A.5.1.1). For operating bands with an unpaired DL part (as noted in Table 5.5-1), the requirements only apply for carriers assigned in the paired part.

Table 7.5A-1: Adjacent channel selectivity

		Channel bandwidth
Rx Parameter	Units	1.4 MHz
ACS	dB	33.0

Table 7.5A-2: Test parameters for Adjacent channel selectivity, Case 1

Rx Parameter	Units	Channel bandwidth
		1.4 MHz
Power in Transmission Bandwidth Configuration	dBm	REFSENS + 14 dB
$P_{Interferer}$	dBm	REFSENS +45.5dB
$BW_{Interferer}$	MHz	1.4
$F_{Interferer}$ (offset)	MHz	1.4+0.0025 / -1.4-0.0025
NOTE 1: The transmitter shall be set to 4dB below P_{CMAX_L} at the minimum uplink configuration specified in Table 7.3A-3 with P_{CMAX_L} as defined in subclause 6.2.5 of TS 36.101 [7]. NOTE 2: The interferer consists of the Reference measurement channel specified in TS 36.101 [7] Annex A.3.2 with one sided dynamic OCNG Pattern OP.1 FDD as described in Annex A.5.1.1 and set-up according to Annex C.3.1. NOTE 3: For DL category M1 UE, the reference sensitivity for category M1 in table 7.3A-1 should be used as REFSENS for the power in Transmission Bandwidth Configuration. NOTE 4: For DL category M1 UE, the parameters for the applicable channel bandwidth apply.		

Table 7.5A-3: Test parameters for Adjacent channel selectivity, Case 2

Rx Parameter	Units	Channel bandwidth
		1.4 MHz
Power in Transmission Bandwidth Configuration	dBm	-71.5
$P_{Interferer}$	dBm	-40
$BW_{Interferer}$	MHz	1.4
$F_{Interferer}$ (offset)	MHz	1.4+0.0025 / -1.4-0.0025
NOTE 1: The transmitter shall be set to 24dB below P_{CMAX_L} at the minimum uplink configuration specified in Table 7.3A-3 with P_{CMAX_L} as defined in subclause 6.2.5 of TS 36.101 [7]. NOTE 2: The interferer consists of the Reference measurement channel specified in TS 36.101 [7] Annex A.3.2 with one sided dynamic OCNG Pattern OP.1 FDD as described in Annex A.5.1.1 and set-up according to Annex C.3.1.		

7.5B Adjacent Channel Selectivity for category NB1 and NB2

Adjacent Channel Selectivity (ACS) is a measure of a receiver's ability to receive a E-UTRA signal at its assigned channel frequency in the presence of an adjacent channel signal at a given frequency offset from the centre frequency of the assigned channel. ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channel(s).

Category NB1 and NB2 UE shall fulfil the minimum requirement specified in Table 7.5B-1 for all values of an adjacent channel interferer up to -40 dBm. However, it is not possible to directly measure the ACS, instead the lower and upper range of test parameters are chosen in Table 7.5B-1 where the throughput shall be ≥ 95% of the maximum throughput of the reference measurement channel as specified in TS 36.101 [7] Annex A.3.2.

Table 7.5B-1: Adjacent channel selectivity parameters for category NB1 and NB2

ACS1 test Parameters		
Interferer	**GSM (GMSK)**	**E-UTRA**
Category NB1 or NB2 signal power (P_{wanted}) / dBm	REFSENS + 14 dB	
Interferer signal power ($P_{Interferer}$) / dBm	REFSENS + 42 dB	REFSENS + 47 dB
Interferer bandwidth	200 kHz	5 MHz
Interferer offset from category NB1 or NB2 channel edge	±200 kHz	±2.5 MHz
ACS2 test Parameters		
Interferer	**GSM (GMSK)**	**E-UTRA**
Category NB1 or NB2 signal power (P_{wanted}) / dBm	-68 dBm	-73 dBm
Interferer signal power ($P_{Interferer}$) / dBm	-40 dBm	
Interferer bandwidth	200 kHz	5 MHz
Interferer offset from category NB1 or NB2 channel edge	±200 kHz	±2.5 MHz

7.5C Adjacent Channel Selectivity for BOG

Adjacent Channel Selectivity (ACS) is a measure of a receiver's ability to receive a E-UTRA signal at its assigned channel frequency in the presence of an adjacent channel signal at a given frequency offset from the centre frequency of the assigned channel. ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channel(s).

The UE shall fulfil the minimum requirement specified in Table 7.5C -1 for all values of an adjacent channel interferer up to -40 dBm. However, it is not possible to directly measure the ACS, instead the lower and upper range of test parameters are chosen in Table 7.5C-2 and Table 7.5C-3 where the throughput shall be ≥ 95% of the maximum throughput as represented by a reported BLER of <5% for the reference measurement channels as specified in Annex A.1.3.

Table 7.5C-1: Adjacent channel selectivity for BOG

Rx Parameter	Units	PMCH bandwidth
		10 MHz
ACS	dB	33
NOTE: Values in this table apply only to UE implementations that relies on digital filtering according to the configured broadcast channel bandwidth		

Table 7.5C-2: Test parameters for Adjacent channel selectivity for BOG, Case 1

Rx Parameter	Units	PMCH bandwidth
		10 MHz
Power in Transmission Bandwidth Configuration	dBm	REFSENS + 14 dB
$P_{Interferer}$	dBm	REFSENS +45.5dB
$BW_{Interferer}$	MHz	5
$F_{Interferer}$ (offset)	MHz	7.5+0.0075 / -7.5-0.0075
NOTE: The interferer consists of the Reference measurement channel specified in Annex A.1.3.		

Table 7.5C-3: Test parameters for Adjacent channel selectivity for BOG, Case 2

Rx Parameter	Units	PMCH bandwidth
		10 MHz
Power in Transmission Bandwidth Configuration	dBm	-53.5
$P_{Interferer}$	dBm	-40
$BW_{Interferer}$	MHz	5
$F_{Interferer}$ (offset)	MHz	7.5+0.0075 / -7.5-0.0075
NOTE: The interferer consists of the Reference measurement channel specified in Annex A.1.3.		

7.6 Blocking characteristics

This clause is reserved.

Editor's note: the additional blocking requirements for band 253 will be introduced following further feedback from ETSI and additional studies.

7.6A Blocking characteristics for category M1

7.6A.1 General

The blocking characteristic is a measure of the receiver's ability to receive a wanted signal at its assigned channel frequency in the presence of an unwanted interferer on frequencies other than those of the spurious response or the adjacent channels, without this unwanted input signal causing a degradation of the performance of the receiver beyond a specified limit. The blocking performance shall apply at all frequencies except those at which a spurious response occurs.

7.6A.2 In-band blocking requirements for category M1

In-band blocking is defined for an unwanted interfering signal falling into the UE receive band or into the first 15 MHz below or above the UE receive band at which the relative throughput shall meet or exceed the minimum requirement for the specified measurement channels.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in TS 36.101 [7] Annexes A.2.2, A.2.3 and A.3.2 (with one sided dynamic OCNG Pattern OP.1 FDD for the DL-signal as described in TS 36.101 [7] Annex A.5.1.1) with parameters specified in Tables 7.6A.2-1 and 7.6A.2-2. For operating bands with an unpaired DL part (as noted in Table 5.2A-1), the requirements only apply for carriers assigned in the paired part.

Table 7.6A.2-1: In band blocking parameters

Rx parameter	Units	Channel bandwidth
		1.4 MHz
Power in Transmission Bandwidth Configuration	dBm	REFSENS + channel bandwidth specific value below
		6
$BW_{Interferer}$	MHz	1.4
$F_{Ioffset, case 1}$	MHz	2.1+0.0125
$F_{Ioffset, case 2}$	MHz	3.5+0.0075
NOTE 1: The transmitter shall be set to 4dB below P_{CMAX_L} at the minimum uplink configuration specified in Table 7.3A-3 with P_{CMAX_L} as defined in subclause 6.2.5 of TS 36.101 [7]. NOTE 2: The interferer consists of the Reference measurement channel specified in TS 36.101 [7] Annex A.3.2 with one sided dynamic OCNG Pattern OP.1 FDD as described in Annex A.5.1.1 and set-up according to Annex C.3.1. NOTE 3: For DL category M1 UE, the reference sensitivity for category M1 in table 7.3A-1 should be used as REFSENS for the power in Transmission Bandwidth Configuration. NOTE 4: For DL category M1 UE, the parameters for the applicable channel bandwidth apply.		

Table 7.6A.2-2: In-band blocking

E-UTRA band	Parameter	Unit	Case 1	Case 2
	$P_{Interferer}$	dBm	-56	-44
	$F_{Interferer}$ (offset)	MHz	=-BW/2 – $F_{Ioffset,case 1}$ & =+BW/2 + $F_{Ioffset,case 1}$	≤-BW/2 – $F_{Ioffset,case 2}$ & ≥+BW/2 + $F_{Ioffset,case 2}$
256, 255, 254, 253, 252	$F_{Interferer}$	MHz	(NOTE 2)	F_{DL_low} – 15 to F_{DL_high} + 15
NOTE 1: For certain bands, the unwanted modulated interfering signal may not fall inside the UE receive band, but within the first 15 MHz below or above the UE receive band NOTE 2: For each carrier frequency the requirement is valid for two frequencies: a. the carrier frequency -BW/2 - $F_{Ioffset, case 1}$ and b. the carrier frequency +BW/2 + $F_{Ioffset, case 1}$ NOTE 3: $F_{Interferer}$ range values for unwanted modulated interfering signal are interferer center frequencies				

7.6A.3 Out-of-band blocking requirements for category M1

Out-of-band band blocking is defined for an unwanted CW interfering signal falling more than 15 MHz below or above the UE receive band. For the first 15 MHz below or above the UE receive band the appropriate in-band blocking or adjacent channel selectivity in subclause 7.5A and subclause 7.6A.2 shall be applied.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in TS 36.101 [7] Annexes A.2.2, A.2.3 and A.3.2 (with one sided dynamic OCNG Pattern OP.1 FDD for the DL-signal as described in TS 36.101 [7] Annex A.5.1.1) with parameters specified in Tables 7.6A.3-1 and 7.6A.3-2.

Table 7.6A.3-1: Out-of-band blocking parameters for category M1 UE

RX parameter	Units	Channel bandwidth (MHz)
		1.4
Power in transmission bandwidth configuration	dBm	REFSENS + 6 dB
NOTE 1: The transmitter shall be set to 4dB below P_{CMAX_L} at the minimum uplink configuration specified in Table 7.3.1-2 in TS 36.101 [7] with P_{CMAX_L} as defined in subclause 6.2.5.		

Table 7.6A.3-2: Out-of-band blocking for category M1 UE

Operating Band	Parameter	Unit	Range 1	Range 2	Range 3
	$P_{interferer}$	dBm	-44	-30	-15
253, 254[2,] 255	$F_{interferer}$ (C`W)	MHz	-60 < f – F_{DL_low} < -15 or 15 < f – F_{DL_high} < 60	-85 < f – F_{DL_low} ≤ -60 or 60 ≤ f – F_{DL_high} < 85	1 ≤ f ≤ F_{DL_low} – 85 or F_{DL_high} + 85 ≤ f ≤ 12750
256	$F_{interferer}$ (CW)	MHz	-100 < f – F_{DL_low} < -15 or 15 < f – F_{DL_high} < 60	-145 < f – F_{DL_low} ≤ -100 or 60 ≤ f – F_{DL_high} < 85	1 ≤ f ≤ F_{DL_low} – 145 or F_{DL_high} + 85 ≤ f ≤ 12750
252	$F_{interferer}$ (CW)	MHz	-110 < f – F_{DL_low} < -15 or 15 < f – F_{DL_high} < 60	-155 < f – F_{DL_low} ≤ -110 or 60 ≤ f – F_{DL_high} < 85	1 ≤ f ≤ F_{DL_low} – 155 or F_{DL_high} + 85 ≤ f ≤ 12750
NOTE 1: Void. NOTE 2: The power level of the interferer ($P_{interferer}$) for Range 3 shall be modified to -20 dBm for $F_{interferer}$ > 2585 MHz and $F_{Interferer}$ < 2775 MHz.					

For Table 7.6A.3-2 in frequency range 1, 2 and 3, up to $\max\left(24,\ 6\cdot\lceil N_{RB}/6\rceil\right)$ exceptions are allowed for spurious response frequencies in each assigned frequency channel when measured using a 1MHz step size, where N_{RB} is the number of resource blocks in the downlink transmission bandwidth configuration. For these exceptions the requirements of subclause 7.7A spurious response are applicable.

7.6A.4 Narrow band blocking for category M1

This requirement is measure of a receiver's ability to receive a E-UTRA signal at its assigned channel frequency in the presence of an unwanted narrow band CW interferer at a frequency, which is less than the nominal channel spacing.

The relative throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in TS 36.101 [7] Annexes A.2.2, A.2.3 and A.3.2 (with one sided dynamic OCNG Pattern OP.1 FDD for the DL-signal as described in TS 36.101 [7] Annex A.5.1.1) with parameters specified in Table 7.6A.4-1. For operating bands with an unpaired DL part (as noted in Table 5.2-1), the requirements only apply for carriers assigned in the paired part.

Table 7.6A.4-1: Narrow-band blocking

Parameter	Unit	Channel Bandwidth
		1.4 MHz
P_w	dBm	$P_{REFSENS}$ + channel-bandwidth specific value below
		22
P_{uw} (CW)	dBm	-55
F_{uw} (offset for Δf = 15 kHz)	MHz	0.9075
F_{uw} (offset for Δf = 7.5 kHz)	MHz	
NOTE 1: The transmitter shall be set a 4 dB below P_{CMAX_L} at the minimum uplink configuration specified in Table 7.3A-3 with P_{CMAX_L} as defined in subclause 6.2.5 of TS 36.101 [7]. NOTE 2: Reference measurement channel is specified in TS 36.101 [7] Annex A.3.2 with one sided dynamic OCNG Pattern OP.1 FDD as described in Annex A.5.1.1 of TS 36.101 [7]. NOTE 3: For DL category M1 UE, the reference sensitivity for category M1 in table 7.3A-1 should be used as $P_{REFSENS}$ for P_w. NOTE 4: For DL category M1 UE, the parameters for the applicable channel bandwidth apply. NOTE 5: For DL category M1 UE, the parameter, P_w, for all the channel bandwidth will be $P_{REFSENS}$ +22 dBm.		

7.6B Blocking characteristics for category NB1 and NB2

7.6B.1 General

The blocking characteristic is a measure of the receiver's ability to receive a wanted signal at its assigned channel frequency in the presence of an unwanted interferer on frequencies other than those of the spurious response or the adjacent channels, without this unwanted input signal causing a degradation of the performance of the receiver beyond a specified limit. The blocking performance shall apply at all frequencies except those at which a spurious response occurs.

7.6B.2 In-band blocking requirements for category NB1 and NB2

In-band blocking is defined for an unwanted interfering signal falling into the UE receive band or into the first 15 MHz below or above the UE receive band at which the relative throughput shall meet or exceed the minimum requirement for the specified measurement channels.

For category NB1 and NB2 UE, the requirements in clause 7.6.1.1F of TS 36.101 [7] shall apply.

7.6B.3 Out-of-band blocking requirements for category NB1 and NB2

For the first 15 MHz below or above the UE receive band the appropriate in-band blocking or adjacent channel selectivity in subclause 7.5B and subclause 7.6B.2 shall be applied.

The category NB1 and NB2 UE throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in TS 36.101 [7] Annexes A.3.2 with parameters specified in Table 7.6B.3-1.

For Table 7.6B.3-1 in frequency range 1, 2 and 3, up to 24 exceptions are allowed for spurious response frequencies in each assigned frequency channel when measured using a 1MHz step size. For these exceptions the requirements of subclause 7.7B spurious response are applicable.

Table 7.6B.3-1: Out-of-band blocking parameters for category NB1 and NB2 UE

Operating Band	Parameter	Unit	Range 1	Range 2	Range 3
	P_w	dBm	REFSENS + 6 dB		
	$P_{interferer}$	dBm	-44	-30	-15[3]
249, 253, 254[5], 255	$F_{interferer}$ (CW)	MHz	$-60 < f - F_{DL\_low} < -15$ or $15 < f - F_{DL\_high} < 60$	$-85 < f - F_{DL\_low} \le -60$ or $60 \le f - F_{DL\_high} < 85$	$1 \le f \le F_{DL\_low} - 85$ or $F_{DL\_high} + 85 \le f \le 12750$
256	$F_{interferer}$ (CW)	MHz	$-100 < f - F_{DL\_low} < -15$ or $15 < f - F_{DL\_high} < 60$	$-145 < f - F_{DL\_low} \le -100$ or $60 \le f - F_{DL\_high} < 85$	$1 \le f \le F_{DL\_low} - 145$ or $F_{DL\_high} + 85 \le f \le 12750$
252	$F_{interferer}$ (CW)	MHz	$-110 < f - F_{DL\_low} < -15$ or $15 < f - F_{DL\_high} < 60$	$-155 < f - F_{DL\_low} \le -110$ or $60 \le f - F_{DL\_high} < 85$	$1 \le f \le F_{DL\_low} - 155$ or $F_{DL\_high} + 85 \le f \le 12750$

NOTE 1: Void.
NOTE 2: Void.
NOTE 3: For operating bands which downlink band frequency range is between 1475.9 MHz < f < 2690 MHz the power level of the interferer ($P_{Interferer}$) for Range 3 shall be modified to: -20 dBm for the frequency range which is bounded by F_{DL_low}- 200 MHz of the lowest band that UE supports in frequency range 1475.9 MHz < f < 2690 MHz and F_{DL_high} + 200 MHz of the highest band that UE supports in frequency range 1475.9 MHz < f < 2690 MHz."
NOTE 4: The power level of the interferer ($P_{Interferer}$) for Range 3 shall be modified to -20 dBm for $F_{Interferer}$ > 2800 MHz and $F_{Interferer}$ < 4400 MHz.
NOTE 5: The power level of the interferer ($P_{interferer}$) for Range 3 shall be modified to -20 dBm for $F_{interferer}$ > 2585 MHz and $F_{Interferer}$ < 2775 MHz.

7.6B.4 Narrow band blocking for category NB1 and NB2

For category NB1 and NB2 UE, this is not applicable.

7.6C Blocking characteristics for BOG

7.6C.1 General

The blocking characteristic is a measure of the receiver's ability to receive a wanted signal at its assigned channel frequency in the presence of an unwanted interferer on frequencies other than those of the spurious response or the adjacent channels, without this unwanted input signal causing a degradation of the performance of the receiver beyond a specified limit. The blocking performance shall apply at all frequencies except those at which a spurious response occurs.

7.6C.2 In-band blocking requirements for BOG

In-band blocking is defined for an unwanted interfering signal falling into the UE receive band or into the first 15 MHz below or above the UE receive band at which the relative throughput shall meet or exceed the minimum requirement for the specified measurement channels.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annex A.1.3 with parameters specified in Tables 7.6C.2-1 and 7.6C.2-2.

Table 7.6C.2-1: In band blocking parameters

Rx parameter	Units	PMCH bandwidth
		10 MHz
Power in Transmission Bandwidth Configuration	dBm	REFSENS + 6
$BW_{Interferer}$	MHz	5
$F_{Ioffset, case 1}$	MHz	7.5+0.0025
$F_{Ioffset, case 2}$	MHz	12.5+0.0125
NOTE 1: The interferer consists of the Reference measurement channel specified in Annex A.1.3.		

Table 7.6C.2-2: In-band blocking

Operating band	Parameter	Unit	Case 1	Case 2
	$P_{Interferer}$	dBm	-56	-44
	$F_{Interferer}$ (offset)	MHz	=-BW/2 – $F_{Ioffset,case 1}$ & =+BW/2 + $F_{Ioffset,case 1}$	≤-BW/2 – $F_{Ioffset,case 2}$ & ≥+BW/2 + $F_{Ioffset,case 2}$
246	$F_{Interferer}$	MHz	(NOTE 2)	F_{DL_low} – 15 to F_{DL_high} + 15

NOTE 1: For certain bands, the unwanted modulated interfering signal may not fall inside the UE receive band, but within the first 15 MHz below or above the UE receive band

NOTE 2: For each carrier frequency the requirement is valid for two frequencies:

a. the carrier frequency -BW/2 - $F_{Ioffset, case 1}$ and

b. the carrier frequency +BW/2 + $F_{Ioffset, case 1}$

NOTE 3: $F_{Interferer}$ range values for unwanted modulated interfering signal are interferer center frequencies

7.6C.3 Out-of-band blocking requirements for BOG

Out-of-band band blocking is defined for an unwanted CW interfering signal falling more than 15 MHz below or above the UE receive band. For the first 15 MHz below or above the UE receive band the appropriate in-band blocking or adjacent channel selectivity in subclause 7.5C and subclause 7.6C.2 shall be applied.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annex A.1.3 with parameters specified in Tables 7.6C.3-1 and 7.6C.3-2.

Table 7.6C.3-1: Out-of-band blocking parameters

Rx Parameter	Units	PMCH bandwidth
		10 MHz
Power in Transmission Bandwidth Configuration	dBm	REFSENS + 6
NOTE: Reference measurement channel is specified in Annex A.1.3.		

Table 7.6C.3-2: Out of-band blocking

Operating Band	Parameter	Unit	Range 1	Range 2	Range 3
	P_w	dBm	REFSENS + 6 dB		
	$P_{interferer}$	dBm	-44	-30	-15
246	$F_{interferer}$ (CW)	MHz	-95 < f – F_{DL_low} < -15 or 15 < f – F_{DL_high} < 85	-95 < f – F_{DL_low} ≤ -120 or 85 ≤ f – F_{DL_high} < 110	1 ≤ f ≤ F_{DL_low} – 120 or F_{DL_high} + 110 ≤ f ≤ 12750

For Table 7.6C.3-2 in frequency range 1, 2 and 3, up to $\max\left(24, \quad 6\cdot\lceil N_{RB}/6\rceil\right)$ exceptions are allowed for spurious response frequencies in each assigned frequency channel when measured using a 1MHz step size, where N_{RB} is the number of resource blocks in the downlink transmission bandwidth configuration. For these exceptions the requirements of subclause 7.7C spurious response are applicable.

7.6C.4 Narrow band blocking for BOG

Narrow-band blocking requirements are not applicable to LTE based 5G broadcast over GSO satellite.

7.7 Spurious response

This clause is reserved.

7.7A Spurious response for category M1

Spurious response is a measure of the receiver's ability to receive a wanted signal on its assigned channel frequency without exceeding a given degradation due to the presence of an unwanted CW interfering signal at any other frequency at which a response is obtained i.e. for which the out of band blocking limit as specified in subclause 7.6A.2 is not met.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in TS 36.101 [7] Annexes A.2.2, A.2.3 and A.3.2 (with one sided dynamic OCNG Pattern OP.1 FDD for the DL-signal as described in TS 36.101 [7] Annex A.5.1.1) with parameters specified in Tables 7.7A-1 and 7.7A-2.

Table 7.7A-1: Spurious response parameters

Rx parameter	Units	Channel bandwidth
		1.4 MHz
Power in Transmission Bandwidth Configuration	dBm	REFSENS + channel bandwidth specific value below
		6
NOTE 1: The transmitter shall be set to 4dB below P_{CMAX_L} at the minimum uplink configuration specified in Table 7.3A-3 with P_{CMAX_L} as defined in subclause 6.2.5 of TS 36.101 [7]. N OTE 2: Reference measurement channel is specified in TS 36.101 [7] Annex A.3.2 with one sided dynamic OCNG Pattern OP.1 FDD as described in Annex A.5.1.1 of TS 36.101 [7]. NOTE 3: The REFSENS power level is specified in Table 7.3A-1.		

Table 7.7A-2: Spurious response

Parameter	Unit	Level
$P_{Interferer}$ (CW)	dBm	-44
$F_{Interferer}$	MHz	Spurious response frequencies

7.7B Spurious response for category NB1 and NB2

Spurious response is a measure of the receiver's ability to receive a wanted signal on its assigned channel frequency without exceeding a given degradation due to the presence of an unwanted CW interfering signal at any other frequency at which a response is obtained i.e. for which the out of band blocking limit as specified in subclause 7.6B.3 is not met.

For category NB1 and NB2 UE, the minimum requirements in clause 7.7.1F of TS 36.101 [7] shall apply.

7.7C Spurious response for BOG

Spurious response is a measure of the receiver's ability to receive a wanted signal on its assigned channel frequency without exceeding a given degradation due to the presence of an unwanted CW interfering signal at any other frequency at which a response is obtained i.e. for which the out of band blocking limit as specified in subclause 7.6C.2 is not met.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annex A.1.3 with parameters specified in Tables 7.7C-1 and 7.7C-2.

Table 7.7C-1: Spurious response parameters

Rx parameter	Units	Channel bandwidth
		10 MHz
Power in Transmission Bandwidth Configuration	dBm	REFSENS + channel bandwidth specific value below
		6
NOTE: Reference measurement channel is specified in Annex A.1.3.		

Table 7.7C-2: Spurious response

Parameter	Unit	Level
$P_{Interferer}$ (CW)	dBm	-44
$F_{Interferer}$	MHz	Spurious response frequencies

7.8 Intermodulation characteristics

Intermodulation response rejection is a measure of the capability of the receiver to receiver a wanted signal on its assigned channel frequency in the presence of two or more interfering signals which have a specific frequency relationship to the wanted signal.

7.8A Intermodulation characteristics for category M1

The definition in clause 7.8 shall apply. The wide band intermodulation requirement is defined following the same principles using modulated E-UTRA carrier and CW signal as interferer.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in TS 36.101 [7] Annexes A.2.2, A.2.3 and A.3.2 (with one sided dynamic OCNG Pattern OP.1 FDD for the DL-signal as described in TS 36.101 [7] Annex A.5.1.1) with parameters specified in Table 7.8A.1 for the specified wanted signal mean power in the presence of two interfering signals.

Table 7.8A-1: Wide band intermodulation

Rx Parameter	Units	Channel bandwidth
		1.4 MHz
Power in Transmission Bandwidth Configuration	dBm	REFSENS + channel bandwidth specific value below
		12
$P_{Interferer\ 1}$ (CW)	dBm	-46
$P_{Interferer\ 2}$ (Modulated)	dBm	-46
$BW_{Interferer\ 2}$		1.4
$F_{Interferer\ 1}$ (Offset)	MHz	-BW/2 –2.1 / +BW/2+ 2.1
$F_{Interferer\ 2}$ (Offset)	MHz	2*$F_{Interferer\ 1}$

NOTE 1: The transmitter shall be set to 4dB below P_{CMAX_L} at the minimum uplink configuration specified in Table 7.3A-3 with P_{CMAX_L} as defined in subclause 6.2.5 of TS 36.101 [7].
NOTE 2: Reference measurement channel is specified in TS 36.101 [7] Annex A.3.2 with one sided dynamic OCNG Pattern OP.1 FDD as described in Annex A.5.1.1 of TS 36.101 [7].
NOTE 3: The modulated interferer consists of the Reference measurement channel specified in TS 36.101 [7] Annex A.3.2 with one sided dynamic OCNG Pattern OP.1 FDD as described in Annex A.5.1.1 with set-up according to Annex C.3.1.
NOTE 4: For DL category M1 UE, the reference sensitivity for category M1 in table 7.3A-1 should be used as REFSENS for the power in Transmission Bandwidth Configuration.
NOTE 5: For DL category M1 UE, the parameters for the applicable channel bandwidth apply, and BW refers to the corresponding channel bandwidth.

7.8B Intermodulation characteristics for category NB1 and NB2

For category NB1 and NB2 UE, the definition in clause 7.8 and the requirements in clause 7.8.1F of TS 36.101 [7] shall apply.

7.8C Intermodulation characteristics for BOG

The definition in clause 7.8 shall apply. The wide band intermodulation requirement is defined following the same principles using modulated E-UTRA carrier and CW signal as interferer.

The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channels as specified in Annex A.1.3 with parameters specified in Table 7.8C.1 for the specified wanted signal mean power in the presence of two interfering signals.

Table 7.8C-1: Wide band intermodulation

Rx Parameter	Units	PMCH bandwidth
		10 MHz
Power in Transmission Bandwidth Configuration	dBm	REFSENS + 6
$P_{Interferer\ 1}$ (CW)	dBm	-46
$P_{Interferer\ 2}$ (Modulated)	dBm	-46
$F_{Interferer\ 1}$ (Offset)	MHz	-BW/2 – 7.5 / +BW/2 + 7.5
$F_{Interferer\ 2}$ (Offset)	MHz	2*$F_{Interferer\ 1}$
NOTE 1: Reference measurement channel is specified in Annex A.1.3.		

7.9 Spurious emissions

The spurious emissions power is the power of emissions generated or amplified in a receiver that appear at the UE antenna connector.

The spurious emissions requirements in clause 7.9.1 of TS 36.101 [7] shall apply.

8 Performance requirement

This clause contains performance requirements for the physical channels specified in TS 36.211 [3]. The performance requirements for the UE in this clause are specified for the measurement channels specified in Annex A, the propagation conditions in Annex D and the downlink channels in Annex B.

8.1 General

8.1.1 Receiver antenna capability

The performance requirements are based on UE(s) that utilize one or more antenna receivers.

For all test cases, the SNR is defined as

$$SNR = \frac{\sum_{j=1}^{N_{RX}} \hat{E}_s^{(j)}}{\sum_{j=1}^{N_{RX}} N_{oc}^{(j)}}$$

where N_{RX} denotes the number of receiver antenna connectors and the superscript receiver antenna connector j. The above SNR definition assumes that the REs are not precoded. The SNR definition does not account for any gain which can be associated to the precoding operation. The relative power of physical channels transmitted is defined in Annex C. The SNR requirement applies for the UE categories given for each test.

8.1.2 Applicability of requirements

8.1.2.1 Applicability of requirements for different channel bandwidths

In Clause 8 the test cases may be defined with different channel bandwidth to verify the same target FRC conditions with the same propagation conditions, correlation matrix and antenna configuration.

8.1.2.2 Applicability of requirements for optional UE features

The performance requirements in Table 8.1.2.2-1 shall apply for UEs which support optional UE features only. If same test is listed for different UE features/capabilities in Clauses 8.1.2.2, then this test shall apply for UEs which support all corresponding UE features/capabilities.

For UEs supporting NTN access (*ntn-Connectivity-EPC-r17*), the requirements in TS36.101 [7] Clause 8 also apply with NTN configurations, e.g., including Ephemeris, K_offset and NTN bands, according to the UE category and capability, as summarized in Table 8.1.2.2-2.

Table 8.1.2.2-1: Requirements applicability for optional UE features

UE feature/capability	Test list	Applicability notes
NTN access (ntn-Connectivity-EPC-r17)	Clause 8.2.1.1 (Test 1, Test 2, Test 3)	The requirements apply only for UE Category M1
	Clause 8.3.1.1 (Test 1, Test 2)	The requirements apply only for UE Category NB1, NB2
NTN scenario support (ntn-ScenarioSupport-r17)	Clause 8.2.1.1 (Test 1, Test 2, Test 3)	The requirements apply only for UE Category M1, and only when ntn-ScenarioSupport-r17 is “ngso” or is not included
	Clause 8.3.1.1 (Test 1, Test 2)	The requirements apply only for UE Category NB1, NB2, and only when ntn-ScenarioSupport-r17 is “ngso” or is not included
Operation in coverage enhancement mode A (ce-ModeA-r13)	Clause 8.2.1.1 (Test 1, Test 2)	The requirements apply only for UE Category M1
Operation in coverage enhancement mode B (ce-ModeB-r13)	Clause 8.2.1.1 (Test 3)	The requirements apply only for UE Category M1
Note: Void		

Table 8.1.2.2-2: Requirements applicability combinations of TS 36.101 and TS 36.102

	Supported bands	
ntn-ScenarioSupport-r17	**Both TN and NTN bands**	**Only NTN bands**
gso (GSO only)	TS 36.101 Clause 8 & 9 (with TN configurations)	TS 36.101 Clause 8 (with NTN GSO configurations)
ngso (NGSO only)	TS 36.101 Clause 8 &.9 (with TN configurations) TS 36.102 Clause 8 (with NTN NGSO configurations)	TS 36.101 Clause 8 (with NTN NGSO configurations) TS 36.102 Clause 8 (with NTN NGSO configurations)
not included (Both GSO and NGSO)	TS 36.101 Clause 8 & 9 (with TN configurations) TS 36.102 Clause 8 (with NTN NGSO configurations)	TS 36.101 Clause 8 (with NTN GSO configurations) TS 36.102 Clause 8 (with NTN NGSO configurations)

8.1.2.3 Applicability of requirements for different channel modelling

The applicability rules for requirements in section 8 are specified in Table 8.1.2.3-1 and Table 8.1.2.3-2.

Table 8.1.2.3-1: Applicability of requirements for UE category M1

If UE has passed			UE can skip			Applicability notes
Test type		Test list	Test type		Test list	
FDD and half-duplex FDD	PDSCH	Table 8.2.1.1.1.1-3 (Test 1)	FDD and half-duplex FDD	PDSCH	Table 8.2.1.1.1.1-2 (Test 1 and Test 3)	
FDD and half-duplex FDD	PDSCH	Table 8.2.1.1.1.1-3 (Test 2)	FDD and half-duplex FDD	PDSCH	Table 8.2.1.1.1.1-2 (Test 2 and Test 3)	

Table 8.1.2.3-2: Applicability of requirements for UE category NB1 and NB2

If UE has passed			UE can skip			Applicability notes
Test type		Test list	Test type		Test list	
Half-duplex FDD	NPDSCH	Table 8.3.1.1.1.1-3 (Test 1)	Half-duplex FDD	NPDSCH	Table 8.3.1.1.1.1-2 (Test 1 and Test 2)	

8.1.3 UE category and UE DL category

UE category and UE DL category refer to *ue-Category*, *ue-CategoryDL, and ue-Category-NB* define in 4.1, 4.1A and 4.1C from [11]. A UE that belongs to either a UE category or a UE DL category indicated in UE performance requirements in subclause 8 shall fulfil the corresponding requirements.

8.2 Demodulation performance requirements for UE category M1

The requirements for UE DL Category M1 in this sub-clause are defined based on the simulation results with UE DL Category M1 unless otherwise stated.

8.2.1 FDD and half-duplex FDD

8.2.1.1 PDSCH

The parameters specified in Table 8.2.1.1-1 are valid for FDD and half-duplex FDD tests unless otherwise stated.

Table 8.2.1.1-1: Common Test Parameters (FDD and half-duplex FDD)

Parameter	Unit	CE Mode A	CE Mode B
Inter-TTI Distance		1	1
Number of HARQ processes per component carrier	Processes	8	2
Maximum number of HARQ transmission		4	4
Redundancy version coding sequence rv_{idx} (Note 1)		{0, 2, 3, 1} for QPSK and 16QAM	{0,0,0,0,2,2,2,2,3,3,3,3,1,1,1,1 …} for QPSK
Cyclic Prefix		Normal	Normal
Beamforming Precoder for MPDCCH		N/A	N/A
BL/CE DL subframe configuration (fdd-DownlinkOrTddSubframeBitmapBR)		1111111111	1111111111
HARQ bundling(ce-HARQ-AckBundling)		Disabled	Disabled
K_{offset} (k-Offset)	ms	8	8
Note 1: rv_{idx} is defined in TS 36.213 [12] Table 7.1.7.1-2.			

8.2.1.1.1 Single-antenna port performance

8.2.1.1.1.1 Minimum Requirements

The requirements are specified in Table 8.2.1.1.1.1-2 and Table 8.2.1.1.1.1-3, with the addition of the parameters in Table 8.2.1.1.1.1-1, and the downlink physical channel setup according to Annex B.3.2. The purpose is to verify the performance of single antenna port configuration.

Table 8.2.1.1.1.1-1: Test Parameters for single antenna port (FRC)

Parameter		Unit	Test 1 in Table 8.2.1.1.1.1-2 Test 1 in Table B.2.1.1.1.1-3	Test 2 in Table 8.2.1.1.1.1-2 Test 2 in Table 8.2.1.1.1.1-3	Test 3 in Table 8.2.1.1.1.1-2
Downlink power allocation	ρ_A		-3	-3	-3
	ρ_B		-3 (Note 1)	-3 (Note 1)	-3 (Note 1)
	σ		0	0	0
	δ		3	3	3
N_{oc} at antenna port		dBm/15kHz	-98	-98	-98
Coverage enhancement mode			CE Mode A	CE Mode A	CE Mode B
PDSCH transmission mode			1	1	1
OFDM starting symbol (startSymbolBR)			2	2	2
Maximum number of repetitions (for PDSCH (*pdsch-maxNumRepetitionCEmodeA/ pdsch-maxNumRepetitionCEmodeB*))			Not configured	Not configured	Not configured
PDSCH repetition number			1	8	64
Frequency hopping (mpdcch-pdsch-HoppingConfig)			Disabled	Disabled	Disabled
Frequency hopping offset (mpdcch-pdsch-HoppingOffset)			N/A	N/A	N/A
Frequency hopping interval (interval-FDD)		ms	N/A	N/A	N/A
MPDCCH transmission duration (mPDCCH-NumRepetition)		ms	1	8	64
MPDCCH repetition number			1	8	64
Number of narrowbands for frequency hopping (mpdcch-pdsch-HoppingNB)			N/A	N/A	N/A
Starting subframe configuration for MPDCCH (mpdcch_startSF_UESS)			1	4	2.5
Narrowband for MPDCCH (mpdcch_Narrowband)			0	0	0
MPDCCH aggregation level			8	24	24

Note 1: $P_B = 1$.
Note 2: For each test, DC subcarrier puncturing shall be considered.
Note 3: If not otherwise stated, the values in this table refer to parameters in TS 36.211 [3] or/and TS 36.213 [12] as appropriate.

Table 8.2.1.1.1.1-2: Minimum performance for single antenna port (FRC)

Test number	Bandwidth and MCS	Reference Channel	OCNG Pattern	Propagation Condition	Correlation Matrix and Antenna Configuration	Reference value		UE Category
						Fraction of Maximum Throughput (%)	SNR (dB)	
1	1.4MHz 16QAM 1/2	R.1 FDD	OP.1 FDD	NTN-TDLC5-30	1x1	70	10.4	M1
2	1.4MHz QPSK 1/3	R.2 FDD	OP.1 FDD	NTN-TDLA100-200	1x1	70	-4.2	M1
3	1.4MHz QPSK 1/10	R.3 FDD	OP.1 FDD	NTN-TDLA100-10	1x1	70	-11.5	M1

Table 8.2.1.1.1.1-3: Minimum performance for single antenna port (FRC) with time-varying Doppler shift and propagation delay model

Test number	Bandwidth and MCS	Reference Channel	OCNG Pattern	Propagation Condition	Correlation Matrix and Antenna Configuration	Reference value		UE Category
						Fraction of Maximum Throughput (%)	SNR (dB)	
1	1.4MHz 16QAM 1/2	R.1 FDD	OP.1 FDD	NTN-TDLC5-30	1x1	70	11.4	M1
2	1.4MHz QPSK 1/3	R.2 FDD	OP.1 FDD	NTN-TDLA100-200	1x1	70	-3.2	M1
Note 1: The time-varying Doppler shift and propagation delay model, specified in Annex E, is applied.								

8.3 Demodulation performance requirements for UE category NB1 and NB2

8.3.1 Half-duplex FDD

8.3.1.1 NPDSCH demodulation requirements

The parameters specified in Table 8.3.1.1-1 and Table 8.3.1.1-2 are valid for all half-duplex FDD tests unless otherwise stated.

Table 8.3.1.1-1: Common Test Parameters

Parameter	Unit	Value
Number of HARQ processes per component carrier	Processes	1
Maximum number of HARQ transmission		4
Cyclic Prefix		Normal
eutraControlRegionSize-r13		N/A
downlinkBitmap-r13 and dl-Gap-r13		Not configured
dl-GapNonAnchor-r13 and downlinkBitmapNonAnchor-r13		Not configured
Unused REs or RB		OCNG
OCNG pattern		NB.OP.1

Table 8.3.1.1-2: Test Parameters of related NPDCCH and NPUSCH format 2 configurations

Parameter	Unit	Value
DCI format		DCI format N1
scheduling delay field (I_{Delay})		1
N_{Rep}^{AN} (*ack-NACK-NumRepetitions-r13*)		1
ACK/NACK resource field		0
Reference channel for NPDCCH		R.NB.3 FDD
α_{offset}(*npdcch-Offset-USS-r13*)		0
K_offset	ms	8

8.3.1.1.1 Single-antenna port performance

8.3.1.1.1.1 Minimum Requirements for standalone operation and in-band operation in NR carrier

The requirements are specified in Table 8.3.1.1.1.1-2 and Table 8.3.1.1.1.1-3 for bands other than 249 and in Table 8.3.1.1.1.1-5 for band 249, with the addition of the parameters in Table 8.3.1.1.1.1-1 for bands other than 249 and in Table 8.3.1.1.1.1-4 for band 249and the downlink physical channel setup according to Annex B.3.3. The purpose of these tests is to verify the performance.

Note: For the in-band requirement these apply to cases where there is no CRS and no control region under in-band operation.

Table 8.3.1.1.1.1-1: Test Parameters for NPDSCH under Standalone and In-band Operations

Parameter	Unit		Value
N_{oc} at antenna port	N_{oc1}	dBm/15kHz	-93 (Note 1)
	N_{oc2}	dBm/15kHz	-99 (Note 2)
NPDCCH repetition number		subframe	For Table 8.3.1.1.1.1-2, 32 for Test 1; 128 for Test 2. For Table 8.3.1.1.1.1-3, 32 for Test 1
$R_{\max}$ (*npdcch-NumRepetitions-r13*)		subframe	For Table 8.3.1.1.1.1-2, 64 for Test 1; 256 for Test 2. For Table 8.3.1.1.1.1-3, 64 for Test 1
G (*nPDCCH-startSF-USS-r13*)			1.5
Note 1: This noise is applied to all subframes from the end of the NPDCCH to the end of the following NPDSCH transmission. Note 2: This noise is applied to all subframes from the end of the NPDSCH to the end of the following NPDCCH transmission.			

Table 8.3.1.1.1.1-2: Minimum performance for NPDSCH under Standalone Operations and In-band Operations with 1 NRS port for frequency bands other than band 249

Test number	Bandwidth	Carrier Type	Reference Channel	Repetition number	Propagation condition	Number of NRS ports	Antenna Configuration	Reference value		UE Category
								Fraction of Maximum Throughput (%)	SNR (dB)	
1	200kHz	Anchor	R.NB.1 FDD	32	NTN-TDLC5-200	1	1x1	70%	-4.7	NB1, NB2
2	200kHz	Non-anchor	R.NB.2 FDD	128	NTN-TDLA100-10	1	1x1	70%	-10.6	NB1, NB2

Table 8.3.1.1.1.1-3: Minimum performance for NPDSCH under Standalone Operations and In-band Operations with 1 NRS port with time-varying Doppler shift and propagation delay model

Test number	Bandwidth	Carrier Type	Reference Channel	Repetition number	Propagation condition	Number of NRS ports	Antenna Configuration	Reference value		UE Category
								Fraction of Maximum Throughput (%)	SNR (dB)	
1	200kHz	Anchor	R.NB.1 FDD	32	NTN-TDLC5-200	1	1x1	70%	-4.2	NB1, NB2
Note 1: The time-varying Doppler shift and propagation delay model, specified in Annex E, is applied.										

Table 8.3.1.1.1.1-4: Test Parameters for NPDSCH under Standalone and In-band Operations for frequency band 249

Parameter	Unit		Test 1, 2
N_{oc} at antenna port	N_{oc1}	dBm/15kHz	-103 (Note 1)
	N_{oc2}	dBm/15kHz	-109 (Note 2)
NPDCCH repetition number		subframe	4 for Test 1 and Test 2.
R_{max} (*npdcch-NumRepetitions-r13*)		subframe	8 for Test 1 and Test 2.
G (*nPDCCH-startSF-USS-r13*)			16
Note 1: This noise is applied to all subframes from the end of the NPDCCH to the end of the following NPDSCH transmission. Note 2: This noise is applied to all subframes from the end of the NPDSCH to the end of the following NPDCCH transmission.			

Table 8.3.1.1.1-5: Minimum performance for NPDSCH under Standalone Operations and In-band Operations with 1 NRS port for frequency band 249**Test number**	**Bandwidth**	**Carrier Type**	**Reference Channel**	**Repetition number**	**Propagation condition**	**Number of NRS ports**	**Antenna Configuration**	**Reference value**		**UE Category**
								Fraction of Maximum Throughput (%)	**SNR (dB)**	
1	200kHz	Anchor	R.NB.1 FDD	4	NTN-TDLC5-200	1	1x1	70%	1.0	NB1, NB2
2	200kHz	Non-anchor	R.NB.2 FDD	4	NTN-TDLA100-10	1	1x1	70%	1.4	NB1, NB2

8.4 Demodulation performance requirements for BOG

8.4.1 Minimum requirements for PMCH

8.4.1.1 Minimum requirements with 15kHz subcarrier spacing

The receive characteristic of MBMS is determined by the BLER.

For the parameters specified in Table 8.4.1.1-1, the average downlink SNR shall be below the specified value for the BLER shown in Table 8.4.1.1-2.

Table 8.4.1.1-1: Test Parameters

Parameter		Unit	Value
Number of HARQ processes		Processes	None
Subcarrier spacing		kHz	15 kHz
Allocated subframes per Radio Frame			10 subframes
Number of OFDM symbols for PDCCH			2
Cyclic Prefix			Extended
Downlink power allocation	ρ_A	dB	0
	ρ_B	dB	0 (Note 1)
	σ	dB	0
N_{oc} at antenna port		dBm/15kHz	-98
Note 1: $P_B = 0$.			

Table 8.4.1.1-2: Minimum performance

Test number	Cell	Bandwidth (MHz)	Reference Channel	OCNG Pattern	Propagation condition	Correlation Matrix and antenna	Reference value		MBMS UE Category
							BLER (%)	SNR(dB)	
1	MBMS Dedicated Cell	10	R.PMCH.1 FDD	NA	NTN-TDLC5-5	1x2 low	1	3.7	≥1
2	MBMS Dedicated Cell	10	R.PMCH.2 FDD	NA	NTN-TDLC5-5	1x2 low	1	10.6	≥1

Annex A (normative): Measurement channels

A.1 DL reference measurement channels

A.1.1 Reference measurement channels for NPDSCH performance requirements

A.1.1.1 Standalone operation and in-band operation in NR carrier

Table A.1.1.1-1: NPDSCH Reference Channel with 1Tx Antenna for UE Category NB1 and NB2 for FDD

Parameter	Unit	Value	Value
Reference channel		R.NB.1 FDD	R.NB.2 FDD
Carrier Type		Anchor	Non-anchor
Channel bandwidth	KHz	200	200
Allocated subframes per Radio Frame		Note 1	Note 1
Modulation		QPSK	QPSK
I_{TBS}/I_{SF}		9/3	6/3
Target Coding Rate		1/2	1/3
Coding Rate		0.5	0.33
Information Bit Payload			
For Sub-Frames 1,2,3,6,7,8	Bits	616	392
For Sub-Frame 0,5	Bits	N/A	392
For Sub-Frame 4,9	Bits	Note 2	392
Number of Code Blocks			
For Sub-Frames 1,2,3,6,7,8		1	1
For Sub-Frame 0,5	Bits	N/A	1
For Sub-Frame 4,9	Bits	Note 3	1
Binary Channel Bits			
For Sub-Frames 1,2,3,6,7,8	Bits	320	320
For Sub-Frame 0,5	Bits	N/A	320
For Sub-Frame 4,9	Bits	Note 4	320
Max. Average Throughput	Bps	Note 5	Note 5
UE Category		NB1,NB2	NB1,NB2

Note 1: It shall depend on the specific NPDSCH scheduling. Note 2: N/A when n_f mod 2 = 0, otherwise 616.

Note 3: N/A when n_f mod 2 = 0, otherwise 1.

Note 4: N/A when n_f mod 2 = 0, otherwise 320.

Note 5: Maximum Average Throughput equals to sum of TB(i) divided by sum of T(i), where TB(i) is the TB size of NPDSCH over i^{th} NPDSCH scheduling period, and T(i) is the total time consisting of NPDCCH transmission duration, NPDCCH to NPDSCH scheduling delay, NPDSCH transmission duration, NPDSCH to NPUSCH format 2 scheduling delay, NPUSCH format 2 transmission duration, possible delay between NPUSCH format 2 and NPDCCH for next NPDSCH scheduling and subframes used for NPSS/NSSS/NPBCH/NB-SIB1/NB-SIB2 transmission during the i^{th} NPDSCH scheduling period.

Table A.1.1.1-2: NPDCCH Reference Channel for Category NB1 and NB2 UE

Parameter	Unit	Value
Reference channel		R.NB.3 FDD
Number of NRS ports		1
Channel bandwidth	MHz	0.2
Aggregation level	NCCE	2
DCI Format		N1
Payload (without CRC)	Bits	23

A.1.2 Reference measurement channels for PDSCH performance requirements

A.1.2.1 Single-antenna transmission (Common Reference Symbols)

Table A.1.2.1-1: Fixed Reference Channel Single Antenna Port

Parameter	Unit	Value		
Reference channel		R.1 FDD	R.2 FDD	R.3 FDD
Channel bandwidth	MHz	1.4	1.4	1.4
Allocated resource blocks		Note3	6	6
Allocated DL subframes per Radio Frame		Note 4	Note 5	Note 6
Modulation		16QAM	QPSK	QPSK
Target Coding Rate		1/2	1/3	1/10
Information Bit Payload				
For Sub-Frames 0,1,2,3,4,5,6,7,8,9	Bits	744	504	152
Number of Code Blocks				
For Sub-Frames 0,1,2,3,4,5,6,7,8,9	Code blocks	1	1	1
Binary Channel Bits				
For Sub-Frames 0,1,2,3,4,5,6,7,8,9	Bits	1656 (Note 7, 8)	1656 (Note 7, 8)	1656 (Note 7, 8)
Max. Throughput averaged over one period	Kbps	149	15.75	0.950
UE DL Category		M1	M1	M1

Note 1: Void.
Note 2: Reference signal, synchronization signals and PBCH are allocated as per TS 36.211 [3].
Note 3: Allocated PRB positions for PDSCH are {3, 4, 5}.
Note 4: The downlink subframes are scheduled at the 8^{th} and 9^{th} subframes every 10ms (starting from 0th subframe). Information bit payload is available from the 8^{th} to 9^{th} subframes. The corresponding MPDCCH is scheduled 2 subframes before the corresponding PDSCH transmissions.
Note 5: PDSCH subframes are scheduled at the 10^{th} to 17^{th} subframes every period (32ms). Information bit payload is available from the 10^{th} to 17^{th} subframes with repetition. (Starting from the 0^{th} subframe). The corresponding MPDCCH is scheduled from 1^{st} to 8^{th} subframe every 32ms (starting from 0^{th} subframe).
Note 6: PDSCH subframes are scheduled at the 96^{th} to 159^{th} subframes every period (160ms). Information bit payload is available at the 96^{th} to 159^{th} subframes with repetition. (Starting from the 0th subframe) The corresponding MPDCCH is scheduled from 31^{st} to 94^{th} subframe every 160ms (starting from 0^{th} subframe).
Note 7: MPDCCH, and PDSCH are dropped when overlapped with SIB1-BR, or SIB2 or SIB3.
Note 8: MPDCCH, and PDSCH are punctured in overlapping Resource Elements (RE)s with PSS/SSS/PBCH.

A.1.3 Reference measurement channels for PMCH performance requirements

A.1.3.1 SDO

A.1.3.1-1 Fixed Reference Channel for PMCH Receiver Requirements (15 kHz SCS)

Parameter	PMCH (15 kHz SCS)		
	Unit	Value	
Reference channel		R.PMCH.1	R.PMCH.2
PMCH bandwidth	MHz	10	10
Allocated resource blocks		50	50
Allocated subframes per Radio Frame(Note3)		10	10
Modulation		QPSK	16QAM
Target Coding Rate		1/3	1/2
Information Bit Payload (Note 1)			
For Sub-Frames 0,1,2,3,4,5,6,7,8,9	Bits	3624	9912
Number of Code Blocks per Sub-Frame (Note 2)		1	2
Binary Channel Bits Per Subframe			
For Sub-Frames 0,1,2,3,4,5,6,7,8,9	Bits	10200	20400
MBMS UE Category		≥ 1	≥ 1
Note 1: 2 OFDM symbols are reserved for PDCCH; and no CRS allocated as per TS 36.211 [3]. Note 2: If more than one Code Block is present, an additional CRC sequence of L = 24 Bits is attached to each Code Block (otherwise L = 0 Bit). Note 3: For FDD mode, all 10 subframes are available for MBMS, in line with TS 36.331 [6].			

A.2 OFDMA Channel Noise Generator (OCNG)

A.2.1 OCNG Patterns for Narrowband IoT

The following OCNG patterns are used for modelling allocations to virtual narrowband IoT UEs (which are not under test). The OCNG pattern for each sub frame specifies the allocations that shall be filled with OCNG, and furthermore, the relative power level of each such allocation.

In each test case the OCNG is expressed by parameters OCNG_RA and OCNG_RB which together with a relative power level (γ) specifies the NPDSCH EPRE-to-NRS EPRE ratios in OFDM symbols with and without Narrowband reference symbols, respectively. The relative power, which is used for modelling boosting per virtual UE allocation, is expressed by:

$$\gamma_i = \text{NPDSCH}_i\_\text{RA} / \text{OCNG}\_\text{RA} = \text{NPDSCH}_i\_\text{RB} / \text{OCNG}\_\text{RB},$$

where γ_i denotes the relative power level of the i:th virtual UE. The parameter settings of OCNG_RA, OCNG_RB and the set of relative power levels are chosen such that when also taking allocations to the UE under test into account, as given by a NPDSCH or NPDCCH reference channel, a transmitted power spectral density that is constant on an OFDM symbol basis is targeted.

A.2.1.1 Narrowband IoT OCNG pattern 1

Table A.2.1.1-1: NB.OP.1 FDD: OCNG FDD Pattern 1 Bandwidth	Relative power level γ [dB]	NPDCCH and corresponding NPDSCH Data
	Subframe	
	Unused subframes	
200KHz	0	Note 2
Note 1: These subframes are assigned to an arbitrary number of virtual UEs with one NPDSCH per virtual UE with corresponding NPDCCH; the data transmitted over the OCNG NPDSCHs shall be uncorrelated pseudo random data, which is QPSK modulated. The parameter γ is used to scale the power of NPDSCH and NPDCCH. Note 2: Subframes and/or REs available for narrowband IOT DL transmission depend on the in-band, guard band or standalone mode indicated in MIB, and scheduling delay between NPDCCH, NPDSCH, NPUSCH format 2 and NPDCCH specified in test cases.		

A.2.2 OCNG Patterns for FDD

The following OCNG patterns are used for modelling allocations to virtual UEs (which are not under test) and/or allocations used for MBSFN. The OCNG pattern for each sub frame specifies the allocations that shall be filled with OCNG, and furthermore, the relative power level of each such allocation.

In each test case the OCNG is expressed by parameters OCNG_RA and OCNG_RB which together with a relative power level (γ) specifies the PDSCH EPRE-to-RS EPRE ratios in OFDM symbols with and without reference

symbols, respectively. The relative power, which is used for modelling boosting per virtual UE allocation, is expressed by:

$$\gamma_i = NPDSCH_i\_RA / OCNG\_RA = NPDSCH_i\_RB / OCNG\_RB,$$

where γ_i denotes the relative power level of the i:th virtual UE. The parameter settings of OCNG_RA, OCNG_RB and the set of relative power levels are chosen such that when also taking allocations to the UE under test into account, as given by a NPDSCH or NPDCCH reference channel, a transmitted power spectral density that is constant on an OFDM symbol basis is targeted.

Moreover, the OCNG pattern is accompanied by a PCFICH/PDCCH/PHICH reference channel which specifies the control region. For any aggregation and PHICH allocation, the PDCCH and any unused PHICH groups are padded with resource element groups with a power level given respectively by PDCCH_RA/RB and PHICH_RA/RB as specified in the test case such that a total power spectral density in the control region that is constant on an OFDM symbol basis is targeted.

A.2.2.1 OCNG FDD Pattern 1: Two sided dynamic OCNG FDD pattern

This OCNG Pattern fills with OCNG all empty PRB-s (PRB-s with no allocation of data or system information) of the DL sub-frames, when the unallocated area is discontinuous in frequency domain (divided in two parts by the allocated area – two sided), starts with PRB 0 and ends with PRB $N_{RB} - 1$.

Table A.2.2.1-1: OP.1 FDD: Two sided dynamic OCNG FDD Pattern

Relative power level γ_{PRB} [dB]			**PDSCH Data**
Subframe			
0	5	1 – 4, 6 – 9	
Allocation			
0 – (First allocated PRB-1) and (Last allocated PRB+1) – (N_{RB} –1)	0 – (First allocated PRB-1) and (Last allocated PRB+1) – (N_{RB} –1)	0 – (First allocated PRB-1) and (Last allocated PRB+1) – (N_{RB} –1)	
0	0	0	Note 1
Note 1: These physical resource blocks are assigned to an arbitrary number of virtual UEs with one PDSCH per virtual UE; the data transmitted over the OCNG PDSCHs shall be uncorrelated pseudo random data, which is QPSK modulated. The parameter γ_{PRB} is used to scale the power of PDSCH.			

A.3 Testing related to Satellite Access

A.3.1 General

The following test conditions should be maintained for Satellite Access when test equipment emulates the snapshot of the satellite link channel.

- The same ephemeris info will be maintained during each test.
- A set of ephemeris information are pre-defined for each satellite corresponding to respective epoch times in TS 36.508 [14].
- The range of the selected constant delay shift is as follows:
    - For NGSO an altitude of 600km and 1200km on a circular orbit are considered. The range of the one-way delay between UE and satellite is from 2ms (lowest value for LEO orbit 600km) to 6.67ms (highest value for LEO orbit 1200km).
- Constant delay value is derived from ephemeris info (SIB31) and UE location associated to zero Doppler or non-zero Doppler value under test.

The following test conditions should be maintained for Satellite Access when test equipment emulates the time varying satellite link based on Annex E.

- The ephemeris info will be updated according to the velocity and position of satellite during each test.
- The Doppler shift and propagation delay vary due to satellite motion and Earth rotation.

A.3.2 Test condition for transmitter characteristics

All requriements in section 6 for transmitter characteristics, other than frequency error in clauses 6.4A.1 and 6.4B.1, shall be verified when Doppler conditions are set to zero and delay conditions are set to constant for all types of satellites.

Frequency error requirement in clauses 6.4A.1 and 6.4B.1 shall be verified for at least two cases: one with zero Doppler condition and the other one with constant Doppler (different from zero) up to 0.93 ppm for GSO satellites and up to 24 ppm for NGSO satellites.

A.3.3 Test condition for receiver characteristics

All requirements in section 7 for receiver characteristics shall be verified when Doppler conditions related to satellite motion for DL in service link are set to zero and delay conditions are set to constant for all types of satellites.

A.3.4 Test condition for performance requirements

All requirements defined in Table 8.2.1.1.1.1-2 and Table 8.3.1.1.1.1-2 of section 8 for performance requirements shall be verified when Doppler conditions related to satellite motion for DL in service link are set to zero and delay conditions are set to constant for all types of NGSO at an altitude of 600km is 2ms.

All requirements defined in Table 8.2.1.1.1.1-3 and Table 8.3.1.1.1.1-3 of section 8 for performance requirements shall be verified when Doppler conditions related to satellite motion for DL in service link are set to time varying and delay conditions are set to time varying for all types of NGSO satellites as defined in Annex E.

A.4 UL reference measurement channels

A.4.1 General

The measurement channels in the following subclauses are defined to derive the requirements in clause 6 (Transmitter Characteristics) and clause 7 (Receiver Characteristics). The measurement channels represent example configurations of physical channels for different data rates.

A.4.1.1 Applicability and common parameters

The UL reference measurement channels comprise transmission of PUSCH and Demodulation Reference signals only.

The following conditions apply:

- 1 HARQ transmission
- Cyclic Prefix normal
- PUSCH hopping off
- Link adaptation off
- Demodulation Reference signal as per TS 36.211 [3] subclause 5.5.2.1.2.

Where ACK/NACK is transmitted, it is assumed to be multiplexed on PUSCH as per TS 36.212 [15] subclause 5.2.2.6.

- ACK/NACK 1 bit
- ACK/NACK mapping adjacent to Demodulation Reference symbol
- ACK/NACK resources punctured into data
- Max number of resources for ACK/NACK: 4 SC-FDMA symbols per subframe
- No CQI transmitted, no RI transmitted

A.4.1.2 Determination of payload size

The algorithm for determining the payload size A is as follows; given a desired coding rate R and radio block allocation N_{RB}:

1. Calculate the number of channel bits N_{ch} that can be transmitted during the first transmission of a given sub-frame.
2. Find A such that the resulting coding rate is as close to R as possible, that is,

$$\min\left|R-(A+24*(N_{CB}+1))/N_{ch}\right|,\ where\ \ N_{CB}=\begin{cases}0,\ if\ \ C=1\\ C,\ if\ \ C>1\end{cases},$$

subject to

a) A is a valid TB size according to clause 7.1.7 of TS 36.213 [12] assuming an allocation of N_{RB} resource blocks.

b) *C* is the number of Code Blocks calculated according to section 5.1.2 of TS 36.212 [15].

c) For RMC-s, which at the nominal target coding rate do not cover all the possible UE categories for the given modulation, reduce the target coding rate gradually (within the same modulation), until the maximal possible number of UE categories is covered.

3. If there is more than one *A* that minimises the equation above, then the larger value is chosen per default and the chosen code rate should not exceed 0.93.

A.4.1.3 Overview of UL reference measurement channels

In Table A.4.1.3-1 to A.4.1.3-2 are listed the UL reference measurement channels specified in Annexes A.4.2 and A.4.3 of this release of TS 36.102. This table is informative and serves only to a better overview. The reference for the concrete reference measurement channels and corresponding implementation's parameters as to be used for testing are annexes A.4.2 and A.4.3 as appropriate.

Table A.4.1.3-1: Overview of UL reference measurement channels

Duplex	Table	Name	BW	Mod	TCR	RB	RB Offset	UE Categ	Notes
FDD, Full RB allocation, QPSK									
FDD / HD-FDD	Table A.4.2.1.1-1		1.4	QPSK	1/3	6		M1	
FDD, Full RB allocation, 16-QAM									
FDD / HD-FDD	Table A.4.2.1.2-1		1.4	16QAM	1/3	6		M1	
FDD, Partial RB allocation, QPSK									
FDD / HD-FDD	Table A.4.2.2.1-1		1.4	QPSK	1/3	1		M1	
FDD / HD-FDD	Table A.4.2.2.1-1		1.4	QPSK	1/3	2		M1	
FDD / HD-FDD	Table A.4.2.2.1-1		1.4	QPSK	1/3	3		M1	
FDD / HD-FDD	Table A.4.2.2.1-1		1.4	QPSK	1/3	4		M1	
FDD / HD-FDD	Table A.4.2.2.1-1		1.4	QPSK	1/3	5		M1	
FDD, Partial RB allocation, 16-QAM									
FDD / HD-FDD	Table A.4.2.2.2-1		1.4	16QAM	1/2	1		M1	
FDD / HD-FDD	Table A.4.2.2.2-1		1.4	16QAM	1/2	2		M1	
FDD / HD-FDD	Table A.4.2.2.2-1		1.4	16QAM	1/2	3		M1	
FDD / HD-FDD	Table A.4.2.2.2-1		1.4	16QAM	2/5	4		M1	
FDD, SubPRB allocation									
FDD / HD-FDD	Table A.4.2.3-1		1.4	π/2 BPSK	1/3	1		M1	2 out of 3 subcarriers
FDD / HD-FDD	Table A.4.2.3-1		1.4	QPSK	1/3	1		M1	3 subcarriers
FDD / HD-FDD	Table A.4.2.3-1		1.4	QPSK	1/3	1		M1	6 subcarriers

Table A.4.1.3-2: Overview of UL reference measurement channels (HD-FDD, NB-IoT)

Duplex	Table	Name	BW	Mod	TCR	RB	RB Off set	UE Cat eg	Notes
HD-FDD	Table A.4.3-1		0.2	π/2 BPSK	1/3	1		NB1	
HD-FDD	Table A.4.3-1		0.2	π/4 QPSK	1/3	1		NB1	
HD-FDD	Table A.4.3-1		0.2	π/2 BPSK	1/3	1		NB1	
HD-FDD	Table A.4.3-1		0.2	π/4 QPSK	1/3	1		NB1	
HD-FDD	Table A.4.3-1		0.2	QPSK	1/3	1		NB1	
HD-FDD	Table A.4.3-1		0.2	QPSK	1/3	1		NB1	
HD-FDD	Table A.4.3-1		0.2	QPSK	1/3	1		NB1	

A.4.2 Reference measurement channels for FDD

A.4.2.1 Full RB allocation

A.4.2.1.1 QPSK

Table A.4.2.1.1-1: Reference Channels for QPSK with full/maximum RB allocation for UE category M1

Parameter	Unit	Value
Channel bandwidth	MHz	1.4
Allocated resource blocks		6
DFT-OFDM Symbols per Sub-Frame		12
Modulation		QPSK
Target Coding rate		1/3
Payload size	Bits	600
Transport block CRC	Bits	24
Number of code blocks per Sub-Frame		1
Total number of bits per Sub-Frame	Bits	1728
Total symbols per Sub-Frame		864
UE Category		M1
NOTE 1: If more than one Code Block is present, an additional CRC sequence of L = 24 Bits is attached to each Code Block (otherwise L = 0 Bit) NOTE 2: For HD-FDD UE, the uplink subframes are scheduled at the 4th, 5th and 6th subframes every 10ms for the channel bandwidth 5MHz/10MHz/15MHz/20MHz. For HD-FDD UE, the uplink subframes are scheduled at the 5th, 6th, and 7th subframes every 10ms for the channel bandwidth 1.4MHz/3MHz. Information bit payload is available if uplink subframe is scheduled. N_{abs}^{PUSCH} is total number of absolute subframes a PUSCH with repetition spans [4]. NOTE 3: For HD-FDD UE with $N_{abs}^{PUSCH} > 1$, MPDCCH are scheduled at 0th DL subframe every N_{abs}^{PUSCH} +5 subframes (starting from the 0th subframe). The associated PUSCH is scheduled at the 4th to (N_{abs}^{PUSCH} +3)-th UL subframes every N_{abs}^{PUSCH} +5 subframes. Information bit payload is available if uplink subframe is scheduled.		

A.4.2.1.2 16-QAM

Table A.4.2.1.2-1: Reference Channels for 16-QAM with maximum RB allocation for UE category M1

Parameter	Unit	Value
Channel bandwidth	MHz	1.4
Allocated resource blocks		6
DFT-OFDM Symbols per Sub-Frame		12
Modulation		16QAM
Target Coding rate		1/3
Payload size	Bits	872
Transport block CRC	Bits	24
Number of code blocks per Sub-Frame		1
Total number of bits per Sub-Frame	Bits	2880
Total symbols per Sub-Frame		720
UE Category		M1
NOTE 1: If more than one Code Block is present, an additional CRC sequence of L = 24 Bits is attached to each Code Block (otherwise L = 0 Bit) NOTE 2: For HD-FDD UE, the uplink subframes are scheduled at the 5th, 6th, and 7th subframes every 10ms for the channel bandwidth 1.4MHz. Information bit payload is available if uplink subframe is scheduled.		

A.4.2.2 Partial RB allocation

For each channel bandwidth, various partial RB allocations are specified. The number of allocated RBs is chosen according to values specified in the Tx and Rx requirements. The single allocated RB case is included.

The allocated RBs are contiguous and start from one end of the channel bandwidth. A single allocated RB is at one end of the channel bandwidth.

A.4.2.2.1 QPSK

Table A.4.2.2.1-1: Reference Channels for QK with partial RB allocation for UE category M1

Parameter	Ch BW	Allocated RBs	DFT-OFDM Symbols per Sub-Frame	Mod'n	Target Coding rate	Payload size	Trans-port block CRC	Number of code blocks per Sub-Frame (Note 1)	Total number of bits per Sub-Frame	Total symbols per Sub-Frame	UE Category
Unit	**MHz**					**Bits**	**Bits**		**Bits**		
	1.4	1	12	QPSK	1/3	72	24	1	288	144	M1
	1.4	2	12	QPSK	1/3	176	24	1	576	288	M1
	1.4	3	12	QPSK	1/3	256	24	1	864	432	M1
	1.4	4	12	QPSK	1/3	392	24	1	1152	576	M1
	1.4	5	12	QPSK	1/3	424	24	1	1440	720	M1
Note 1: If more than one Code Block is present, an additional CRC sequence of L = 24 Bits is attached to each Code Block (otherwise L = 0 Bit) Note 2: For HD-FDD UE, the uplink subframes are scheduled at the 5th, 6th, and 7th subframes every 10ms for the channel bandwidth 1.4MHz/3MHz. Information bit payload is available if uplink subframe is scheduled.											

A.4.2.2.2 16-QAM

Table A.4.2.2.2-1: Reference Channels for 16-QAM with partial RB allocation for UE category M1

Parameter	Ch BW	Allocated RBs	DFT-OFDM Symbols per Sub-Frame	Mod'n	Target Coding rate	Payload size	Transport block CRC	Number of code blocks per Sub-Frame (Note 1)	Total number of bits per Sub-Frame	Total symbols per Sub-Frame	UE Category
Unit	**MHz**					**Bits**	**Bits**		**Bits**		
	1.4	1	12	16QAM	1/2	256	24	1	576	144	M1
	1.4	2	12	16QAM	1/2	552	24	1	1152	288	M1
	1.4	3	12	16QAM	1/2	840	24	1	1728	432	M1
	1.4	4	12	16QAM	2/5	904	24	1	2304	576	M1
Note 1: If more than one Code Block is present, an additional CRC sequence of L = 24 Bits is attached to each Code Block (otherwise L = 0 Bit). Note 2: For HD-FDD UE, the uplink subframes are scheduled at the 5th, 6th, and 7th subframes every 10ms for the channel bandwidth 1.4MHz/3MHz. Information bit payload is available if uplink subframe is scheduled.											

A.4.2.3 subPRB allocation

The location of allocated RB for subPRB allocation is chosen according to values specified in the Tx requirements.

Table A.4.2.3-1: Reference Channels for SubPRB allocation

Parameter	Unit	Value		
Channel bandwidth	MHz	1.4	1.4	1.4
Allocated resource blocks		1	1	1
Number of subcarriers		2 out of 3	3	6
DFT-OFDM Symbols per Sub-Frame		12	12	12
Modulation		π/2 BPSK	QPSK	QPSK
Target Coding rate		1/3	1/3	1/3
Payload size	Bits	32	72	72
Transport block CRC	Bits	24	24	24
Number of code blocks		1	1	1
Total number of bits per resource unit	Bits	192	288	288
Total symbols per resource unit		192	144	144
Tx time	ms	8	4	2
UE UL Category		M1	M1	M1
NOTE 1: If more than one Code Block is present, an additional CRC sequence of L = 24 Bits is attached to each Code Block (otherwise L = 0 Bit)				

A.4.3 Reference measurement channels for category NB1

Table A.4.3-1 Reference Channels for category NB1

Parameter	Value						
Sub-carrier spacing (kHz)	3.75	3.75	15	15	15	15	15
Number of tone	1	1	1	1	3	6	12
Modulation	π/2 BPSK	π/4 QPSK	π/2 BPSK	π/4 QPSK	QPSK	QPSK	QPSK
Number of NPUSCH repetition (NOTE 5)	1	1	1	1	1	1	1
IMCS / ITBS	0 / 0	3 / 3	0 / 0	3 / 3	5 / 5	5 / 5	5 / 5
Payload size (bits)	32	40	32	40	72	72	72
Allocated resource unit	2	1	2	1	1	1	1
Code rate (target)	1/3	1/3	1/3	1/3	1/3	1/3	1/3
Code rate (effective)	0.29	0.33	0.29	0.33	0.33	0.33	0.33
Transport block CRC (bits)	24	24	24	24	24	24	24
Code block CRC size (bits)	0	0	0	0	0	0	0
Number of code blocks - C	1	1	1	1	1	1	1
Total number of bits per resource unit	96	192	96	192	288	288	288
Total symbols per resource unit	96	96	96	96	144	144	144
Tx time (ms)	64	32	16	8	4	2	1
NOTE 1: If more than one Code Block is present, an additional CRC sequence of L = 24 Bits is attached to each Code Block (otherwise L = 0 Bit). NOTE 2: Parameters related to NPUSCH format 1 scheduling are defined in Table A.4.3-2. NOTE 3: NPDCCH is not transmitted in the subframes used for transmission of SI messages. NOTE 4: SI messages transmission should be prioritized over NPDCCH transmission in case of collision. NPDCCH transmission is postponed until the next NB-IoT downlink subframe in case NPDCCH transmission occurs in a non NB-IoT downlink subframe, where an NB-IoT downlink subframe is a subframe that does not contain NPSS/NSSS/NPBCH/SIB1-NB transmission. NOTE 5: Number of repetition N_{Rep} as defined in table 16.5.1.1-3 in TS 36.213 [12].							

Table A.4.3-2: NPDCCH configuration for NPUSCH format 1 scheduling

Parameter	Unit	Value
DCI format		DCI format N0
NPDCCH format		1
Scheduling delay (I_{Delay})		0
DCI subframe repetition number		00
$R_{\max}$ (*npdcch-NumRepetitions*)		1
G (*NPDCCH-startSF-USS*)		8
α_{offset} (*npdcch-Offset-USS*)		1/4

Annex B (normative): Downlink physical channels

B.1 General

This annex specifies the downlink physical channels that are needed for setting a connection and channels that are needed during a connection.

B.2 Set-up

Table B.2-1 and B.2-2 describes the downlink Physical Channels that are required for connection set up.

Table B.2-1: Downlink Physical Channels required for connection set-up (Cat-M1)

Physical Channel
PBCH
SSS
PSS
MPDCCH
PDSCH

Table B.2-2: Downlink Physical Channels required for connection set-up (Cat NB1/NB2)Physical Channel
NPBCH
NSSS
NPSS
NPDCCH
NPDSCH

B.3 Connection

The following clauses, describes the downlink Physical Channels that are transmitted during a connection i.e., when measurements are done.

B.3.1 Measurement of Receiver Characteristics

Unless otherwise stated, Table B.3.1-1 is applicable for measurements on the Receiver Characteristics (clause 7).

Table B.3.1-1: Downlink Physical Channels transmitted during a connection

Physical Channel	EPRE Ratio
PBCH	PBCH_RA = 0 dB
	PBCH_RB = 0 dB
PSS	PSS_RA = 0 dB
SSS	SSS_RA = 0 dB
PDSCH	PDSCH_RA = 0 dB
	PDSCH_RB = 0 dB
OCNG	OCNG_RA = 0 dB
	OCNG_RB = 0 dB

NOTE 1: No boosting is applied.

Table B.3.1-2: Power allocation for OFDM symbols and reference signals

Parameter	Unit	Value	Note
Transmitted power spectral density I_{or}	dBm/15 kHz	Test specific	1. I_{or} shall be kept constant throughout all OFDM symbols
Cell-specific reference signal power ratio E_{RS}/I_{or}		0 dB	

B.3.2 Measurement of Performance requirements

Table B.3.2-1 is applicable for measurements in which uniform RS-to-EPRE boosting for all downlink physical channels, unless otherwise stated.

Table B.3.2-1: Downlink Physical Channels transmitted during a connection

Physical Channel	EPRE Ratio
PBCH	PBCH_RA = ρ_A+ σ
	PBCH_RB = ρ_B+ σ
PSS	PSS_RA = 0 (Note 3)
SSS	SSS_RA = 0 (Note 3)
MPDCCH	MPDCCH_RA = ρ_A+δ
	MPDCCH_RB = ρ_B+δ
PDSCH	PDSCH_RA = ρ_A
	PDSCH_RB = ρ_B
OCNG	OCNG_RA = ρ_A+ σ
	OCNG_RB = ρ_B+ σ

NOTE 1: ρ_A= ρ_B = 0 dB means no RS boosting.

NOTE 2: OCNG are not defined downlink physical channels in [3].

NOTE 3: Assuming PSS and SSS transmitted on a single antenna port.

NOTE 4: ρ_A, ρ_B, σ, and δ are test specific.

Table B.3.2-2: Power allocation for OFDM symbols and reference signals

Parameter	Unit	Value	Note
Total transmitted power spectral density I_{or}	dBm/15 kHz	Test specific	1. I_{or} shall be kept constant throughout all OFDM symbols
Cell-specific reference signal power ratio E_{RS}/I_{or}		Test specific	1. Applies for antenna port *p*
Energy per resource element EPRE		Test specific	1. The complex-valued symbols $y^{(p)}(i)$ and $a_{k,l}^{(p)}$ defined in TS 36.211 [3] shall conform to the given EPRE value.

B.3.3 Measurement of Receiver Characteristics for Narrowband IoT

For the performance requirements for Narrowband IoT, the power allocation for the physical channels is listed in Table B.3.3-1.

Table B.3.3-1: Downlink Physical Channels transmitted during a connection

Physical Channel	EPRE Ratio for one NRS antenna port	EPRE Ratio for two NRS antenna ports
NPBCH	0 dB	-3 dB
NPDCCH	0 dB	-3 dB
NPDSCH	0 dB	-3 dB
NPSS	0 dB	0 dB
NSSS	0 dB	0 dB

NOTE 1: Assuming NPSS and NSSS transmitted on one NRS antenna port.

Table B.3.3-2: Power allocation for OFDM symbols and reference signals

Parameter	Unit	Value	Note
Transmitted power spectral density I_{or}	dBm/15 kHz	Test specific	I_{or} shall be kept constant throughout all OFDM symbols
Narrowband reference signal power ratio E_{CRS}/I_{or}		0 dB	Applicable for Stand-alone operation
Narrowband reference signal power over cell-specific reference signal power E_{NRS}/E_{RS}		0 dB	Applicable for In-band operation

Annex C (normative): Environment conditions

C.1 General

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

C.2 Environmental

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

C.2.1 Temperature

The UE shall fulfil all the requirements in the full temperature range of:

Table C.2.1-1

+15°C to +35°C	for normal conditions (with relative humidity of 25 % to 75 %)

Outside this temperature range the UE, if powered on, shall not make ineffective use of the radio frequency spectrum. In no case shall the UE exceed the transmitted levels as defined in clause 6.2 of TS 36.101 [7] for extreme operation.

C.2.2 Voltage

The UE shall fulfil all the requirements in the full voltage range defined in Table C.2.2-1.

Table C.2.2-1

Power source	Normal conditions voltage
AC mains	nominal
Regulated lead acid battery	1,1 * nominal
Non regulated batteries: Leclanché Lithium Mercury/nickel & cadmium	 Nominal 1,1 * Nominal Nominal

Outside this voltage range the UE if powered on, shall not make ineffective use of the radio frequency spectrum. In no case shall the UE exceed the transmitted levels as defined in clause 6.2 of TS 36.101 [7] for extreme operation. In particular, the UE shall inhibit all RF transmissions when the power supply voltage is below the manufacturer declared shutdown voltage.

C.2.3 Vibration

The UE shall fulfil all the requirements when vibrated at the following frequency/amplitudes.

Table C.2.3-1

Frequency	ASD (Acceleration Spectral Density) random vibration
5 Hz to 20 Hz	0,96 m^2/s^3
20 Hz to 500 Hz	0,96 m^2/s^3 at 20 Hz, thereafter –3 dB/Octave

Outside the specified frequency range the UE, if powered on, shall not make ineffective use of the radio frequency spectrum. In no case shall the UE exceed the transmitted levels as defined in TS 36.101 [6] for extreme operation.

Annex D (normative): Propagation conditions

D.1 Multi-path fading propagation conditions

The multipath propagation conditions consist of several parts:

- A delay profile in the form of a "tapped delay-line", characterized by a number of taps at fixed positions on a sampling grid. The profile can be further characterized by the r.m.s. delay spread and the maximum delay spanned by the taps.
- A combination of channel model parameters that include the Delay profile and the Doppler spectrum that is characterized by a classical spectrum shape and a maximum Doppler frequency.

D.1.1 Delay profiles

The delay profiles are derived from the TR 38.811 [13] NTN-TDL models for the desired delay spread and tap resolution. After scaling the normalized delay spread values for each tap by the desired RMS delay spread, the tap delays are quantized to a delay resolution of 5ns by rounding to the nearest multiple of the delay resolution.

Table D.1.1-1: Delay profiles for IoT NTN and BOG channel models

Type	Model	Delay spread (r.m.s.)	Delay resolution
NLOS	NTN-TDLA100	100 ns	5 ns
LOS	NTN-TDLC5	5 ns	5 ns

Table D.1.1-2: NTN-TDLA100 (DS = 100 ns)

Tap #	Delay [ns]	Power [dB]	Fading distribution
1	0	0	Rayleigh
2	110	-4.7	Rayleigh
3	285	-6.5	Rayleigh

Table D.1.1-3 NTN-TDLC5 (DS = 5 ns)

Tap #	Delay [ns]	Power [dB]	Fading distribution
1	0	-0.6	LOS path
	0	-8.9	Rayleigh
2	60	-21.5	Rayleigh
Note 1: Tap #1 follows a Rician distribution.			

D.1.2 Combinations of channel model parameters

The propagation conditions used for the performance measurements in multi-path fading environment are indicated as a combination of a channel model name and a maximum Doppler frequency, i.e., NTN-TDLA<DS>-<Doppler>, or NTN-TDLC<DS>-<Doppler> where '<DS>' indicates the desired delay spread and '<Doppler>' indicates the maximum Doppler frequency (Hz).

Table D.1.2-1 show the propagation conditions that are used for the performance measurements in multi-path fading environment for NLOS and LOS propagation conditions.

Table D.1.2-1: Channel model parameters for NTN

Combination name	Model	Maximum Doppler frequency
NTN-TDLA100-10	NTN-TDLA100	10 Hz
NTN-TDLA100-200	NTN-TDLA100	200 Hz
NTN-TDLC5-30	NTN-TDLC5	30 Hz
NTN-TDLC5-200	NTN-TDLC5	200 Hz
NTN-TDLC5-5	NTN-TDLC5	5 Hz

Annex E (Normative): Modelling of time varying Doppler shift and propagation delay for NGSO

E.1 General

This annex specifies the methodologies for time varying Doppler shift and propagation delay modelling for NGSO.

E.2 Satellite position/velocity estimation

As a first step, it is necessary to perform the satellite's orbital calculations. There are two methodologies applicable to model the time varying Doppler shift and propagation delay by a test equipment, i.e. Newton-Raphson method to solve Keplerian model and fourth-order Runge-Kutta method to solve equation of motion. It is up to the implementation for test equipment on which method to apply to.

Table E.2-1: Input values for calculation of satellite orbit in format of orbital parameters

Parameters	Unit	Description
Semi-major axis (a)	m	Half the length of the longest diameter of the elliptical orbit in Earth-centred Inertial frame (ECI).
Eccentricity (e)	rad	Shape of the orbit, ranging from 0 to 1.
Inclination (i)	rad	Angle between the orbital plane and the reference plane (typically Earth's equatorial plane)
Longitude of ascending node (Ω)	rad	Angle from a reference direction (i.e. vernal equinox) to the ascending node, where the satellite crosses the equatorial plane from south to north.
Argument of periapsis (ω)	rad	Angle from the ascending node to the perigee—the point where the satellite is closest to Earth.
Mean anomaly (M_0)	rad	Satellite's position along its orbit at time 0, expressed as an angle measured from perigee.
t	second	Time to derive the satellite position and velocity.Set to 0 at the initialization.

Table E.2-2: Input values for calculation of satellite orbit in format of state vectors

Parameters	Unit	Description
$\boldsymbol{r_0^{ECEF}} = \left[r_{0,x}^{ECEF} \quad r_{0,y}^{ECEF} \quad r_{0,z}^{ECEF}\right]$	km	Initial satellite position state vector at time 0 in Earth-centred earth-fixed frame (ECEF)
$\boldsymbol{v_0^{ECEF}} = \left[v_{0,x}^{ECEF} \quad v_{0,y}^{ECEF} \quad v_{0,z}^{ECEF}\right]$	km/s	Initial satellite velocity state vector at time 0 in Earth-centred earth-fixed frame (ECEF)
t	second	Time to derive the satellite position and velocity. Set to 0 at the initialization.

Table E.2-3: Output values in format of orbital parameters

Parameters	Unit	Description
Semi-major axis (a)	m	Half the length of the longest diameter of the elliptical orbit in Earth-centred Inertial frame (ECI).
Eccentricity (e)	rad	Shape of the orbit, ranging from 0 to 1.
Inclination (i)	rad	Angle between the orbital plane and the reference plane (typically Earth's equatorial plane).
Longitude of ascending node (Ω)	rad	Angle from a reference direction (i.e. vernal equinox) to the ascending node, where the satellite crosses the equatorial plane from south to north.
Argument of periapsis (ω)	rad	Angle from the ascending node to the perigee, the point where the satellite is closest to Earth.
Mean anomaly (M_t)	rad	Satellite's position along its orbit at time *t*, expressed as an angle measured from perigee.

Table E.2-4: Output values in format of state vectors

Parameters	Unit	Description
$\boldsymbol{r_t^{ECEF}} = \begin{bmatrix} r_{t,x}^{ECEF} & r_{t,y}^{ECEF} & r_{t,z}^{ECEF} \end{bmatrix}$	km	Satellite position state vector at time *t* in Earth-centred earth-fixed frame (ECEF)
$\boldsymbol{v_t^{ECEF}} = \begin{bmatrix} v_{t,x}^{ECEF} & v_{t,y}^{ECEF} & v_{t,z}^{ECEF} \end{bmatrix}$	km/s	Satellite velocity state vector at time *t* in Earth-centred earth-fixed frame (ECEF)

Table E.2-5: Constant parameters

Parameters	Description	Values	Unit
μ	Gravitational parameter for Earth	$3.986004418 \times 10^{5}$	km^2/s^2
ω_E	Earth angular speed	$7.2921151467 \times 10^{-5}$	rad/s

E.2.1 Newton-Raphson method

E.2.1.1 Keplerian model based estimation

The method specified in this sub clause is applicable to cases that Eccentricity (e) in Step 1-4 is more than zero. In case e=0, use the method specified in E.2.2.

Step 0 Check format of initial ephemeris information in SIB31

Choose the following step 1 or step 2-1 to proceed depending on the format of provided initial ephemeris information in *SIB31*. If the provided ephemeris information is described in the format of the state vector, proceed to step 1. Otherwise, if the information is described in the format of the orbital elements, proceed to step 2-1.

Step 1 Derive six orbital elements (a, e, i, Ω, ω, M_0)

Step 1-0 Convert the initial position/velocity state vectors from ECEF format to ECI format

Note we assume the x-axis of ECI and ECEF the same for simplicity.

$$\boldsymbol{r_0} = \boldsymbol{r_0^{ECEF}} = \begin{bmatrix} r_{0,x}^{ECEF} & r_{0,y}^{ECEF} & r_{0,z}^{ECEF} \end{bmatrix}$$

$$\boldsymbol{v_0^{ECI}} = \begin{bmatrix} v_{0,x}^{ECI} & v_{0,y}^{ECI} & v_{0,z}^{ECI} \end{bmatrix} = \boldsymbol{v_0^{ECEF}} + \begin{bmatrix} 0 & 0 & \omega_E \end{bmatrix} \times \boldsymbol{r_0^{ECEF}}$$

$$= \begin{bmatrix} v_{0,x}^{ECEF} - \omega_E r_{0,y}^{ECEF} & v_{0,y}^{ECEF} + \omega_E r_{0,x}^{ECEF} & v_{0,z}^{ECEF} \end{bmatrix}$$

Step 1-1 Position magnitude (r), velocity magnitude (v), and orbital angular momentum (h)

$$r = \left\|\boldsymbol{r_0^{ECI}}\right\| = \sqrt{\left(r_{0,x}^{ECI}\right)^2 + \left(r_{0,y}^{ECI}\right)^2 + \left(r_{0,z}^{ECI}\right)^2}$$

$$v = \left\|\boldsymbol{v_0^{ECI}}\right\| = \sqrt{\left(v_{0,x}^{ECI}\right)^2 + \left(v_{0,y}^{ECI}\right)^2 + \left(v_{0,z}^{ECI}\right)^2}$$

$$v_r = \boldsymbol{v_0^{ECI}} \cdot \frac{\boldsymbol{r_0^{ECI}}}{r} = \frac{r_{0,x}^{ECI} v_{0,x}^{ECI} + r_{0,y}^{ECI} v_{0,y}^{ECI} + r_{0,z}^{ECI} v_{0,z}^{ECI}}{r}$$

$$\boldsymbol{h} = \begin{bmatrix} h_x & h_y & h_z \end{bmatrix} = \boldsymbol{r} \times \boldsymbol{v} = \begin{bmatrix} r_{0,y}^{ECI} v_{0,z}^{ECI} - r_{0,z}^{ECI} v_{0,y}^{ECI} & r_{0,z}^{ECI} v_{0,x}^{ECI} - r_{0,x}^{ECI} v_{0,z}^{ECI} & r_{0,x}^{ECI} v_{0,y}^{ECI} - r_{0,y}^{ECI} v_{0,x}^{ECI} \end{bmatrix}$$

$$h = \|\boldsymbol{h}\| = \sqrt{h_x^2 + h_y^2 + h_z^2}$$

Step 1-2 Inclination (INC, i)

$$\boldsymbol{K} = \begin{bmatrix} 0 & 0 & 1 \end{bmatrix}$$

$$i = \cos^{-1}\left(\frac{\boldsymbol{h} \cdot \boldsymbol{K}}{h}\right) = \cos^{-1}\left(\frac{h_z}{h}\right)$$

Note the range of INC is between 0 and π (radian).

Step 1-3 Right Ascension of the Ascending Node (RAN, Ω)

$$\boldsymbol{n} = \begin{bmatrix} n_x & n_y & n_z \end{bmatrix} = \boldsymbol{K} \times \boldsymbol{h} = \begin{bmatrix} -h_y & h_x & 0 \end{bmatrix}$$

$$n = \|\boldsymbol{n}\| = \sqrt{n_x^2 + n_y^2 + n_z^2}$$

$$\Omega = \begin{cases} \cos^{-1}\left(\frac{n_x}{n}\right), & n_y \geq 0 \\ 2\pi - \cos^{-1}\left(\frac{n_x}{n}\right) & n_y < 0 \end{cases}$$

Note the range of RAN is between 0 and 2π (radian).

Note Ω is called as 'Longitude of ascending node' in TS 36.331 [6] *ephemerisInfo*-r17.

Step 1-4 Eccentricity (ECC, e), Semi-major axis (SMA, a), Period (P)

$$\boldsymbol{e} = \begin{bmatrix} \boldsymbol{e_x} \\ \boldsymbol{e_y} \\ \boldsymbol{e_z} \end{bmatrix}^{\boldsymbol{T}} = \frac{\boldsymbol{1}}{\boldsymbol{\mu}}\left[\left(\boldsymbol{v}^2 - \frac{\boldsymbol{\mu}}{\boldsymbol{r}}\right)\boldsymbol{r_0^{ECI}} - \left(\boldsymbol{r_0^{ECI}} \cdot \boldsymbol{v_0^{ECI}}\right)\boldsymbol{v_0^{ECI}}\right] = \frac{\boldsymbol{1}}{\boldsymbol{\mu}}\left[\left(\boldsymbol{v}^2 - \frac{\boldsymbol{\mu}}{\boldsymbol{r}}\right)\begin{bmatrix} \boldsymbol{r_{0,x}^{ECI}} \\ \boldsymbol{r_{0,y}^{ECI}} \\ \boldsymbol{r_{0,z}^{ECI}} \end{bmatrix}^{\boldsymbol{T}} - \boldsymbol{r} \cdot \boldsymbol{v_r} \begin{bmatrix} \boldsymbol{v_{0,x}^{ECI}} \\ \boldsymbol{v_{0,y}^{ECI}} \\ \boldsymbol{v_{0,z}^{ECI}} \end{bmatrix}^{\boldsymbol{T}}\right]$$

$$e = \|\boldsymbol{e}\| = \sqrt{e_x^2 + e_y^2 + e_z^2}$$

$$a = \frac{h^2}{\mu(1 - e^2)}$$

Period of the satellite around earth, P (sec), is given by:

$$P = 2\pi\sqrt{\frac{a^3}{\mu}}$$

Step 1-5 Argument of Periapsis (AP, ω)

$$\omega = \cos^{-1}\left(\frac{\boldsymbol{e}\cdot\boldsymbol{n}}{e\cdot n}\right) = \begin{cases} \cos^{-1}\left(\dfrac{e_x n_x + e_y n_y + e_z n_z}{e\sqrt{n_x^2+n_y^2+n_z^2}}\right), & e_z \geq 0 \\ 2\pi - \cos^{-1}\left(\dfrac{e_x n_x + e_y n_y + e_z n_z}{e\sqrt{n_x^2+n_y^2+n_z^2}}\right), & e_z < 0 \end{cases}$$

Note the range of AP is between 0 and 2π (radian).

Step 1-6 Mean Anomaly at time 0 (MA, M_0)

True Anomaly at time 0 (ν_0):

$$\nu_0 = \cos^{-1}\left(\frac{\boldsymbol{e}\cdot\boldsymbol{r}_0^{ECI}}{e\cdot r}\right) = \begin{cases} \cos^{-1}\left(\dfrac{e_x r_{0,x}^{ECI} + e_y r_{0,y}^{ECI} + e_z r_{0,z}^{ECI}}{e\cdot r}\right) & v_r \geq 0 \\ 2\pi - \cos^{-1}\left(\dfrac{e_x r_{0,x}^{ECI} + e_y r_{0,y}^{ECI} + e_z r_{0,z}^{ECI}}{e\cdot r}\right) & v_r < 0 \end{cases}$$

Eccentric Anomaly at time 0 (E_0):

$$E_0 = 2\tan^{-1}\left(\sqrt{\frac{1-e}{1+e}}\tan\left(\frac{\nu_0}{2}\right)\right)$$

Mean Anomaly at time 0 (M_0):

$$M_0 = E_0 - e\sin E_0$$

Note the range of M_0 is between 0 and 2π (radian).

Step 2 Determine the satellite position and velocity at time t (sec)

Step 2-1 Mean Anomaly at time *t* (M_t):

$$M_t = M_0 + 2\pi\frac{t}{P} = M_0 + t\sqrt{\frac{\mu}{a^3}}$$

Step 2-2 Derive Eccentric Anomaly at time t (E_t) by solving Kepler's equation with Newton-Raphson method

Build the Kepler's equation between M_t and E_t:

$$M_t = E_t - e\sin E_t$$

Step 2-2-1: Set $E_t^{(0)} = M_t$

Step 2-2-2: Calculate $f\left(E_t^{(n)}\right) = E_t^{(n)} - e\sin E_t^{(n)} - M_t$

Step 2-2-3: Calculate $f'\left(E_t^{(n)}\right) = \frac{df\left(E_t^{(n)}\right)}{dE_t^{(n)}} = 1 - e\cos E_t^{(n)}$

Step 2-2-4: Update $E_t^{(n+1)}$ from $E_t^{(n)}$, $f\left(E_t^{(n)}\right)$, and $f'\left(E_t^{(n)}\right)$, as follows:

$$E_t^{(n+1)} = E_t^{(n)} - \frac{f\left(E_t^{(n)}\right)}{f'\left(E_t^{(n)}\right)} = E_t^{(n)} - \frac{E_t^{(n)} - e\sin E_t^{(n)} - M_t}{1 - e\cos E_t^{(n)}}$$

Step 2-2-5: If $n \geq 4$, then set $E_t = E_t^{(n+1)}$ and go to Step 2-3. Otherwise, go to Step 2-2-2 by setting n := n+1.

Step 2-3 Derive True Anomaly at time *t* (ν_t)

$$\nu_t = 2\tan^{-1}\left(\sqrt{\frac{1+e}{1-e}}\tan\frac{E_t}{2}\right)$$

Note the range of ν_t is between 0 and 2π (radian).

Step 2-4 Convert the orbital elements to the state vector

Convert to the state vector in perifocal frame,

$$\begin{bmatrix} r_{t,x}^{pqw} \\ r_{t,y}^{pqw} \\ r_{t,z}^{pqw} \end{bmatrix} = r_t \begin{bmatrix} \cos\nu_t \\ \sin\nu_t \\ 0 \end{bmatrix} = \frac{h^2}{\mu}\frac{1}{1+e\cos\nu_t}\begin{bmatrix} \cos\nu_t \\ \sin\nu_t \\ 0 \end{bmatrix} = \frac{a(1-e^2)}{1+e\cos\nu_t}\begin{bmatrix} \cos\nu_t \\ \sin\nu_t \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} v_{t,x}^{pqw} \\ v_{t,y}^{pqw} \\ v_{t,z}^{pqw} \end{bmatrix} = \frac{\mu}{h}\begin{bmatrix} -\sin\nu_t \\ (e+\cos\nu_t) \\ 0 \end{bmatrix} = \sqrt{\frac{\mu}{a(1-e^2)}}\begin{bmatrix} -\sin\nu_t \\ (e+\cos\nu_t) \\ 0 \end{bmatrix}$$

Convert the state vector from perifocal frame to ECI.

$$\begin{bmatrix} r_{t,x}^{ECI} \\ r_{t,y}^{ECI} \\ r_{t,z}^{ECI} \end{bmatrix} = \begin{bmatrix} \cos(\Omega) & -\sin(\Omega) & 0 \\ \sin(\Omega) & \cos(\Omega) & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(i) & -\sin(i) \\ 0 & \sin(i) & \cos(i) \end{bmatrix}\begin{bmatrix} \cos(\omega) & -\sin(\omega) & 0 \\ \sin(\omega) & \cos(\omega) & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} r_{t,x}^{pqw} \\ r_{t,y}^{pqw} \\ r_{t,z}^{pqw} \end{bmatrix}$$

$$\begin{bmatrix} v_{t,x}^{ECI} \\ v_{t,y}^{ECI} \\ v_{t,z}^{ECI} \end{bmatrix} = \begin{bmatrix} \cos(\Omega) & -\sin(\Omega) & 0 \\ \sin(\Omega) & \cos(\Omega) & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(i) & -\sin(i) \\ 0 & \sin(i) & \cos(i) \end{bmatrix}\begin{bmatrix} \cos(\omega) & -\sin(\omega) & 0 \\ \sin(\omega) & \cos(\omega) & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} v_{t,x}^{pqw} \\ v_{t,y}^{pqw} \\ v_{t,z}^{pqw} \end{bmatrix}$$

Convert the state vector from ECI to ECEF.

$$\begin{bmatrix} r_{t,x}^{ECEF} \\ r_{t,y}^{ECEF} \\ r_{t,z}^{ECEF} \end{bmatrix} = \begin{bmatrix} \cos(-\omega_E t) & -\sin(-\omega_E t) & 0 \\ \sin(-\omega_E t) & \cos(-\omega_E t) & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} r_{t,x}^{ECI} \\ r_{t,y}^{ECI} \\ r_{t,z}^{ECI} \end{bmatrix}$$

$$\begin{bmatrix} v_{t,x}^{ECEF} \\ v_{t,y}^{ECEF} \\ v_{t,z}^{ECEF} \end{bmatrix} = \begin{bmatrix} \cos(-\omega_E t) & -\sin(-\omega_E t) & 0 \\ \sin(-\omega_E t) & \cos(-\omega_E t) & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} v_{t,x}^{ECI} \\ v_{t,y}^{ECI} \\ v_{t,z}^{ECI} \end{bmatrix} - \begin{bmatrix} 0 & -\omega_E & 0 \\ \omega_E & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} r_{t,x}^{ECEF} \\ r_{t,y}^{ECEF} \\ r_{t,z}^{ECEF} \end{bmatrix}$$

To generate the ephemeris information in *SIB31* in orbital parameters, convert the state vector to orbital parameters by procedures from Step 1-0 to Step 2-1 in E.2 at time *t*.

E.2.2 Fourth-order Runge-Kutta method

E.2.2.1 Equations of motion based estimation

Step 1: Conversion of initial six Keplerian orbital elements to a state vector

When the initial ephemeris information is provided by six Keplerian orbital elements in *SIB31*, convert the six orbital elements to a state vector by E.2.1.1 step 2-4, where set time t=0.

Step 2: Initialization

$$n := 0$$

$$\boldsymbol{r}_{\boldsymbol{n\Delta t}} = [r_{n\Delta t,x} \quad r_{n\Delta t,y} \quad r_{n\Delta t,z}] = [r_{0,x}^{ECEF} \quad r_{0,y}^{ECEF} \quad r_{0,z}^{ECEF}] = \boldsymbol{r}_{\boldsymbol{0}}^{\boldsymbol{ECEF}}$$

$$\boldsymbol{v}_{\boldsymbol{n\Delta t}} = [v_{n\Delta t,x} \quad v_{n\Delta t,y} \quad v_{n\Delta t,v}] = [v_{0,x}^{ECEF} \quad v_{0,y}^{ECEF} \quad v_{0,z}^{ECEF}] = \boldsymbol{v}_{\boldsymbol{0}}^{\boldsymbol{ECEF}}$$

Set time step size of position/velocity updates. Set $\Delta t = 1$ (sec), for example, if updating the satellite position/velocity every one second.

Step 3: Solve the equation of motion with the fourth-order Runge-Kutta method.

$$\boldsymbol{k}_{\boldsymbol{1},\boldsymbol{r}} = [k_{1,r,x} \quad k_{1,r,y} \quad k_{1,r,z}] = \boldsymbol{v}_{\boldsymbol{n\Delta t}}\Delta t$$

$$\boldsymbol{k}_{\boldsymbol{1},\boldsymbol{v}} = [k_{1,v,x} \quad k_{1,v,y} \quad k_{1,v,z}] = f(\boldsymbol{r}_{\boldsymbol{n\Delta t}}, \boldsymbol{v}_{\boldsymbol{n\Delta t}})\Delta t$$

$$\boldsymbol{k}_{\boldsymbol{2},\boldsymbol{r}} = [k_{2,r,x} \quad k_{2,r,y} \quad k_{2,r,z}] = \left(\boldsymbol{v}_{\boldsymbol{n\Delta t}} + \frac{1}{2}\boldsymbol{k}_{\boldsymbol{1},\boldsymbol{v}}\right)\Delta t$$

$$\boldsymbol{k}_{\boldsymbol{2},\boldsymbol{v}} = [k_{2,v,x} \quad k_{2,v,y} \quad k_{2,v,z}] = f\left(\boldsymbol{r}_{\boldsymbol{n\Delta t}} + \frac{1}{2}\boldsymbol{k}_{\boldsymbol{1},\boldsymbol{r}}, \boldsymbol{v}_{\boldsymbol{n\Delta t}} + \frac{1}{2}\boldsymbol{k}_{\boldsymbol{1},\boldsymbol{v}}\right)\Delta t$$

$$\boldsymbol{k}_{\boldsymbol{3},\boldsymbol{r}} = [k_{3,r,x} \quad k_{3,r,y} \quad k_{3,r,z}] = \left(\boldsymbol{v}_{\boldsymbol{n\Delta t}} + \frac{1}{2}\boldsymbol{k}_{\boldsymbol{2},\boldsymbol{v}}\right)\Delta t$$

$$\boldsymbol{k}_{\boldsymbol{3},\boldsymbol{v}} = [k_{3,v,x} \quad k_{3,v,y} \quad k_{3,v,z}] = f\left(\boldsymbol{r}_{\boldsymbol{n\Delta t}} + \frac{1}{2}\boldsymbol{k}_{\boldsymbol{2},\boldsymbol{r}}, \boldsymbol{v}_{\boldsymbol{n\Delta t}} + \frac{1}{2}\boldsymbol{k}_{\boldsymbol{2},\boldsymbol{v}}\right)\Delta t$$

$$\boldsymbol{k}_{\boldsymbol{4},\boldsymbol{r}} = [k_{4,r,x} \quad k_{4,r,y} \quad k_{4,r,z}] = (\boldsymbol{v}_{\boldsymbol{n\Delta t}} + \boldsymbol{k}_{\boldsymbol{3},\boldsymbol{v}})\Delta t$$

$$\boldsymbol{k}_{\boldsymbol{4},\boldsymbol{v}} = [k_{4,v,x} \quad k_{4,v,y} \quad k_{4,v,z}] = f(\boldsymbol{r}_{\boldsymbol{n\Delta t}} + \boldsymbol{k}_{\boldsymbol{3},\boldsymbol{r}}, \boldsymbol{v}_{\boldsymbol{n\Delta t}} + \boldsymbol{k}_{\boldsymbol{3},\boldsymbol{v}})\Delta t$$

$$\boldsymbol{r}_{\boldsymbol{(n+1)\Delta t}} = [r_{(n+1)\Delta t,x} \quad r_{(n+1)\Delta t,y} \quad r_{(n+1)\Delta t,z}] = \boldsymbol{r}_{\boldsymbol{n\Delta t}} + \frac{1}{6}(\boldsymbol{k}_{\boldsymbol{1},\boldsymbol{r}} + 2\boldsymbol{k}_{\boldsymbol{2},\boldsymbol{r}} + 2\boldsymbol{k}_{\boldsymbol{3},\boldsymbol{r}} + \boldsymbol{k}_{\boldsymbol{4},\boldsymbol{r}})$$

$$\boldsymbol{v}_{\boldsymbol{(n+1)\Delta t}} = [v_{(n+1)\Delta t,x} \quad v_{(n+1)\Delta t,y} \quad v_{(n+1)\Delta t,z}] = \boldsymbol{v}_{\boldsymbol{n\Delta t}} + \frac{1}{6}(\boldsymbol{k}_{\boldsymbol{1},\boldsymbol{v}} + 2\boldsymbol{k}_{\boldsymbol{2},\boldsymbol{v}} + 2\boldsymbol{k}_{\boldsymbol{3},\boldsymbol{v}} + \boldsymbol{k}_{\boldsymbol{4},\boldsymbol{v}})$$

where

$$f(\boldsymbol{r}_{\boldsymbol{t}}, \boldsymbol{v}_{\boldsymbol{t}}) = f(r_{t,x}, r_{t,y}, r_{t,z}, v_{t,x}, v_{t,y}, v_{t,z}) = \begin{bmatrix} -\frac{\mu}{r_t^3} r_{t,x} + 2\omega_E v_{t,y} + \omega_E^2 r_{t,x} \\ -\frac{\mu}{r_t^3} r_{t,y} - 2\omega_E v_{t,x} + \omega_E^2 r_{t,y} \\ -\frac{\mu}{r_t^3} r_{t,z} \end{bmatrix}^T$$

$$r_t = |\boldsymbol{r}_{\boldsymbol{t}}| = \sqrt{r_{t,x}^2 + r_{t,y}^2 + r_{t,z}^2}$$

Step 4: Determine the satellite position/velocity at time t.

If $t = (n + 1)\Delta t$:

$$\boldsymbol{r}_{\boldsymbol{t}}^{\boldsymbol{ECEI}} = \boldsymbol{r}_{\boldsymbol{(n+1)\Delta t}} = [r_{(n+1)\Delta t,x} \quad r_{(n+1)\Delta t,y} \quad r_{(n+1)\Delta t,z}]$$

$$\boldsymbol{v}_{\boldsymbol{t}}^{\boldsymbol{ECEI}} = \boldsymbol{v}_{\boldsymbol{(n+1)\Delta t}} = [v_{(n+1)\Delta t,x} \quad v_{(n+1)\Delta t,y} \quad v_{(n+1)\Delta t,z}]$$

Otherwise, set $n \coloneqq n + 1$, and go to Step 2.

To generate the ephemeris information in *SIB31* in orbital parameters, convert the state vector to orbital parameters by procedures from Step 1-0 to Step 2-1 in E.2 at time *t*.

E.3 Varying Doppler shift and propagation delay generation

E.3.1 Determine UE position

This step calculates the UE position according to the earth angular speed. This clause assumes UE location is given by a format of latitude, longitude, and altitude. This clause specifies how to convert values to ECEF format to align with the satellite position and velocity state vectors.

Table E.3.1-1: Input values for calculation of UE position

Parameters	Unit	Description
$UE_{latitude}$	degree	Initial UE latitude
$UE_{lontitude}$	degree	Initial UE longitude
$UE_{altitude}$	km	Initial UE altitude

Table E.3.1-2: Output values

Parameters	Unit	Description
$[UE_{t,x}^{ECEF} \quad UE_{t,y}^{ECEF} \quad UE_{t,z}^{ECEF}]$	km	UE position state vector at time t in Earth-centred earth-fixed frame (ECEF)

Table E.3.1-3: Constant parameters

Parameters	Description	Values	Unit
a_E	Earth radius	6378.137	km
e_E^2	Square of Earth eccentricity	$6.6943799014 \times 10^{-3}$	

$$\phi = \frac{\pi}{180} UE_{latitude}$$

$$\lambda = \frac{\pi}{180} UE_{longitude}$$

$$N = \frac{a_E}{\sqrt{1 - e_E^2 \sin^2 \phi}}$$

Since the UE is stationary during the tests, UE position does not change regardless of time *t*.

$$\begin{cases} UE_{t,x}^{ECEF} = (N + UE_{altitude}) \cos \phi \cos \lambda \\ UE_{t,y}^{ECEF} = (N + UE_{altitude}) \cos \phi \sin \lambda \\ UE_{t,z}^{ECEF} = \{N(1 - e_E^2) + UE_{altitude}\} \sin \phi \end{cases}$$

E.3.2 Doppler shift and propagation delay

This step calculates the Doppler shift and propagation delay based on the satellite position/velocity and UE position state vectors calculated in the earlier steps.

Table E.3.2-1: Input values for calculation of Doppler shift and propagation delay

Parameters	Unit	Description
$\left[UE_{t,x}^{ECEF} \quad UE_{t,y}^{ECEF} \quad UE_{t,z}^{ECEF}\right]$	km	UE position state vector at time *t* in Earth-centred earth-fixed frame (ECEF)
$\boldsymbol{r}_{\boldsymbol{t}}^{\boldsymbol{ECEF}} = \left[r_{t,x}^{ECEF} \quad r_{t,y}^{ECEF} \quad r_{t,z}^{ECEF}\right]$	km	Satellite position state vector at time *t* in Earth-centred earth-fixed frame (ECEF)
$\boldsymbol{v}_{\boldsymbol{t}}^{\boldsymbol{ECEF}} = \left[v_{t,x}^{ECEF} \quad v_{t,y}^{ECEF} \quad v_{t,z}^{ECEF}\right]$	km/s	Satellite velocity state vector at time *t* in Earth-centred earth-fixed frame (ECEF)
f_c	Hz	Carrier frequency (e.g., 2.0 x 10^9 for band n256)

Table E.3.2-2: Output values

Parameters	Unit	Description
$Doppler$	Hz	Doppler shift at time *t*
$Delay_{DL}$	sec	Downlink propagation delay at time *t*
$Delay_{UL}$	sec	Uplink propagation delay at time *t*

Table E.3.2-3: Constant parameters

Parameters	Description	Example of values	Unit
c	Speed of light	299792.458	km/s
ω_E	Earth angular speed	7.2921151467 x 10^{-5}	rad/s

Distance between satellite and UE is derived as follows:

$$\boldsymbol{\rho}_{\boldsymbol{t}}^{\boldsymbol{ECEF}} = \begin{bmatrix} \rho_{t,x}^{ECEF} \\ \rho_{t,y}^{ECEF} \\ \rho_{t,z}^{ECEF} \end{bmatrix} = \begin{bmatrix} r_{t,x}^{ECEF} - UE_{t,x}^{ECEF} \\ r_{t,y}^{ECEF} - UE_{t,y}^{ECEF} \\ r_{t,z}^{ECEF} - UE_{t,z}^{ECEF} \end{bmatrix}$$

$$\left\|\boldsymbol{\rho}_{\boldsymbol{t}}^{\boldsymbol{ECEF}}\right\| = \sqrt{\left(\rho_{t,x}^{ECEF}\right)^2 + \left(\rho_{t,y}^{ECEF}\right)^2 + \left(\rho_{t,z}^{ECEF}\right)^2}$$

Using the distance above and the following range rate, Doppler shift is also derived as follows:

$$RangeRate(t) = \frac{\boldsymbol{\rho}_{\boldsymbol{t}}^{\boldsymbol{ECEF}} \cdot \boldsymbol{v}_{\boldsymbol{t}}^{\boldsymbol{ECEF}}}{\left\|\boldsymbol{\rho}_{\boldsymbol{t}}^{\boldsymbol{ECEF}}\right\|} = \frac{\rho_{t,x}^{ECEF} \cdot v_{t,x}^{ECEF} + \rho_{t,y}^{ECEF} \cdot v_{t,y}^{ECEF} + \rho_{t,z}^{ECEF} \cdot v_{t,z}^{ECEF}}{\left\|\boldsymbol{\rho}_{\boldsymbol{t}}^{\boldsymbol{ECEF}}\right\|}$$

$$Doppler(t) = -RangeRate(t) \times \frac{f_c}{c}$$

Next, total propagation delay for downlink and uplink case are derived as follows. Note an influence of the receiver movement (i.e. either UE movement due to the Earth's rotation or Satellite movement) is considered in the following equations.

$$\boldsymbol{v}_t^{ECI} = \begin{bmatrix} v_{t,x}^{ECI} & v_{t,y}^{ECI} & v_{t,z}^{ECI} \end{bmatrix} = \boldsymbol{v}_t^{ECEF} + \begin{bmatrix} 0 & 0 & \omega_E \end{bmatrix} \times \boldsymbol{r}_t^{ECEF}$$
$$= \begin{bmatrix} v_{0,x}^{ECEF} - \omega_E r_{0,y}^{ECEF} & v_{0,y}^{ECEF} + \omega_E r_{0,x}^{ECEF} & v_{0,z}^{ECEF} \end{bmatrix}$$

$$Delay_{DL}(t_R) = \frac{\left\|\boldsymbol{\rho}_{t_R}^{ECEF}\right\|/c}{1 + \frac{1}{c}\boldsymbol{v}_{t_R}^{ECI} \cdot \frac{\boldsymbol{\rho}_{t_R}^{ECEF}}{\left\|\boldsymbol{\rho}_{t_R}^{ECEF}\right\|}}$$

Note t_R is the reception time at UE.

$$Delay_{UL}(t_T) = \frac{\left\|\boldsymbol{\rho}_{t_T}^{ECEF}\right\|/c}{1 - \frac{1}{c}\boldsymbol{v}_{t_T}^{ECI} \cdot \frac{\boldsymbol{\rho}_{t_T}^{ECEF}}{\left\|\boldsymbol{\rho}_{t_T}^{ECEF}\right\|}}$$

Note t_T is the transmission time at UE. It is not mandated that UE follows this formula for UL propagation delay estimation.

Doppler shift and propagation delay for LEO-600, calculated by the Newton-Raphson and fourth-order Runge-Kutta methods, are shown in Figure E.3.2-1 and E.3.2-2. Refer to Annex E.4 for initial conditions.

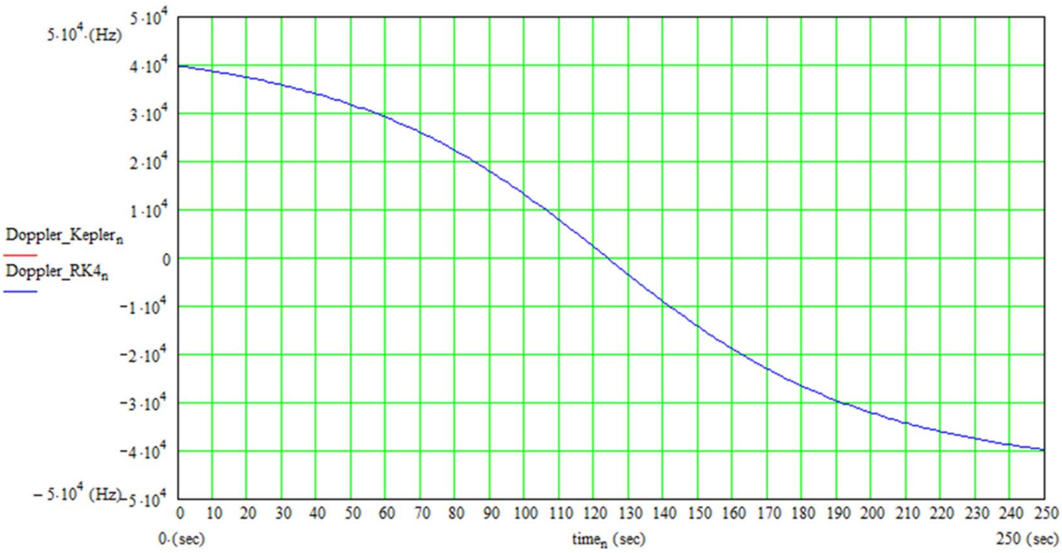

Figure E.3.2-1: Doppler shift of LEO-600 calculated by Newton-Raphson method and fourth-order Runge-Kutta method

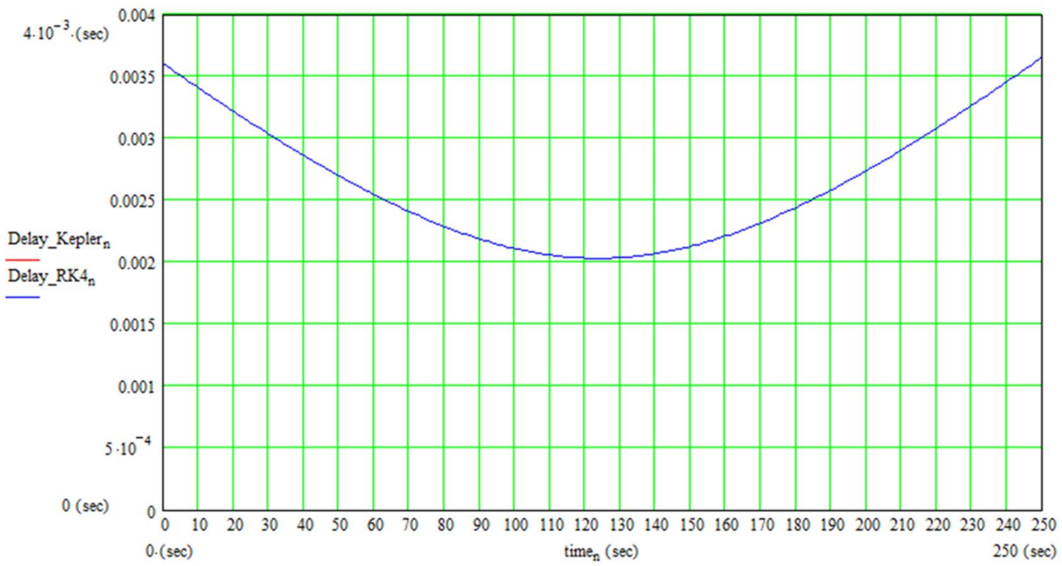

Figure E.3.2-2: Propagation delay of LEO-600 calculated by Newton-Raphson method and fourth-order Runge-Kutta method

E.3.3 Elevation angle and Azimuth angle (for information)

An elevation angle, *El* (degrees), of the satellite position from the UE viewpoint at time *t* can be derived as follows:

$$\boldsymbol{e} = \begin{bmatrix} -\sin\lambda \\ \cos\lambda \\ 0 \end{bmatrix}, \boldsymbol{n} = \begin{bmatrix} -\sin\phi\cos\lambda \\ -\sin\phi\sin\lambda \\ \cos\phi \end{bmatrix}, \boldsymbol{u} = \begin{bmatrix} \cos\phi\cos\lambda \\ \cos\phi\sin\lambda \\ \sin\phi \end{bmatrix}$$

Note $\boldsymbol{e}$, $\boldsymbol{n}$, and $\boldsymbol{u}$ are the unit vectors for east, north, and zenith direction at the UE position at time t.

$$l_{t,e} = \boldsymbol{\rho}_t^{\boldsymbol{ECEI}} \cdot \boldsymbol{e} = \rho_{t,x}^{ECEI} \cdot e_x + \rho_{t,y}^{ECEI} \cdot e_y + \rho_{t,z}^{ECEI} \cdot e_z$$

$$l_{t,n} = \boldsymbol{\rho}_t^{\boldsymbol{ECEI}} \cdot \boldsymbol{n} = \rho_{t,x}^{ECEI} \cdot n_x + \rho_{t,y}^{ECEI} \cdot n_y + \rho_{t,z}^{ECEI} \cdot n_z$$

$$l_{t,u} = \boldsymbol{\rho}_t^{\boldsymbol{ECEI}} \cdot \boldsymbol{u} = \rho_{t,x}^{ECEI} \cdot u_x + \rho_{t,y}^{ECEI} \cdot u_y + \rho_{t,z}^{ECEI} \cdot u_z$$

$$l_{t,h} = \sqrt{l_{t,e}^2 + l_{t,n}^2}$$

$$El(t) = \frac{180}{\pi}\tan^{-1}\frac{l_{t,u}}{l_{t,h}}$$

Azimuth angle, Az (degrees), is also derived as follows.

$$Az(t) = \frac{180}{\pi}\tan^{-1}\frac{l_{t,e}}{l_{t,n}}$$

For example, elevation angle of LEO-600 with maximum positive Doppler scenario is shown in Figure E.3.3-1. Starting the elevation angle from 30 degrees, available connection time between UE and one satellite is approximately 250 seconds.

Figure E.3.3-1: Elevation angle for LEO-600 with maximum positive Doppler scenario

E.4 Initial conditions for numerical solution

E.4.1 Initial ephemeris information for satellites

For LEO-600 scenario, the initial satellite epehemris is specified either by a state vector format in Table E.4.1-1 or by an orbital parameter format in Table E.4.1-2.

Note ephemerisInfo in Table E.4.1-2 is derived from Table E.4.1-1 with the assumption x, y, z axis in ECI are aligned with x, y, z axis in ECEF.

Table E.4.1-1: Initial ephemeris information for NGSO satellites (LEO-600 with Max Doppler in state vector format)

Information Element	Value/remark
SystemInformationBlockType31-r17 ::= SEQUENCE {	
servingSatelliteInfo-r17 SEQUENCE {	
epochTime-r17	NOTE 2
ephemerisInfo-r17 CHOICE {	
stateVectors SEQUENCE {	
positionX-r17	-2654549
positionY-r17	4386991
positionZ-r17	1594205
velocityVX-r17	14581
velocityVY-r17	-34487
velocityVZ-r17	120182
}	
NOTE 1: Satellite-UE elevation angle equal to 30.11 degrees, one-way delay equal to 3.60 ms and Doppler equal to 19.83 ppm. NOTE 2: When ephemerisInfo is updated, epochTime-r17 is set such that ephemerisInfo corresponds to the satellite's position/velocity at the SFN/subframe indicated by epochTime-r17.	

Table E.4.1-2: Initial ephemeris information for NGSO satellites (LEO-600 with Max Doppler in orbital parameter format)

Information Element	Value/remark
SystemInformationBlockType31-r17 ::= SEQUENCE {	
servingSatelliteInfo-r17 SEQUENCE {	
epochTime-r17	NOTE 2
ephemerisInfo-r17 CHOICE {	
orbitalParameters SEQUENCE {	
semiMajorAxis-r17-	127437262
eccentricity-r17	625825
periapsis-r17	1514099
longitude-r17	88985152
inclination-r17	62744502
meanAnomaly-r17	11230448
}	
}	
}	
NOTE 1: Satellite-UE elevation angle equal to 30.11 degrees, one-way delay equal to 3.60 ms and Doppler equal to 19.83 ppm NOTE 2: When ephemerisInfo is updated, epochTime-r17 is set such that ephemerisInfo corresponds to the satellite's position/velocity at the SFN/subframe indicated by epochTime-r17.	

The position and velocity state vectors or orbital parameters of the satellite need to be converted based on the definitions in TS 36.331 [6] as *EphemerisInfo* field descriptions.

The converted satellite coordinate and velocity in ECEF Frame are as follows.

Satellite coordinate: (-3450913.7 [m], 5703088.3 [m], 2072466.5 [m])

Satellite velocity: (874.86 [m/s], -2069.22 [m/s], 7210.92 [m/s])

The converted orbital elements in ECI frame are as follows.

Semi-major axis (a): 7041480.926238 [m]

Eccentricity (e): 0.00895555575 [rad]

Inclination (i): 1.46884879182 [rad]

Longitude of ascending node (Ω): 2.08314240832 [rad]

Argument of periapsis (ω): 0.03544505759 [rad]

Mean anomaly (M_0): 0.26290478768 [rad]

E.4.2 Initial location information for UE

The initial UE position can be referred from TS 36.508 [14].

5.6.1 UE location

UE shall determine its location during the test using any of the following means.

1. UE location for the test shall be provided to the UE via pre-configured means. During the test the UE location is not expected to change unless explicitly stated as a requirement for the test.

2. Other options such as providing UE location via AT command are not precluded.

UE location provided to the UE before the start of the test for RF Tx/Rx and DEMOD test cases for both GSO and NGSO config is as follows:

Longitude: 121.56076999

Latitude: 25.08439333 (NGSO satellites), 55.0 (GSO satellites)

Altitude: 0

Based on the equations described in the annex E.3.1, converted UE location for NGSO satellites in ECEF Frame is as follows.

UE location: (-3025296.935779 [m], 4925102.789830 [m], 2687544.210048 [m])

E.5 Accuracy requirements for maximum delay errors to obtain the propagation delay and Doppler shift trajectory in TE side

The mean of absolute error for Doppler shift should be less than 1 Hz and the mean of absolute error for propagation delay should be less than 0.05μs based on the following error calculation method.

$$Err_{Doppler}(t) = \frac{1}{1000}\sum_{n=1}^{1000}\left|Doppler_{baseline}\left(t+\frac{n}{1000}\right) - Doppler_{interp}\left(t+\frac{n}{1000}\right)\right|, t = 0,1,2,\ldots\,(\mathrm{s})$$

$$Err_{Delay}(t) = \frac{1}{1000}\sum_{n=1}^{1000}\left|Delayr_{baseline}\left(t+\frac{n}{1000}\right) - Delayr_{interp}\left(t+\frac{n}{1000}\right)\right|, t = 0,1,2,\ldots\,(\mathrm{s})$$

where $Doppler_{baseline}(n)$, $Doppler_{interp}(n)$, $Delayr_{baseline}(n)$ and $Delay_{inter}(n)$ are calculated once per 1ms, and the average is taken over every 1 second.

Annex F (informative): Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2022-08	RAN4#104-e	R4-2215118				Initial Skeleton	0.1.0
2022-10	RAN4#105	R4-2218376				Added approved TPs in RAN4#104-bis-e including: R4-2217750, R4-2217752, R4-2217753, R4-2217755, R4-2217807, R4-2217810	0.2.0
2022-11	RAN4#105	R4-2218377				Added approved TPs in RAN4#105 including: R4-2218767, R4-2220803, R4-2220804, R4-2220805, R4-2220806, R4-2220812, R4-2220828, R4-2220835, R4-2220836	0.3.0
2022-12	RAN#98-e	RP-223233				1-step Approval of version 1.0.0	1.0.0

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2022-12	RAN#98-e					Approved by plenary – Rel-18 spec under change control	18.0.0
2023-03	RAN#99	RP-230526	0001	1	F	Updates to the additional emissions requirements related to NS_02N	18.1.0
2023-03	RAN#99	RP-230526	0002	1	F	CR to 36.102 for NTN IoT UE RF requirements corrections	18.1.0
2023-03	RAN#99	RP-230526	0003	1	F	CR to 36.102 for MPR and A-MPR	18.1.0
2023-03	RAN#99	RP-230526	0005	1	F	Update A-MPR for NS_24 for Cat-M1	18.1.0
2023-06	RAN#100	RP-231361	0008	1	B	Big CR to TS36.102: Introduction of IoT-NTN UE demodulation requirements	18.2.0
2023-06	RAN#100	RP-231364	0009		F	CR to add B54/n54 as protected band and correct reference clause in 6.5B.4.3	18.2.0
2023-06	RAN#100	RP-231364	0010		F	Correction on Pcmax and OOBB requirement for category NB1/NB2 UE	18.2.0
2023-06	RAN#100	RP-231364	0011	1	F	CR to 36.102 for NTN IoT UE RF requirements corrections	18.2.0
2023-09	RAN#101	RP-232510	0015		F	CR to TS36.102: Corrections to IoT-NTN requirements	18.3.0
2023-09	RAN#101	RP-232510	0018	1	F	CR to remove PC5 for A-MPR table	18.3.0
2023-09	RAN#101	RP-232510	0019	1	F	Clarifications to 36.102	18.3.0
2023-12	RAN#102	RP-233355	0021		B	CR to TS 36.102 on intrdoucing L+S FDD band for IoT NTN operation	18.4.0
2023-12	RAN#102	RP-233354	0023	1	B	CR to TS36.102 Introduction of the Extended L-band	18.4.0
2023-12	RAN#102	RP-233357	0024		F	Correction of FRC for eMTC UE demodulation requirements	18.4.0
2023-12	RAN#102	RP-233357	0025		F	CR to TS36.102 Addition of downlink physical channels for connection set-up for Cat NB1 and NB2	18.4.0
2023-12	RAN#102	RP-233357	0026	2	F	[LTE_NBIoT_eMTC_NTN_req] CR to 36.102 Clarify test condition for IoT NTN	18.4.0
2024-03	RAN#103	RP-240582	0027	1	F	(LTE_NBIOT_eMTC_NTN_req-Core) CR to 36.102 for IoT NTN UE RF requirements	18.5.0
2024-03	RAN#103	RP-240582	0028		F	[LTE_NBIoT_eMTC_NTN_req] CR to 36.102 Remove square brackets from Doppler values for IoT NTN	18.5.0
2024-03	RAN#103	RP-240610	0029		F	CR to TS36.102: Addition of some missing bands in UE spurious emissions coexistence clause	18.5.0
2024-03	RAN#103	RP-240585	0030	1	F	(IoT_NTN_FDD_LS_band-Core) CR to TS 36.102 for additional spurious emission for band 254	18.5.0
2024-03	RAN#103	RP-240582	0033	1	F	Correction on TX-RX separation for IoT NTN bands	18.5.0
2024-03	RAN#103	RP-240582	0035	1	F	UL RMCs updates for IoT NTN	18.5.0
2024-09	RAN#105	RP-242151	0041	2	F	Correction of MOP requirements on sTTI for NTN Category M1	18.6.0
2024-09	RAN#105	RP-242151	0043	1	F	Correct the MPR requirements for NTN Category NB1 and NB2	18.6.0
2024-12	RAN#106	RP-243026	0050	1	F	(IoT_NTN_FDD_LS_band) CR to TS 36.102 adding missing regulatory EIRP density requirements in clauses 6.2A.1 and 6.2B.1 for B254	18.7.0
2024-12	RAN#106	RP-243027	0052	1	F	(LTE_NBIOT_eMTC_NTN_req-Core) CR to 36.102 for A-SEM and additional spurious emission arrangement improvements	18.7.0
2025-03	RAN#107	RP-250600	0055	1	F	CR for TS36.102, applicability rules for IoT-NTN requirements	18.8.0
2025-03	RAN#107	RP-250611	0057	3	B	(TEI18) CR to 36.102 NB-IoT NTN inband operation with NR NTN [NTNNBIoT_inbandNTNNR]	18.8.0
2025-03	RAN#107	RP-250600	0059	1	F	(LTE_NBIOT_eMTC_NTN_req-Core) CR to TS 36.102 on variable TX-RX frequency separation	18.8.0
2025-03	RAN#107	RP-250600	0060	1	F	CR to TS 36.102: B255 emissions	18.8.0
2025-03	RAN#107	RP-250609	0061		F	(LTE_NBIoT_eMTC_NTN_req-Core) Correction of reference to Suspended version of ITU-R SM.329 Recommendation	18.8.0
2025-06	RAN#108	RP-250923	0063	1	F	(IoT_NTN_FDD_LS_band-Core) Clarification for the PSD limits for a UE operating in 1610-1626.5 MHz frequency range	18.9.0
2025-06	RAN#108	RP-250923	0065	1	F	(LTE_NBIoT_eMTC_NTN_req-Core) CR to TS 36.102 B256 OOB Note (Rel-18)	18.9.0
2025-06	RAN#108	RP-250923	0068		F	CR on Remove GSM_ACLR for NB-Iot based Iot-NTN	18.9.0
2025-06	RAN#108	RP-250923	0069		F	(LTE_NBIOT_eMTC_NTN_req-Core) Corrections on A-MPR requirements subclause for category M1 UE	18.9.0
2025-06	RAN#108	RP-250937	0067	2	B	(IoT_NTN_FDD_S_band-Core) CR to TS 36.102 Introduction of IoT-NTN B252 (Rel-19)	19.0.0
2025-09	RAN#109	RP-252390	0074		A	(LTE_NBIOT_eMTC_NTN_req-Perf) CR to 36.102 related to Demodulation for NB-IoT NTN inband operation with NR NTN (Rel-19, Cat A)	19.1.0
2025-09	RAN#109	RP-252390	0076		A	(LTE_NBIoT_eMTC_NTN_req-Perf) CR for TS36.102 on applicability rules for IoT-NTN requirements	19.1.0
2025-09	RAN#109	RP-252409	0078	1	B	Big CR on TS 36.102: New LTE band for 5G broadcast for region 3 utilizing a geosynchronous satellite	19.1.0
2025-09	RAN#109	RP-252389	0080		F	(IoT_NTN_FDD_LS_band-Core) Correction of the IoT NTN band 254 NS flag references to the sub-clauses with additional requirements	19.1.0
2025-09	RAN#109	RP-252389	0082		A	(IoT_NTN_FDD_LS_band-Core) Introduction of AMPR for the IOT NTN band 254	19.1.0

2025-09	RAN#109	RP-252405	0083		D	(IoT_NTN_FDD_S_band-Core) Editorial corrections to the IoT NTN band 252 NS flags and sub-clauses with additional requirements	19.1.0
2025-09	RAN#109	RP-252395	0085	1	F	(TEI18) Updates related to NB-IoT inband operation in NTN NR [NTNNBIoT_inbandNTNNR]	19.1.0
2025-09	RAN#109	RP-252422	0086		B	Big CR for 36.102 for Iot-NTN HPUE	19.1.0
2025-09	RAN#109	RP-252390	0088		A	Correction of single-tone MPR requirement for NB-Iot based Iot-NTN	19.1.0
2025-09	RAN#109	RP-252407	0092		B	(IoT_NTN_TDD) Big CR to 36.102 Rel19 UE RF	19.1.0
2025-09	RAN#109	RP-252405	0093		F	CR to TS 36.102: Adding FCC SEM mask to band 252	19.1.0
2025-09	RAN#109	RP-252389	0095	1	A	(IoT_NTN_FDD_LS_band-Core) Rel19 Transmit power density requirements conversion to conducted requirements	19.1.0
2025-12	RAN#110	RP-253624	0108		F	(IoT_NTN_TDD-Perf) CR on removing support for segmented precompensation	19.2.0
2025-12	RAN#110	RP-253664	0098		F	Renaming NTN IOT band 256 NS_24 flag to NS_24N	19.2.0
2025-12	RAN#110	RP-253668	0097		A	Clarification for the measurement method in ETSI requirements for the 1610-1626.5MHz range	19.2.0
2026-03	RAN#111	RP-260453	0114		F	Clarification for the NTN IOT band 255, 254 and 252	19.3.0
2026-03	RAN#111	RP-260453	0121		A	(LTE_NBIoT_eMTC_NTN_req-Core) CR to 36.102 to correct subclause number for A-MPR requirements for eMTC and NB-IoT UE_R19_CAT_A	19.3.0
2026-03	RAN#111	RP-260453	0125		A	(LTE_NBIOT_eMTC_NTN_req-Core) CR to TS 36.102 on missing NS values	19.3.0
2026-03	RAN#111	RP-260460	0127		A	(IoT_NTN_FDD_LS_band-Core) CR to TS 36.102 for correcting errors	19.3.0
2026-03	RAN#111	RP-260448	0128		B	CR on demodulation performance for TS 36.102 - IoT_NTN_TDD	19.3.0
2026-03	RAN#111	RP-260438	0123	1	B	Big CR for 36.102 for NTN NGSO testing	19.3.0
2026-03	RAN#111	RP-260449	0122	2	B	(LTE_band_5G_bcast_GSO-Perf) CR on adding UE demodulation requirements for 5G broadcast over GSO	19.3.0

History

Version	Date	Status
V19.1.0	October 2025	Publication
V19.2.0	February 2026	Publication
V19.3.0	April 2026	Publication