

ETSI TS 138 124 V16.3.0 (2021-09)



**5G;
NR;
Electromagnetic compatibility (EMC)
requirements for mobile terminals and ancillary equipment
(3GPP TS 38.124 version 16.3.0 Release 16)**



Reference

RTS/TSGR-0438124vg30

Keywords

5G

ETSI

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Foreword

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

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

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 - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

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.

- can** indicates that something is possible
- cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

- 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 essential EMC requirements for "3rd generation" digital cellular mobile terminal equipment and ancillary accessories in combination with a 3GPP NR user equipment (UE).

The equipment conforming to the requirements laid out in the present document and used in its intended electromagnetic environment in accordance with the manufacturer's instructions

- shall not generate electromagnetic disturbances at a level which may interfere with the intended operation of other equipment;
- has an adequate level of intrinsic immunity to electromagnetic disturbances to operate as intended;

The present document specifies the applicable EMC tests, methods of measurement, frequency ranges, applicable limits and minimum performance criteria for all types of NR UE(s) and their accessories. NR base station equipment operating within network infrastructure is outside the scope of the present document. However, the present document does cover mobile and portable equipment that is intended to be operated in a fixed location while connected to the AC mains. NR base station equipment operating within network infrastructure is covered by the technical specification TS 38.113 [2].

Requirements for the radiated emission from the enclosure port of integral antenna equipment and ancillaries are included in the present document. Technical specifications for conducted emissions from the antenna connector are found in the 3GPP specifications for the radio interface of NR UE, e.g. TS 38.101-1 [3], for the effective use of the radio spectrum.

Requirements for the radiated emissions from the enclosure port and ancillaries cover the following case:

- UE equipment supporting operations in a frequency range for which antenna connectors are available (i.e. for operations in FR1 as defined in e.g. TS 38.101-1 [3] for the radio interface).

The immunity requirements are selected to ensure an adequate level of compatibility for apparatus in residential, commercial, light industrial and vehicular environments. The levels however, do not cover extreme cases, which may occur in any location but with low probability of occurrence.

Compliance of radio equipment to the requirements of the present document does not signify compliance to any requirement related to the use of the equipment (i.e. licensing requirements).

Compliance to the requirements of the present document does not signify compliance to any safety requirement. However, any temporary or permanent unsafe condition caused by EMC is considered as non-compliance.

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 38.113: "NR; Base Station (BS) ElectroMagnetic Compatibility (EMC)".
- [3] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".
- [4] 3GPP TS 38.101-2: " NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone".

- [5] ITU-R Recommendation SM.329: "Unwanted emissions in the spurious domain".
- [6] Void
- [7] Void.
- [8] IEC 61000-3-2: "Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)".
- [9] IEC 61000-3-3: "Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection".
- [10] IEC 61000-4-3: "Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency electromagnetic field immunity test".
- [11] IEC 61000-4-2: "Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test".
- [12] IEC 61000-4-4: "Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test - Basic EMC publication".
- [13] IEC 61000-4-6: "Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances induced by radio frequency fields".
- [14] Void
- [15] ISO 7637-2: "Road vehicles -- Electrical disturbances from conduction and coupling -- Part 2: Electrical transient conduction along supply lines only".
- [16] IEC 61000-4-11: "Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions, and voltage variations immunity test".
- [17] IEC 61000-4-5: "Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test".
- [18] ITU-R Recommendation SM.1539 (2001): "Variation of the boundary between the out-of-band and spurious domains required for the application of Recommendations ITU-R SM.1541 and ITU-R SM.329".
- [19] IEC 60050-161: "International Electrotechnical Vocabulary - Chapter 161: Electromagnetic compatibility".
- [20] IEC CISPR 32: "Electromagnetic compatibility of multimedia equipment - Emission requirements".
- [21] 3GPP TS 38.508-1: "User Equipment (UE) conformance specification; Part 1: Common test environment".
- [22] 3GPP 38.509: "Special conformance testing functions for User Equipment (UE)".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

Ancillary equipment: Equipment (apparatus), used in connection with a user equipment (UE) is considered as an ancillary equipment (apparatus) if:

- the equipment is intended for use in conjunction with a UE to provide additional operational and/or control features to the UE, (e.g. to extend control to another position or location); and
- the equipment cannot be used on a stand-alone basis to provide user functions independently of a UE; and
- the UE to which it is connected, is capable of providing some intended operation such as transmitting and/or receiving without the ancillary equipment (i.e. it is not a sub-unit of the main equipment essential to the main equipment basic functions).

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

Enclosure port: Physical boundary of the apparatus through which electromagnetic fields may radiate or impinge. In the case of integral antenna equipment, this port is inseparable from the antenna port.

Idle mode: Idle mode is the state of User Equipment (UE) when switched ON but with no Radio Resource Control (RRC) connection.

Integral antenna: Antenna designed to be connected directly to the equipment with or without the use of an external connector and considered to be part of the equipment. An integral antenna may be fitted internally or externally to the equipment.

Necessary bandwidth: For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.

Out of band emissions: Emission on a frequency or frequencies immediately outside the necessary bandwidth, which results from, the modulation process, but excluding spurious emissions.

Spurious emission: Emission on a frequency, or frequencies, which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products but exclude out-of-band emissions.

Transient phenomena: Pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest (IEC 60050-161 [19])

User equipment: is a "Mobile Station" (MS) which is an entity capable of accessing a set of NR services via one or more radio interfaces. This entity may be stationary or in motion within the NR service area while accessing the NR services, and may simultaneously serve one or more users.

3.2 Symbols

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

BW_{Channel}	Channel bandwidth
F_{OOB}	The boundary between the NR out of band emission and spurious emission domains
N_{RB}	Transmission bandwidth configuration, expressed in units of resource blocks

3.3 Abbreviations

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

AC	Alternating Current
CA	Carrier Aggregation
DC	Direct Current
ESD	Electrostatic Discharge
EUT	Equipment Under Test
FAC	Fully Anechoic Chamber
FR	Frequency Range

HCP	Horizontal Coupling Plane
LISN	Line Impedance Stabilising Networks
NR	New Radio
RF	Radio Frequency
RMS	Root Mean Square (value)
UE	User Equipment

4 Test conditions

4.1 General

The equipment shall be tested under normal test conditions according to the relevant product and basic standards. If these conditions are not specified then the manufacturers declared range of humidity, temperature and supply voltage shall be used. The test conditions shall be recorded in the test report.

Whenever the Equipment under test (EUT) is provided with a detachable antenna, the EUT shall be tested with the antenna fitted in a manner typical of normal intended use, unless specified otherwise.

Where the equipment incorporates an external 50 Ω RF antenna connector that is normally connected via a coaxial cable, then the wanted signal to establish a communication link also uses a coaxial cable.

Where the equipment has an external 50 Ω RF antenna connector that is not normally connected via a coaxial cable or where the equipment has no external 50 Ω RF connector (i.e., integral antenna equipment), then the wanted signal, to establish a communication link, shall be delivered from the equipment to an antenna located within the test environment.

Requirements throughout the RF specifications are in many cases defined separately for different frequency ranges (FR). The frequency ranges in which a UE equipment (NR) can operate according to this version of the specification are identified as described in table 4.1-1. The test conditions may be different for operations in FR1 and FR2.

Table 4.1-1: Definition of frequency ranges

Frequency range designation	Corresponding frequency range
FR1	410 MHz – 7125 MHz
FR2	24250 MHz – 52600 MHz

4.2 Arrangements for establishing a communication link

For transmitters with an integral antenna, the wanted RF output signal to establish a communication link shall be delivered from the EUT to an antenna located within the test environment. This antenna shall be connected to the external measuring equipment by a coaxial cable.

For transmitters with an antenna connector, the wanted RF output signal to establish a communication link shall be delivered from the antenna connector to the external measuring equipment by a shielded transmission line, such as a coaxial cable. Adequate measures shall be taken to minimize the effect of unwanted common mode currents on the external conductor of the transmission line at the point of entry to the transmitter.

The wanted RF input signal nominal frequency shall be selected by setting the NR Absolute Radio Frequency Channel Number to an appropriate number.

For UE equipment only support operations in FR1 a communication link shall be set up with a suitable base station simulator (hereafter called "the test system"). The test system shall be located outside of the test environment.

When the EUT is required to be in the traffic mode, a call is set up according to the generic call set-up procedure [and the following conditions shall be met:

See TS 38.508-1 [21] and TS 38.509 [22] for details regarding generic call set-up procedure and throughput test loop scenarios.

- Set and send continuously positive TPC commands to the UE;
- The DTX shall be disabled;
- Uplink power control shall be enabled;
- transmitting and/or receiving (UL/DL) bit rate for reference test channel shall be the reference measurement channel as specified in annex A in TS 38.101-1 [3] with parameters specified in table 7.3.2-1 and table 7.3.2-2 in TS 38.101-1 [3];
- Adequate measures shall be taken to avoid the effect of the unwanted signal on the measuring equipment;
- For immunity testing, the wanted input signal level shall be set to 40 dB above the reference sensitivity level to provide a stable communication link. The reference sensitivity level is defined in TS 38.101-1 [3];
- For emission testing, the wanted input signal level shall be no more than 15 dB above the reference sensitivity level, such that the performance of the measuring receiver is not limited by strong signal effects.

When the EUT is required to be in the idle mode the following conditions shall be met.

- UE shall be camped on a cell
- UE shall perform Location Registration (LR) before the test, but not during the test;
- UE's neighbour cell list shall be empty;
- Paging repetition period and DRX cycle shall be set to minimum (shortest possible time interval).

For immunity tests, clause 4.3 applies.

4.3 Narrow band responses on receivers

Responses on receivers or duplex transceivers occurring during the test at discrete frequencies, which are narrow band responses (spurious responses), are identified by the following method:

- If during an immunity test the quantity being monitored goes outside the specified tolerances, it is necessary to establish whether the deviation is due to an unwanted effect on the receiver of the UE or on the test system (narrow band response) or to a wide band (EMC) phenomenon. Therefore, the test shall be repeated with the unwanted signal frequency increased or decreased by BW_{Channel} MHz, where BW_{Channel} is the channel bandwidth as defined in TS 38.101-1 [3];
- If the deviation does not disappear, the procedure is repeated the unwanted signal frequency increased or decreased by $2 \times BW_{\text{Channel}}$ MHz, where BW_{Channel} is the channel bandwidth as defined in TS 38.101-1 [3];
- If the deviation does not disappear with the increased and/or decreased frequency, the phenomenon is considered wide band and therefore an EMC problem and the equipment fails the test.

Narrow band responses are disregarded.

The procedure above does not apply to conducted immunity tests in the frequency range 150 kHz to 80 MHz.

4.4 Receiver exclusion band

The receiver exclusion band for terminals extends from the lower frequency of the allocated receiver band minus 85 MHz to the upper frequency of the allocated receiver band plus 85 MHz. The *receiver exclusion band* for UE is the frequency range over which no tests of radiated immunity of a receiver are made. The exclusions bands are as set out below:

$$F_{\text{DL,low}} - 85 < f < F_{\text{DL,high}} + 85 \text{ (MHz)}$$

Where values of $F_{\text{DL,low}}$ and $F_{\text{DL,high}}$ are defined for each operating band in TS 38.101-1 [3], clause 5.2.

5 Performance assessment

5.1 General

The manufacturer shall at the time of submission of the equipment for test, supply the following information to be recorded in the test report:

- The primary functions of the radio equipment to be tested during and after the EMC testing;
- If applicable, the method to be used to verify that a communications link is established and maintained;
- The intended functions of the radio equipment which shall be in accordance with the documentation accompanying the equipment;
- The user-control functions and stored data that are required for normal operation and the method to be used to assess whether these have been lost after EMC stress;
- The ancillary equipment to be combined with the radio equipment for testing (where applicable);
- Information about ancillary equipment intended to be used with the radio equipment;
- An exhaustive list of ports, classified as either power or signal/control. Power ports shall further be classified as AC or DC power;
- The humidity range, temperature, and supply voltage for all equipment submitted for testing.

5.2 Equipment which can provide a continuous communication link

The test arrangement and signals, given in clause 4, apply to radio equipment or a combination of radio equipment and ancillary equipment that permits the establishment of a communication link. The assessment of equipment performance shall be based on data transfer according to the criteria in clause 6.

5.3 Equipment which can only provide a discontinuous communication link (packet data/transmission)

If the equipment does not permit or allow for a communications link to be established and maintained during the EMC tests (as in clause 5.2), the manufacturer shall define the performance assessment. The manufacturer shall provide the method of observing the degradation of performance of the equipment.

5.4 Equipment which does not provide a communication link

If the equipment is of a specialised nature which does not permit a communication link to be established, the manufacturer shall define the method of test to determine the acceptable level of performance or degradation of performance during and/or after the test. The manufacturer shall provide the method of observing the degradation of performance of the equipment.

The performance assessment carried out shall be simple, but at the same time give adequate proof that the primary functions of the equipment are operational.

5.5 Conformance of ancillary equipment

Ancillary equipment shall be tested with it connected to a UE in which case compliance shall be demonstrated to the appropriate clauses of the present document.

5.6 Equipment classification

Equipment is classified according to the source of power:

- If power is derived from a fixed AC or DC supply network installation the equipment is classified "for fixed use";
- If power is derived from a vehicular power supply (car battery + alternator) the equipment is classified "for vehicular use";
- If power is derived from an integral battery the equipment is classified "for portable use".

6 Performance criteria

6.1 General

The maintenance of a communications link shall be assessed by using an indicator, which may be part of the test system or the equipment under test.

Specifically the equipment shall meet the minimum performance criteria as specified in the following clauses as appropriate.

Portable equipment intended for use whilst powered by the main battery of a vehicle shall additionally fulfil the applicable requirements set out by the present document for mobile equipment for vehicular use.

Portable equipment intended for use whilst powered by AC mains shall additionally fulfil the applicable requirements set out by the present document for equipment for fixed use.

If an equipment is of such nature, that the performance criteria described in the following clauses are not appropriate, then the manufacturer shall declare, for inclusion in the test report, his own specification for an acceptable level of performance or degradation of performance during and/or after testing, as required by the present document.

The performance criteria specified by the manufacturer shall give the same degree of immunity protection as called for in the following clauses.

In addition, the test shall also be performed in idle mode to ensure the transmitter does not unintentionally operate.

The requirements apply to all types of NR for the UE.

6.2 Performance criteria for continuous phenomena

A communication link shall be established at the start of the test, and maintained during the test, clauses 4.1 and 4.2.

In the data transfer mode, the performance criteria shall be that the throughput shall be $\geq 95\%$ of the maximum throughput of the reference measurement channel as specified in annex A in TS 38.101-1 [3] or TS 38.101-2 [4], with parameters specified in clause 7.3.2 in TS 38.101-1 [3] or TS 38.101-2 [4] during the test sequence.

At the conclusion of the test, the EUT shall operate as intended with no loss of user control functions or stored data, and the communication link shall have been maintained.

In addition to confirming the above performance in traffic mode, the test shall be performed in idle mode, and the transmitter shall not unintentionally operate.

6.3 Performance criteria for transient phenomena

A communications link shall be established at the start of the test, clauses 4.1 and 4.2.

At the conclusion of each exposure the EUT shall operate with no user noticeable loss of the communication link.

At the conclusion of the total test comprising the series of individual exposures, the EUT shall operate as intended with no loss of user control functions or stored data, as declared by the manufacturer, and the communication link shall have been maintained.

In addition to confirming the above performance in traffic mode, the test shall also be performed in idle mode, and the transmitter shall not unintentionally operate.

7 Applicability overview tables

7.1 EMC emissions

Table 7.1-1: Emission applicability

Phenomenon	Application	Equipment test requirement			Reference clause in the present document	Reference standard
		Equipment connected to fixed AC or DC power installations	Equipment connected to vehicular DC supplies	Equipment powered by integral battery		
Radiated emission	Enclosure	applicable	applicable	applicable	8.2	ITU-R SM.329 [5] TS 38.101-1 [3]
Conducted emission	DC power input/output port	applicable	applicable	not applicable	8.3	CISPR 32 [20]
Conducted emission	AC mains input/output port	applicable	not applicable	not applicable	8.4	CISPR 32 [20]
Harmonic current emissions	AC mains input port	applicable	not applicable	not applicable	8.5	IEC 61000-3-2 [8]
Voltage fluctuations and flicker	AC mains input port	applicable	not applicable	not applicable	8.6	IEC 61000-3-3 [9]

For UE equipment operating in FR1 (table 4.1-1), the radiated emission applies to the enclosure port with antenna ports available.

For UE equipment supporting operations in FR2 (table 4.1-1) the enclosure port is inseparable from the antenna port.

7.2 Immunity

Table 7.2-1: Immunity applicability

Phenomenon	Application	Equipment test requirement			Reference clause in the present document	Reference standard
		Equipment connected to fixed AC or DC power installations	Equipment connected to vehicular DC supplies	Equipment powered by integral battery		
RF electro-magnetic field (80 MHz to 6000 MHz)	Enclosure	applicable	applicable	applicable	9.2	IEC 61000-4-3 [10]
Electrostatic discharge	Enclosure	applicable	applicable	applicable	9.3	IEC 61000-4-2 [11]
Fast transients common mode	Signal and control ports, DC and AC power input ports	applicable	not applicable	not applicable	9.4	IEC 61000-4-4 [12]
RF common mode 0.15 MHz to 80 MHz	Signal and control ports, DC and AC power input ports	applicable	applicable	applicable	9.5	IEC 61000-4-6 [13]
Transients and surges, vehicular environment	DC power input ports	not applicable	applicable	not applicable	9.6	ISO 7637 Part 1 [14] and ISO 7637 Part 2 [15]
Voltage dips and interruptions	AC mains power input ports	applicable	not applicable	not applicable	9.7	IEC 61000-4-11 [16]
Surges, common and differential mode	DC and AC power input ports	applicable	not applicable	not applicable	9.8	IEC 61000-4-5 [17]

8 Methods of measurement and limits for EMC emissions

8.1 Test configurations

This clause defines the configurations for emission tests as follows:

- the equipment shall be tested under normal test conditions;
- the test configuration shall be as close to normal intended use as possible;
- if the equipment is part of a system, or can be connected to ancillary equipment, then it shall be acceptable to test the equipment while connected to the minimum configuration of ancillary equipment necessary to exercise the ports;
- if the equipment has a large number of ports, then a sufficient number shall be selected to simulate actual operation conditions and to ensure that all the different types of termination are tested;
- the test conditions, test configuration and mode of operation shall be recorded in the test report;

- ports which in normal operation are connected shall be connected to an ancillary equipment or to a representative piece of cable correctly terminated to simulate the input/output characteristics of the ancillary equipment, Radio Frequency (RF) input/output ports shall be correctly terminated;
- ports that are not connected to cables during normal operation, e.g. service connectors, programming connectors; temporary connectors etc. shall not be connected to any cables for the purpose of EMC testing. Where cables have to be connected to these ports, or interconnecting cables have to be extended in length in order to exercise the EUT, precautions shall be taken to ensure that the evaluation of the EUT is not affected by the addition or extension of these cables;
- emission tests shall be performed in two modes of operation:
 - with a communication link established (traffic mode); and
 - in the idle mode.

8.2 Radiated emission

8.2.1 General

This test is applicable to radio communications equipment and ancillary equipment.

This test shall be performed on the radio equipment and/or a representative configuration of the ancillary equipment.

8.2.2 Definition

This test assesses the ability of radio equipment and ancillary equipment to limit unwanted emissions from the enclosure port.

For UE equipment supporting operations in FR2 (table 4.1-1) with integral antennas only (no antenna connectors available), the EMC radiated emissions cannot be distinguished between the intended emissions nor to any spurious emissions related to these intentional transmissions:

- This test is applicable to UE equipment without integral antennas, i.e. FR1.
- For UE equipment with integral antennas only, i.e. FR2, the radiated emission is covered by radiated spurious emission requirement in TS 38.101-2 [4].

8.2.3 Test method

Whenever possible the site shall be a fully anechoic chamber (FAC) simulating the free-space conditions. EUT shall be placed on a non-conducting support. Mean power of any spurious components shall be detected by the test antenna and measuring receiver (e.g. a spectrum analyser).

At each frequency at which a component is detected, the EUT shall be rotated to obtain maximum response, and the effective radiated power (e.r.p.) of that component determined by a substitution measurement, which shall be the reference method. The measurement shall be repeated with the test antenna in the orthogonal polarization plane.

NOTE: Effective radiated power e.r.p. refers to the radiation of a half wave tuned dipole instead of an isotropic antenna. There is a constant difference of 2.15 dB between e.i.r.p. and e.r.p.

$$\text{e.r.p. (dBm)} = \text{e.i.r.p. (dBm)} - 2.15, \text{ Ref. ITU-R SM. 329 annex 1 [5]}$$

Measurements are made with a tuned dipole antenna or a reference antenna with a known gain referenced to an isotropic antenna. Unless otherwise stated, all measurements are done as mean power (RMS).

8.2.4 Limits

Unless otherwise stated, the radiated spurious emission limits apply for the frequency ranges that are more than F_{OOB} (MHz) in table 8.2.4-0 from the edge of the channel bandwidth. The radiated spurious emission limits in table 8.2.4-1 apply for all transmitter band configurations (N_{RB}) and channel bandwidths.

The references for these requirements are ITU-R SM 329 [5], SM.1539 [18] and TS 38.101-1 [3] for FR1.

The frequency boundary and reference bandwidths for the detailed transitions of the limits between the requirements for out of band emissions and spurious emissions are based on ITU-R SM 329 [5].

These requirements are only applicable for frequencies in the spurious domain. The limits are specified in table 8.2.4-1 for UE equipment supporting operations in FR1 only.

Table 8.2.4-0: Boundary between NR out of band and general spurious emission domain

Channel bandwidth	OOB boundary F_{OOB} (MHz)
$BW_{Channel}$	$BW_{Channel} + 5$

Table 8.2.4-1: Radiated spurious emissions requirements for UE equipment supporting operations in FR1

Frequency range	Maximum level (dBm)	Measurement bandwidth	Notes
$30 \text{ MHz} \leq f < 1000 \text{ MHz}$	-36	100 kHz	
$1 \text{ GHz} \leq f < 12.75 \text{ GHz}$	-30	1 MHz	4
	-25	1 MHz	3
$12.75 \text{ GHz} \leq f < 5^{\text{th}}$ harmonic of the upper frequency edge of the UL operating band in GHz	-30	1 MHz	1
$12.75 \text{ GHz} < f < 26 \text{ GHz}$	-30	1 MHz	2
NOTE 1: Applies for Band that the upper frequency edge of the UL Band more than 2.69 GHz.			
NOTE 2: Applies for Band that the upper frequency edge of the UL Band more than 5.2 GHz.			
NOTE 3: As specified in TS 38.101-1 [3]: Applies for Band n41, CA configurations including Band n41, and EN-DC configurations that include n41 specified in clause 5.2B of TS 38.101-3 [3] when NS_04 is signalled.			
NOTE 4: As specified in TS 38.101-1 [3]: Does not apply for Band n41, CA configurations including Band n41, and EN-DC configurations that include n41 specified in clause 5.2B of TS 38.101-3 [3] when NS_04 is signalled.			

NOTE: Void.

8.2.5 Interpretation of the measurement results

The interpretation of the results recorded in a test report for the radiated emission measurements described in the present document shall be as follows:

- the measured value related to the corresponding limit will be used to decide whether an equipment meets the requirements of the present document;
- the value of the measurement uncertainty for the measurement of each parameter shall be included in the test report;
- the recorded value of the measurement uncertainty shall be, for each measurement, equal to or lower than the figure in table 8.2.5-1.

Table 8.2.5-1 specifies the Maximum measurement uncertainty of the Test System. The Test System shall enable the equipment under test to be measured with an uncertainty not exceeding the specified values. All tolerances and uncertainties are absolute values, and are valid for a confidence level of 95 %, unless otherwise stated.

A confidence level of 95% is the measurement uncertainty tolerance interval for a specific measurement that contains 95% of the performance of a population of test equipment.

Table 8.2.5-1: Maximum measurement uncertainty

Parameter	Uncertainty
Effective radiated RF power between 30 MHz and 180 MHz	±6 dB
Effective radiated RF power between 180 MHz and 12.75 GHz	±3 dB
Effective radiated RF power between 12.75 GHz and 26 GHz	TBD

NOTE: If the Test System for a test is known to have a measurement uncertainty greater than that specified in table 8.2.5-1, this equipment can still be used, provided that an adjustment is made follows: Any additional uncertainty in the Test System over and above that specified in table 8.2.5-1 is used to tighten the Test Requirements - making the test harder to pass. This procedure will ensure that a Test System not compliant with table 8.2.5-1 does not increase the probability of passing an EUT that would otherwise have failed a test if a Test System compliant with table 8.2.5-1 had been used.

8.3 Conducted emission DC power input/output port

This test is applicable to all equipment, which may have DC cables longer than 3 m.

If the DC power cable of the UE and/or the ancillary equipment is intended to be less than 3 m in length, and intended only for direct connection to a dedicated AC to DC power supply, then the measurement shall be performed only on the AC power input of that power supply as specified in clause 8.4.

This test shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

8.3.1 Definition

This test assesses the ability of radio equipment and ancillary equipment to limit internal noise from the DC power input/output ports.

8.3.2 Test method

The test method shall be in accordance with CISPR 32 [20], and the Line Impedance Stabilising Networks (LISN) shall be connected to a DC power source.

In the case of DC output ports, the ports shall be connected via a LISN to a load drawing the rated current of the source.

A measuring receiver shall be connected to each LISN measurement port in turn and the conducted emission recorded. The LISN measurement ports not being used for measurement shall be terminated with a 50 Ω load.

The equipment shall be installed with a ground plane as defined in CISPR 32 [20]. The reference earth point of the LISNs shall be connected to the reference ground plane with a conductor as short as possible.

8.3.3 Limits

The equipment shall meet the limits according to CISPR 32 [20] table A.9 which are defined for average detector receiver and for quasi peak detector receiver. If the average limit is met when using a quasi-peak detector, the equipment shall be deemed to meet both limits and measurement with the average detector receiver is not necessary.

8.4 Conducted emissions, AC mains power input/output port

This test is applicable to equipment powered by the AC mains.

This test is not applicable to AC output ports, which are connected directly (or via a switch or circuit breaker) to the AC input port.

This test shall be performed on a representative configuration of the radio equipment or a representative configuration of the combination of radio and ancillary equipment.

8.4.1 Definition

This test assesses the ability of radio equipment and ancillary equipment to limit internal noise from the AC mains power input/output ports.

8.4.2 Test method

The test method shall be in accordance with CISPR 32 [20].

8.4.3 Limits

The equipment shall meet the limits according to CISPR 32 [20] table A.10, which are defined for the average detector receiver and for quasi-peak detector receiver. If the average limit is met when using a quasi-peak detector, the equipment shall be deemed to meet both limits and measurement with the average detector receiver is not necessary.

8.5 Harmonic current emissions (AC mains input port)

The requirements of IEC 61000-3-2 [8] for harmonic current emission apply for equipment covered by the scope of the present document.

8.6 Voltage fluctuations and flicker (AC mains input port)

The requirements of IEC 61000-3-3 [9] for voltage fluctuations and flicker apply for equipment covered by the scope of the present document.

9 Test methods and levels for immunity tests

9.1 Test configurations

This clause defines the configurations for immunity tests as follows:

- the equipment shall be tested under normal test conditions as specified in the core specification;
- the test configuration shall be as close to normal intended use as possible;
- if the equipment is part of a system, or can be connected to ancillary equipment, then it shall be acceptable to test the equipment while connected to the minimum configuration of ancillary equipment necessary to exercise the ports;
- if the equipment has a large number of ports, then a sufficient number shall be selected to simulate actual operation conditions and to ensure that all the different types of termination are tested;
- the test conditions, test configuration and mode of operation shall be recorded in the test report;
- ports which in normal operation are connected shall be connected to an ancillary equipment or to a representative piece of cable correctly terminated to simulate the input/output characteristics of the ancillary equipment, Radio Frequency (RF) input/output ports shall be correctly terminated;
- ports, which are not, connected to cables during normal operation, e.g. service connectors, programming connectors, temporary connectors etc. shall not be connected to any cables for the purpose of EMC testing. Where cables have to be connected to these ports, or interconnecting cables have to be extended in length in order to exercise the EUT, precautions shall be taken to ensure that the evaluation of the EUT is not affected by the addition or extension of these cables;
- the test arrangements for transmitter and receiver clauses of the transceiver are described separately for the sake of clarity. However, where possible the test of the transmitter clause and receiver clause of the EUT may be carried out simultaneously to reduce test time;

- immunity tests shall be performed in two modes of operation:
 - with a communication link established (traffic mode); and
 - in the idle mode.

9.2 RF electromagnetic field (80 MHz to 6000 MHz)

The test shall be performed on a representative configuration of the equipment or a representative configuration of the combination of UE and ancillary equipment.

9.2.1 Definition

This test assesses the ability of UE and ancillary equipment to operate as intended in the presence of a radio frequency electromagnetic field disturbance at the enclosure.

9.2.2 Test method and level

The test method shall be in accordance with IEC 61000-4-3 [10]

- For UE and ancillary equipment, the following requirements shall apply;
- The test level shall be 3 V/m amplitude modulated to a depth of 80 % by a sinusoidal audio signal of 1 kHz;
- The stepped frequency increments shall be 1 % of the momentary frequency;
- The test shall be performed over the frequency range 80 MHz to 6000 MHz;
- Responses in stand-alone receivers or receivers which are part of transceivers occurring at discrete frequencies which are narrow band responses, shall be disregarded, see clause 4.3;
- The frequencies selected during the test shall be recorded in the test report.

9.2.3 Performance criteria

The performance criteria of clause 6.1 shall apply.

9.3 Electrostatic discharge

9.3.0 General

The test shall be performed on a representative configuration of the equipment or a representative configuration of the combination of UE and ancillary equipment.

9.3.1 Definition

This test assesses the ability of UE and ancillary equipment to operate as intended in the event of an electrostatic discharge.

9.3.2 Test method and level

The test method shall be in accordance with IEC 61000-4-2 [11]:

- for contact discharge, the equipment shall pass at ± 2 kV and ± 4 kV;
- for air discharge the equipment shall pass at ± 2 kV, ± 4 kV and ± 8 kV (only for non-conducting surfaces, see IEC 61000-4-2 [11]).

NOTE: The EUT shall be fully discharged between each ESD exposure by connecting its ground point (where applicable) to the HCP by a resistive wire with a 470 k Ω resistor in either end.

9.3.3 Performance criteria

The performance criteria of clause 6.2 shall apply.

9.4 Fast transients common mode

9.4.0 General

The test shall be performed on AC mains power input ports.

This test shall be performed on signal ports, control ports and DC power input/output ports if the cables may be longer than 3 m.

Where this test is not carried out on a port or any other ports because the manufacturer declares that it is not intended to be used with cables longer than 3 m, a list of ports which were not tested for this reason shall be included in the test report.

This test shall be performed on a representative configuration of the equipment or a representative configuration of the combination of UE and ancillary equipment.

9.4.1 Definition

This test assesses the ability of UE and ancillary equipment to operate as intended in the event of fast transients present on one of the input/output ports.

9.4.2 Test method and level

The test method shall be in accordance with IEC 61000-4-4 [12]

- the test level for signal and control ports shall be 0,5 kV open circuit voltage as given in IEC 61000-4-4 [12];
- the test level for DC power input/output ports shall be 0,5 kV open circuit voltage as given in IEC 61000-4-4 [12];
- the test level for AC mains power input ports shall be 1 kV open circuit voltage as given in IEC 61000-4-4 [12].

9.4.3 Performance criteria

The performance criteria of clause 6.2 shall apply.

9.5 RF common mode (0.15 MHz to 80 MHz)

9.5.0 General

This test is applicable for UE for fixed, mobile, and portable use and for ancillary equipment.

This test shall be performed on signal, control and DC power input/output ports, which may have cables longer than 3 m.

This test shall be performed on AC mains power input/output ports of UE for fixed use and for fixed ancillary equipment. Where this test is not carried out on a port or any other ports because the manufacturer declares that it is not intended to be used with cables longer than stated above, a list of ports which were not tested shall be included in the test report.

This test shall be performed on a representative configuration of the UE or a representative configuration of the combination of UE and ancillary equipment.

9.5.1 Definition

This test assesses the ability of equipment and ancillary equipment to operate as intended in the presence of a radio frequency electromagnetic disturbance.

9.5.2 Test method and level

The test method shall be in accordance with IEC 61000-4-6 [13]:

- the test signal shall be amplitude modulated to a depth of 80 % by a sinusoidal audio signal of 1 kHz;
- the stepped frequency increments shall be either 50 kHz or 1 % frequency increment of the momentary frequency in the frequency range 150 kHz - 5 MHz and 1 % frequency increment of the momentary frequency in the frequency range 5 MHz - 80 MHz;
- the test level shall be severity level 2 as given in IEC 61000-4-6 [13] corresponding to 3 V RMS, at a transfer impedance of 150 Ω ;
- the test shall be performed over the frequency range 150 kHz - 80 MHz;
- responses of stand alone receivers or receivers which are part of transceivers occurring at discrete frequencies which are narrow band responses, shall be disregarded, see clause 4.3;
- the frequencies selected during the test and the test method used shall be recorded in the test report.

9.5.3 Performance criteria

The performance criteria of clause 6.1 shall apply.

9.6 Transients and surges, vehicular environment

9.6.1 Definition

The tests are applicable to UE intended for use in a vehicular environment.

These tests shall be performed on 12 V and 24 V DC power input.

These tests shall be performed on a representative configuration of the equipment or a representative configuration of the combination of UE and ancillary equipment.

These tests assess the ability of UE and ancillary equipment to operate as intended in the event of transients and surges present on the DC power input ports in a vehicular environment.

9.6.2 Test method and level

The test method shall be in accordance with ISO 7637-2 [15] for nominal 12 V DC powered equipment and nominal 24 V DC powered equipment. The requirements are detailed as follows:

9.6.2.1 12 V DC powered equipment

The test pulse severity levels I/II shall apply for nominal 12 V system as specified in table A.1 in accordance with ISO 7637-2 [15].

Where the manufacturer declares that the EUT requires a direct connection to the vehicle battery, and the corresponding tests are not carried out, this shall be stated in the test report.

9.6.2.2 24 V DC powered equipment

The test pulse severity level I/II shall apply for nominal 24 V system as specified in table A.2 in accordance with ISO 7637-2 [15].

Where the manufacturer declares that the EUT requires a direct connection to the vehicle battery, and the corresponding tests are not carried out, this shall be stated in the test report.

For UE designed to operate at 12 V DC power supply, but operating from a 24 V DC power adapter ancillary, then the UE shall comply with the requirements in 9.6.2.1 and the configuration of the UE and the power adapter shall comply with the requirements of 9.6.2.2.

9.6.3 Performance criteria

The performance criteria of clause 6.2 shall apply. However, where the equipment is powered without the use of a parallel battery back-up, for pulses 1, 2a, 2b the communications link need not be maintained and may have to be re-established and volatile user data may have been lost.

9.7 Voltage dips and interruptions

9.7.0 General

The tests shall be performed on AC mains power input ports.

These tests shall be performed on a representative configuration of the UE or a representative configuration of the combination of UE and ancillary equipment.

9.7.1 Definition

These tests assess the ability of UE and ancillary equipment to operate as intended in the event of voltage dips and interruptions present on the AC mains power input ports.

9.7.2 Test method and level

The following requirements shall apply.

The test method shall be in accordance with IEC 61000-4-11 [16].

The test levels shall be:

- a voltage dip corresponding to a reduction of the supply voltage of 60 % for 5 periods;
- a voltage interruption corresponding to a reduction of the supply voltage of > 95 % for 250 periods.

9.7.3 Performance criteria

The performance criteria of clause 6.2 shall apply. However, in the case where the equipment is powered solely from the AC mains supply (without the use of a parallel battery back-up) the communications link need not be maintained and may have to be re-established and volatile user data may have been lost. In the event of loss of the communications link or in the event of loss of user data, this fact shall be recorded in the test report, the product description and the user documentation.

9.8 Surges, common and differential mode

9.8.1 Definition

The tests shall be performed on AC mains power input ports.

These tests shall be performed on a representative configuration of the UE or a representative configuration of the combination of UE and ancillary equipment.

These tests assess the ability of UE and ancillary equipment to operate as intended in the event of surges being present at the AC mains power input ports.

9.8.2 Test method and level

The test method shall be in accordance with IEC 61000-4-5 [17].

The following requirements and evaluation of test results shall apply:

- the test level for ac mains power input ports shall be 1 kV line to ground and 0,5 kV line to line with the output impedance of the surge generator as given in the IEC 61000-4-5 [17];
- the test generator shall provide the 1,2/50 μ sec pulse as defined in IEC 61000-4-5 [17].

9.8.3 Performance criteria

The performance criteria of clause 6.2 shall apply.

Annex A (informative): Change history

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2017-10	R4#84bis	R4-1710899				Specification template	0.0.1
2017-12	RAN4#85	R4-1714548				Capture approved Text Proposals in RAN4#85 R4-1712520: TP to 38.124: Scope R4-1712521: TP to 38.124: Test conditions R4-1712522: TP to 38.124: Applicability R4-1712523: TP to 38.124: EMC emissions tests R4-1712524: TP to 38.124: Immunity tests	0.1.0
2017-12	RAN#78	RP-172249				Presentation to TSG RAN for approval	1.0.0
2017-12	RAN#78					Approved by plenary – Rel-15 spec under change control	15.0.0
2018-03	RAN#79	RP-180264	0001		F	Implementation of agreed draft CRs	15.1.0
2019-03	RAN#83	RP-190401	0002	2	F	CR to TS 38.124 on FR1 extension	15.2.0
2020-06	RAN#88	RP-200986	0005	1	F	CR to TS 38.124 adding Methods of measurement and limits for EMC emissions	15.3.0
2020-06	RAN#88	RP-200986	0010		F	CR to TS 38.124: specification corrections and removal of [], Rel-15	15.3.0
2020-06	RAN#88	RP-200986	0011	1	F	CR to TS 38.124: correction of UE radiated spurious emissions requirement, Rel-15	15.3.0
2020-06	RAN#88	RP-200986	0012	1	F	CR to TS 38.124: correction of the Rx exclusion band, Rel-15	15.3.0
2020-06	RAN#88	RP-200986	0013		F	CR to TS 38.124: Performance assessment, Rel-15	15.3.0
2020-06	RAN#88	RP-200986	0014		F	CR to TS 38.124: Performance criteria, Rel-15	15.3.0
2020-06	RAN#88	RP-200986	0016	1	B	[EMC] CR TS38.124 CS	15.3.0
2020-06	RAN#88	RP-200986	0017	1	B	[EMC] CR TS38.124 dips	15.3.0
2020-06	RAN#88	RP-200986	0018	1	B	[EMC] CR TS38.124 EFT	15.3.0
2020-06	RAN#88	RP-200986	0019	1	B	[EMC] CR TS38.124 ESD	15.3.0
2020-06	RAN#88	RP-200986	0020	1	F	[EMC] CR TS38.124 references	15.3.0
2020-06	RAN#88	RP-200986	0023	1	B	[EMC] CR TS38.124 surge	15.3.0
2020-06	RAN#88	RP-200986	0024	1	F	[EMC] CR TS38.124 vehicular environment	15.3.0
2020-06	-	-	-	-	-	Update to Rel-16 version (MCC)	16.0.0
2020-09	RAN#89	RP-201512	0026		A	CR to TS 38.124 combined correction R16	16.1.0
2021-03	RAN#91	RP-210117	0032		A	CR for TS 38.124: Correction of FR1 radiated spurious emissions (R16)	16.2.0
2021-06	RAN#92	RP-211080	0036	1	A	CR to 38.124: TBD removal for the maximum measurement uncertainty for measurements above 12.75GHz, Rel-16	16.3.0

History

Document history		
V16.0.0	July 2020	Publication
V16.1.0	November 2020	Publication
V16.2.0	April 2021	Publication
V16.3.0	September 2021	Publication