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**Electromagnetic compatibility (EMC) –
Part 4-41: Testing and measurement techniques – Broadband radiated immunity
tests**

**Compatibilité électromagnétique (CEM) –
Partie 4-41: Techniques d'essai et de mesure – Essais d'immunité aux
rayonnements à large bande**



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INTERNATIONAL
ELECTROTECHNICAL
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IEC 61000-4-41 has been prepared by subcommittee 77B: High frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility. It is an International Standard.

It forms Part 4-41 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

The text of this International Standard is based on the following documents:

Draft	Report on voting
77B/892/FDIS	77B/895/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

- General considerations (introduction, fundamental principles)
- Definitions, terminology

Part 2: Environment

- Description of the environment
- Classification of the environment
- Compatibility levels

Part 3: Limits

- Emission limits
- Immunity limits (in so far as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

- Measurement techniques
- Testing techniques

Part 5: Installation and mitigation guidelines

- Installation guidelines
- Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as international standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

This part is an international standard which gives immunity requirements and test procedures related to radiated disturbances generated by broadband signals.

Modern digital communication signals operate on multiple frequencies such as orthogonal frequency division multiplexing (OFDM) and use bandwidths ranging from tens of MHz to hundreds of MHz, all while employing in-band time division duplexing (TDD) or frequency division duplexing (FDD) transmission technology, or both. Such broadband signals can cause a performance degradation or malfunction of other equipment, or both. In this document, the disturbance is not a frequency sweep of a narrowband signal but a broadband signal with coexisting multiple frequencies which is stepped through the desired frequency range.

Examples of broadband signals are LTE signals and 5G mobile communication signals.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-41: Testing and measurement techniques – Broadband radiated immunity tests

1 Scope

This part of IEC 61000 relates to broadband radiated disturbances generated by, for example, communication devices or services, transmitters or industrial electromagnetic sources or any other devices capable of generating such a signal.

The object of this document is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to broadband radiated electromagnetic fields.

This document specifies testing in the frequency ranges above 80 MHz, limited only by the capabilities of commercially available test instrumentation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61000-4-3:2020, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61000-4-3 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1.1

auxiliary equipment

AE

equipment necessary to provide the equipment under test (EUT) with the signals required for normal operation and equipment to verify the performance of the EUT

3.1.2

equivalent carrier electric field strength

electric field strength at carrier frequency equivalent to the square root of the cumulative electric field power (E^2) caused by the radiation of broadband signal

Note 1 to entry: Equivalent carrier electric field strength is expressed in V/m.

3.1.3**broadband signal**

signal where the energy is distributed over several megahertz, either by the broadband nature of the signal itself or by a modulation, for example by a collection of subcarriers

Note 1 to entry: In typical applications a broadband signal can be as wide as 5 MHz to 100 MHz.

3.1.4**duty cycle**

fraction of the period where a repetitive signal is above a specified threshold

Note 1 to entry: That period is the duration of time for one cycle of a repeating event. It is the reciprocal of repetition frequency.

3.1.5**test generator**

generator capable of generating the required test signal

Note 1 to entry: The test generator can, for example, include a vector signal generator, modulation sources, attenuators, broadband power amplifiers and filters, etc. See Annex A for additional information on test generator.

3.1.6**white noise**

random noise which has a continuous spectrum and a constant power spectral density in the frequency band considered

[SOURCE: IEC 60050-702:1992, 702-08-39, modified – In the term “flat random noise” has been removed.]

3.1.7**electric field spectral density**

quantity derived from the electric power spectral density (PSD) of a broadband signal

Note 1 to entry: Further information can be found in Annex D.

Note 2 to entry: For electric field spectral density, the unit is (V/m)/ $\sqrt{\text{Hz}}$.

3.1.8**power spectral density****PSD**

distribution as a function of frequency of the power per unit bandwidth of the spectral components of a signal or a noise having a continuous spectrum and a finite mean power

Note 1 to entry: A PSD is the measure of signal's power content versus frequency. A PSD is typically used to characterize broadband signals. The amplitude of the PSD is normalized by the spectral resolution employed to measure the signal.

[SOURCE: IEC 60050-713:1998, 713-09-12, modified – In the term “power spectrum density” has been removed and Note 1 has been added.]

3.1.9**crest factor**

ratio between peak amplitude (envelope) and RMS value, usually expressed in dB

3.2 Abbreviated terms

ACLR	adjacent channel leakage power ratio
AE	auxiliary equipment
AWG	arbitrary waveform generator
BPSK	binary phase shift keying
BS	base station
BW	bandwidth
CA	carrier aggregation
CCDF	complementary cumulative distribution function
CW	continuous wave
DFTS-OFDM	discrete Fourier transform spread-OFDM
DL	downlink
eMBB	enhanced Mobile BroadBand
eMTC	enhanced MachineType Communication
eNB	evolved Node B
EUT	equipment under test
E-UTRA	Evolved-Universal mobile telecommunication system Terrestrial Radio Access
EVM	error vector magnitude
FDD	frequency division duplexing
GP	Guard Period
IMT	International Mobile Telecommunications
LTE	Long-Term Evolution
mMTC	massive Machine Type Communication
NB-IoT	narrow band-Internet of Things
NR	New Radio
OFDM	orthogonal frequency division multiplexing
PAPR	peak-to-average power ratio
PM	pulse modulation
PSD	power spectral density
QAM	quadrature amplitude modulation
QPSK	quadrature phase shift keying
RB	resource block
RF	radio frequency
RIT	radio interface technology
SEM	spectral emission mask
TDD	time division duplexing
TTI	transmission time interval
UE	user equipment
UFA	uniform field area
UL	uplink
URLLC	Ultra Reliable Low Latency Communication
WGN	white gaussian noise

4 General

The source of disturbance covered by this document is an electromagnetic field, consisting of broadband signals, generated by, for example, communication devices or services, transmitters or industrial electromagnetic sources or any other devices capable of generating such a signal.

The frequency range covered by this document is specified in Table 3.

5 Test levels and test signal

5.1 Test levels

The test levels are given in terms of an equivalent carrier electric field strength consistent with the level-setting process and the electric field spectral density spread out to the test signal bandwidth.

The levels in columns 3 to 6 of Table 1 show the electric field spectral density derived from the power spectral density of the broadband test signal assuming that the different spectrum components are uncorrelated.

The test level is derived from the uniform field area (UFA) level-setting process. The signal power to generate the test levels of Table 1 should be equal to the total power of the broadband signal.

Table 1 – Test levels

Test level	Equivalent carrier electric field strength V/m	Electric field spectral density $\text{dB} \left(\frac{\mu\text{V}}{\text{m} \cdot \sqrt{\text{Hz}}} \right)$			
		BW = 5 MHz	BW = 20 MHz	BW = 40 MHz	BW = 100 MHz
1	1	53,0	47,0	44,0	40,0
2	3	62,5	56,5	53,5	49,5
3	10	73,0	67,0	64,0	60,0
4	30	82,5	76,5	73,5	69,5
NOTE 5 MHz and 40 MHz bandwidth (BW) are indicated for the convenience of the product committee.					

This document does not suggest that a single test level is applicable over the entire frequency range. The product committees shall select the frequency range(s) to be tested as well as the appropriate test level(s). Annex D provides guidance for product committees on the selection of test levels.

Product committees may use test levels other than those listed in Table 1. However, once the equivalent carrier electric field strength is determined, the test levels for each bandwidth follow the relationship between the test levels in Table 1.

5.2 Test signal

Real broadband communication signals are largely based on orthogonal frequency division multiplexing (OFDM). The parameters (number of carriers, modulation per carrier, etc.) are so diverse that an internationally agreed set of parameters that is representative of all conceivable broadband communication services does not seem to make sense. In accordance with the nature of the interference, a band-limited noise is therefore specified as the test signal. The signal can be generated by a physical noise generator with a filter or by an arbitrary waveform generator, which periodically plays a pseudo-random code. With the latter, care shall be taken that the sequence is long enough to produce a spectrum that is as continuous as possible.

An additional important parameter of the test signal is the crest factor. The crest factor of the signal generator output signal shall be at least 10 dB. Information on test signal characterization is given in Annex F.

NOTE 1 The higher the crest factor, the higher the demands on the dynamic reserves of the power amplifier.

The broadband signals used as test signals in this document are time variant to simulate changes in amplitude due to time division transmission scheme. For testing purposes, a pulse modulation is selected. A 50 % duty cycle is preferred. The modulation is specified in Table 2.

Product committees may select other duty cycles if specific transmission signals are supposed to be emulated by test signals.

Table 2 – Pulse modulation of test signal

Parameter	Value
Modulation frequency	100 Hz $\pm$ 10 Hz
Rise/fall time of the envelope (between 10 % and 90 % of amplitude)	< 20 μ s
Duty cycle	(50 $\pm$ 2) %

Figure 1 and Figure 2 show an example of a test signal with a bandwidth of 100 MHz in the frequency domain and time domain, respectively.

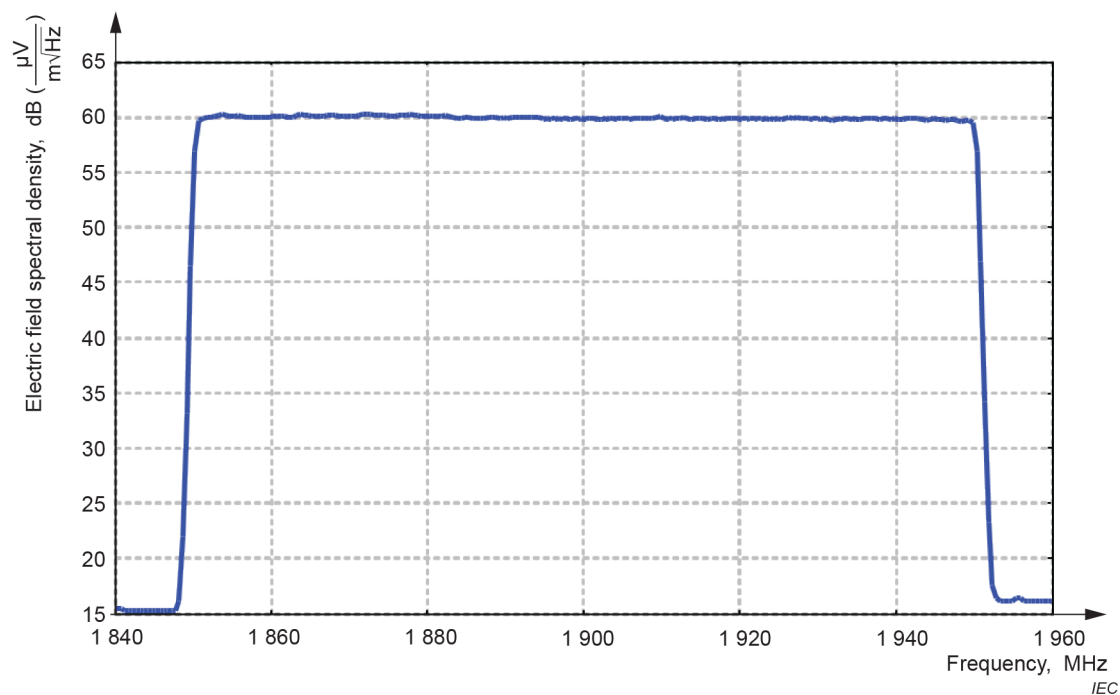


Figure 1 – Example of the envelope of a 100 MHz wide test signal in frequency domain

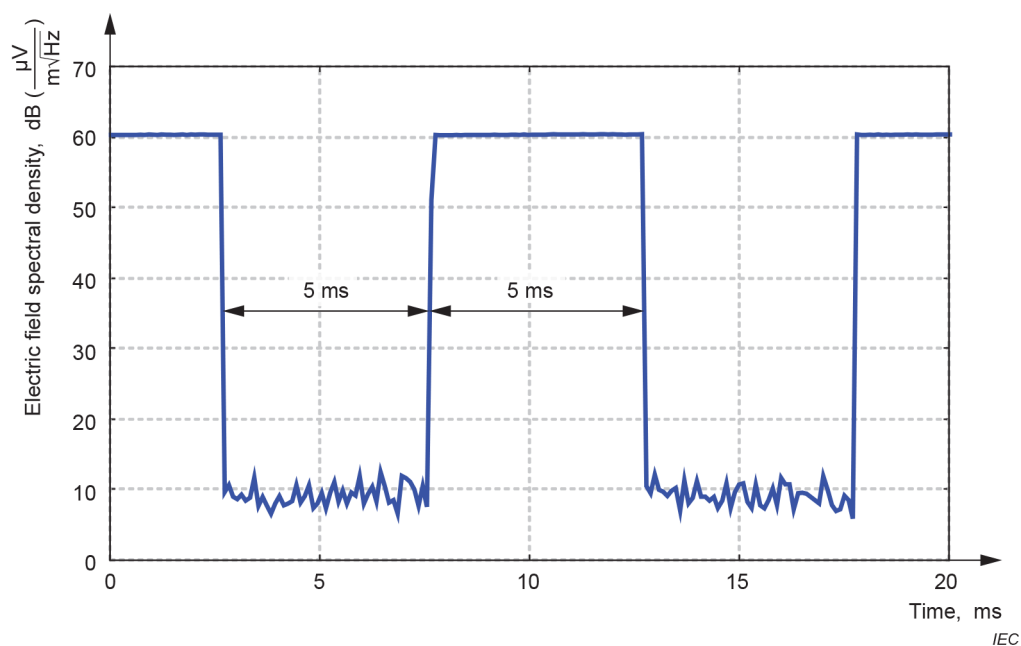


Figure 2 – Example of the envelope of a 100 MHz wide test signal in time domain

The characteristics of a modulated test signal are shown in Figure 3. Note that when the pulse modulation is activated, the energy of the test signal is reduced to 50 % (-3 dB) because the amplitude is close to zero while the signal is “OFF”. The test amplitude during the “ON” period should however remain unchanged at the level derived from the UFA level-setting process.

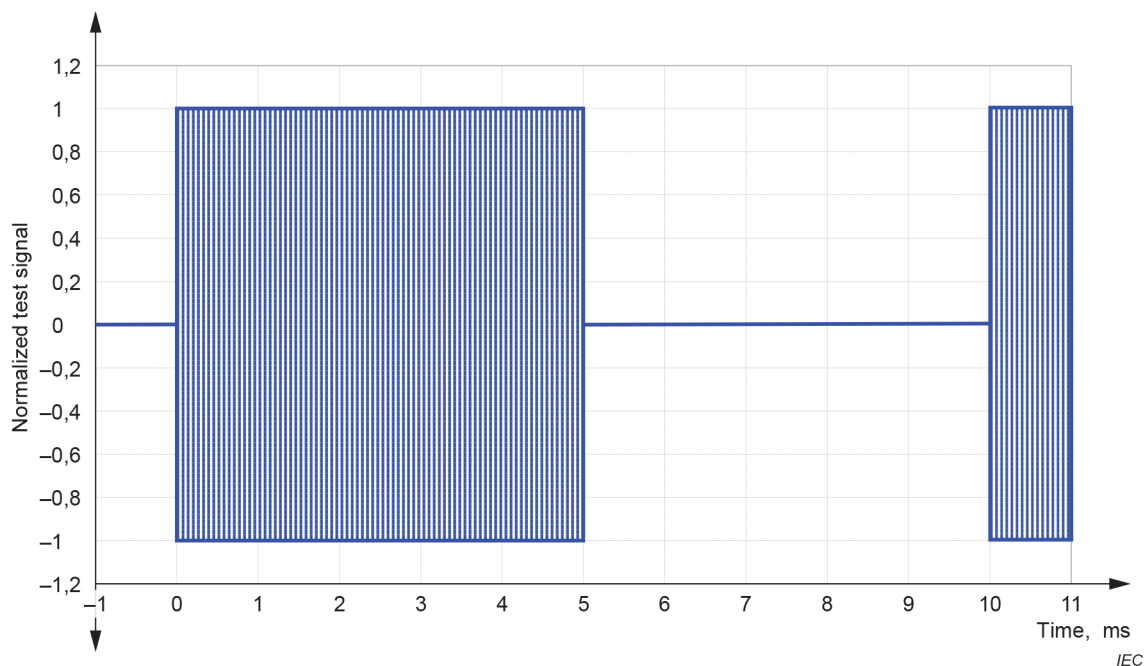


Figure 3 – Pulse modulated test signal, with a period of 10 ms, and 50 % duty cycle

5.3 Frequency range and test signal bandwidth

The test signals for this broadband immunity test standard are selected as being representative of modern digital radio communication signals in the sense that the signals contain electrical energy which is distributed over several megahertz.

The test signal used in this document does not contain any information but is considered as white noise having equal spectral density at all frequencies within the test signal bandwidth.

The test signal bandwidth is specified in Table 3.

Table 3 – Frequency ranges and test signal bandwidth

Start frequency MHz	Stop frequency MHz	Test signal bandwidth MHz
80	600	Under consideration
600	1 800	20
1 800	6 000	100
6 000	Upper frequency limit	Under consideration

This document specifies testing in the frequency ranges above 80 MHz, limited only by the capabilities of commercially available test instrumentation.

Product committees may specify frequency ranges (above 80 MHz) and test signal bandwidth other than those listed in Table 3.

5.4 Spectrum mask

The test signal shall have the spectral properties as specified in Figure 4 and Table 4, which shall be verified at the output of the power amplifier.

The spectral density is measured using a receiver bandwidth of 1 MHz and an RMS detector. If a spectrum analyser is used for the measurement, the resolution bandwidth shall be set to 1 MHz and the video bandwidth shall be set to at least 3 MHz.

The test signal generator shall generate the signal in such a manner that the total RF power without the pulse modulation of the signal (often referred to as the channel power) is equal to the output power when the test generator is set to unmodulated sine wave signal (continuous wave (CW) signal). This will usually be the case for signal generators.

Table 4 – Test signal requirements

Test signal bandwidth	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>
MHz	MHz	dB	dB	dB
5	10	20	6	3
20	10	20	6	3
40	20	20	6	3
100	20	20	6	3

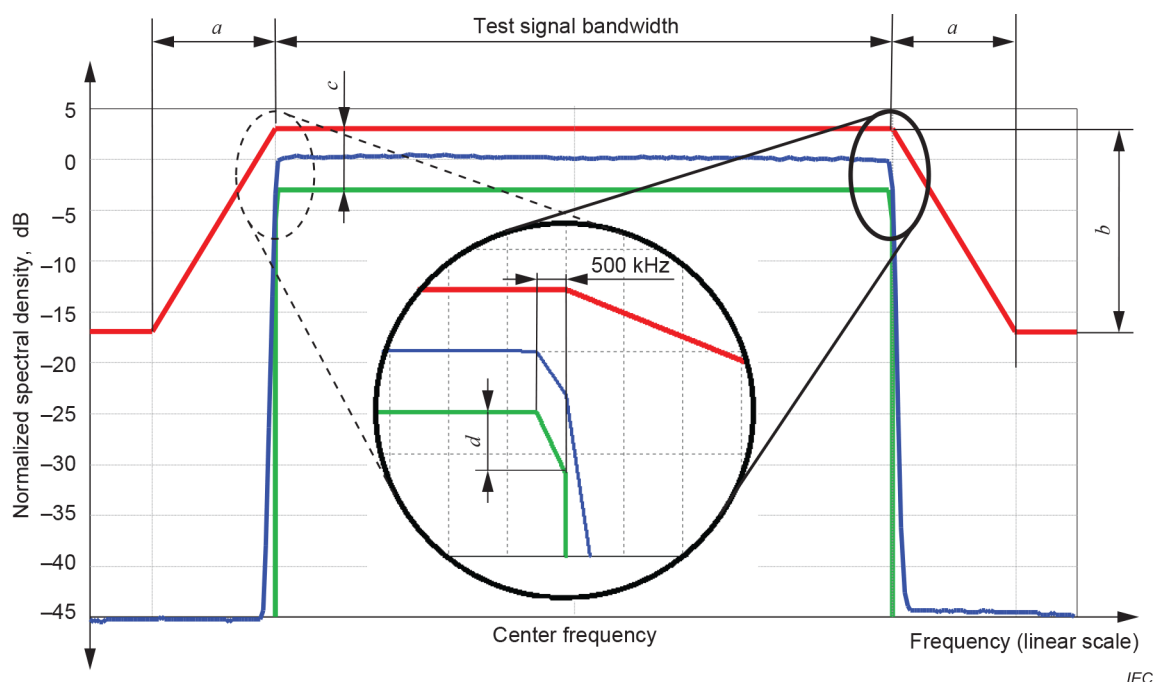
For specification of *a*, *b*, *c* and *d*, see Figure 4.

The value for *a* at test signal bandwidth of 5 MHz was specified due to frequency response of the signal generating equipment.

The upper amplitude limit decays linearly by *b* dB versus frequency within *a* MHz of upper and lower band edges.

The lower amplitude limit decays linearly by *d* dB versus frequency within 500 kHz of upper and lower band edges.

NOTE 5 MHz and 40 MHz test signal bandwidth are indicated for the convenience of product committees.



Key

- Red line upper limit
- Blue line example test signal
- Green line lower limit

NOTE See also Annex A.

Figure 4 – Spectrum mask of the broadband test signal at the output of the power amplifier

5.5 Frequency stepping

The test signal is scanned using step sizes determined by the test signal bandwidth as specified below. The intention is that the test signal shall be applied seamlessly over the entire frequency range in steps of the selected test signal bandwidth.

The start of the frequency stepping shall be performed as specified below. If the specified frequency range does not match the full steps of the test signal bandwidth, then the test signal can exceed beyond the highest test frequency.

Examples of frequency stepping are found below:

- 1) First test frequency f_1 is selected so it is half the test signal bandwidth above the start frequency.

Example 1: Using a 20 MHz test signal bandwidth and starting test at 600 MHz, the first centre frequency setting is $600 \text{ MHz} + \frac{1}{2} \text{ times } 20 \text{ MHz} = 610 \text{ MHz}$.

Example 2: Using a 100 MHz test signal bandwidth and starting test at 1 800 MHz, the first frequency setting is $1\,800 \text{ MHz} + \frac{1}{2} \text{ times } 100 \text{ MHz} = 1\,850 \text{ MHz}$.

- 2) Next test frequency f_2 is selected so it is one test signal bandwidth above f_1 .

Example 1: Using a 20 MHz test signal bandwidth, $f_2 = 610 \text{ MHz} + 20 \text{ MHz} = 630 \text{ MHz}$.

Example 2: Using a 100 MHz test signal bandwidth, $f_2 = 1\,850 \text{ MHz} + 100 \text{ MHz} = 1\,950 \text{ MHz}$.

3) The steps are repeated until the stop frequency is covered by the bandwidth of a test signal.

Example 1: 60 steps are necessary to cover the frequency range 600 MHz to 1 800 MHz using a 20 MHz test signal bandwidth. The last test frequency is 1 790 MHz.

Example 2: 42 steps are necessary to cover the frequency range 1 800 MHz to 6 000 MHz using a 100 MHz test signal bandwidth. The last test frequency is 5 950 MHz.

5.6 Selection of level

The test level is set as the signal power at each test frequency. The testing according to this document is based upon the level-setting process executed for testing with modulated sine wave signals, as specified in IEC 61000-4-3.

If level-setting data are already available for the UFA in the test laboratory, such data are preferred, and can be directly applied for the present testing. Data recorded for testing in accordance with IEC 61000-4-3 are often available at steps of 1 % of the preceding frequency, starting at 80 MHz.

The level-setting data for the centre frequency of the broadband test signal should be chosen from the two neighbouring IEC 61000-4-3 level-setting frequencies by interpolation.

If several IEC 61000-4-3 level-setting frequencies are available within one test signal bandwidth, it is sufficient to select the nearest IEC 61000-4-3 frequency for level setting. For example, when testing with a 20 MHz test signal bandwidth and starting at 600 MHz (600 MHz to 620 MHz), several IEC 61000-4-3 level-setting frequencies are available (603,016 MHz, 609,046 MHz, 615,137 MHz). The frequency closest to the centre of the test signal is selected for level setting (609,046 MHz in this example).

It is, however, also allowed to do an individual UFA level-setting process using the highest level intended for testing (see Table 1), step sizes of 20 MHz or 100 MHz (if not otherwise specified by a product committee) and covering the centre frequencies of the test signals selected for testing.

As the test generator provides the same total RF power for an unmodulated sine wave signal (CW-signal) and for the test signal bandwidth (see 5.4), the test level can be monitored and if necessary adjusted by measuring the unmodulated output signal from the power amplifier using a power meter, which is capable of measuring both CW signals and broadband signals.

6 Test equipment and level adjustment procedure

6.1 Test instrumentation

Test equipment and level adjustment procedures adopted for this document are similar to those specified in IEC 61000-4-3, with minor modifications due to the nature of the test signal:

- Anechoic chamber: of a size adequate to maintain a uniform field of sufficient dimensions with respect to the equipment under test (EUT).
- RF signal generator(s): capable of covering the frequency band of interest and as a minimum being capable of generating the test signal as specified in Clause 5. It can either be equipped with a band-limited white noise generator or an arbitrary waveform generator. In addition, pulse modulation is required either in hardware or as part of the waveform file for the arbitrary waveform generator. For the setting of the test level, it shall be able to adjust the signal amplitude of the broadband signal to a desired channel power (total power).
- EMI filters: if used, the filters shall introduce no additional resonance effects.
- Power amplifiers: to amplify the signal (unmodulated and modulated) and provide antenna drive to the necessary field level.

- Field generating antennas: biconical, log periodic, horn, combination of antennas or any other linearly polarized antenna system capable of satisfying frequency requirements (see 5.3 and 5.4).
- Isotropic field sensor: with adequate frequency range and sensitivity to measure the generated field strength. Since the uniform field is measured with a CW signal, the field sensor is not necessarily required to be able to measure broadband signals.
- Power measurement device for the forward power: a directional coupler and a power meter can be used, or a forward power detector or monitor could be inserted between amplifier and antenna. In case the adjustment of the level (see 5.6) is done with a modulated signal the power measurement device shall be able to measure broadband signals; if it is only used for CW levelling setting, broadband measurement capabilities are not required.
- Associated equipment to record the power levels: necessary for the required field strength and to control the generation of that level for testing.
- Frequency selective measuring device (e.g. spectrum analyser): to verify the shape of the spectral density of the signal provided to the antenna. For the shape verification it is connected to the test system via the directional coupler specified for the power measurement device.

Adequate immunity of the test instrumentation shall be applied.

6.2 Description of the test facility

IEC 61000-4-3:2020, 6.2, applies.

6.3 UFA and validation of the spectrum shape

6.3.1 General

The characterization of the UFA of IEC 61000-4-3 applies.

If a test facility has been successfully validated according to IEC 61000-4-3 over the frequencies of interest of this document, the UFA of this facility is usable also for the purpose of this document.

6.3.2 Saturation check and spectrum validation

6.3.2.1 General

In order to check the amplifier saturation and waveform, 6.3.2.2 and 6.3.2.3 shall be carried out for the frequencies and bandwidths selected for testing. It is intended that these processes should be carried out at least initially and when changes have been made to the setup.

In case of multiple frequency ranges used, the validation of the spectrum and saturation check as described above, shall be performed for each frequency range.

It is assumed that during the level-setting process according to IEC 61000-4-3:2020, 6.3.2 or 6.3.3, the following quantities have been determined for each frequency point:

- E_L : field strength for level setting and field homogeneity investigation (1,8 times the test field strength, if data from IEC 61000-4-3 is reused, or test field strength in case of an individual UFA measurement).
- P_L : forward power required to establish E_L at the determined reference point of the UFA.

6.3.2.2 Saturation check

The procedure for the saturation check is performed at all frequencies as follows.

- a) Select the appropriate test signal bandwidth and start the procedure at the beginning of the frequency range.
- b) With the RF generator unmodulated (CW), adjust the output level to produce the power at the amplifier output $P_T = P_L - 5,1 \text{ dB}$ (if data from IEC 61000-4-3 is reused) or $P_T = P_L$ (in case of an individual UFA measurement) and record the required RF generator output level P_{genT} .
- c) Increase the signal generator power (CW) by 10 dB ($P_{\text{genT}} + 10 \text{ dB}$) and measure the power at the amplifier output P_{PK} . If the difference $P_{\text{PK}} - P_T$ is more than 8 dB, the amplifier is deemed to be sufficiently linear and the test system is suitable for testing. Otherwise, the test system is not suitable for testing.
- d) Set the RF generator to the required centre frequency. The values E_L and P_L are derived in accordance with 5.6 from the IEC 61000-4-3:2020 UFA measurements or an individual UFA measurement.
- e) Move to next test frequency.
- f) Repeat steps b) to e) until the end of the frequency range is reached or exceeded.

It is sufficient to do the saturation check only for the highest test level. It is recommended to be repeated annually and shall be repeated when changes have been made in the test instrumentation (amplifier, antenna, absorber replaced, etc.) or the test configuration (UFA, antenna placement, etc.).

In case that the 10 dB increase according to step c) is not feasible, the crest factor can be measured with one of the methods shown in Annex F. In this case the measured crest factor at the output of the amplifier shall not be less than the requirements specified in 5.2 relaxed by 2 dB.

6.3.2.3 Spectrum validation

The procedure for the spectrum validation is performed as follows.

- a) Select the appropriate test signal bandwidth and start the procedure at the beginning of the frequency range.
 - b) Replace the power meter at the directional coupler by the frequency selective measuring device and switch on the broadband modulation of the RF generator.
 - c) Set the RF generator to the required centre frequency.
 - d) With the RF generator unmodulated (CW), adjust the output level to produce the power at the amplifier output $P_T = P_L - 5,1 \text{ dB}$ (if data from IEC 61000-4-3 is reused) or $P_T = P_L$ (in case of an individual UFA measurement).
 - e) Measure the signal spectrum shape with a resolution bandwidth of 1 MHz, RMS detector and a span of twice the test signal bandwidth selected for the test. The signal generation/amplification is deemed to be suitable for testing if the normalized spectral density is within the parameters specified in Table 4.
- NOTE Application of frequency-dependent correction of the transmission factors of RF cables, directional couplers, and power attenuators ensures proper evaluation of the spectral shape at the amplifier output.
- f) Move to next test frequency.
 - g) Repeat steps c) to f) until the end of the frequency band is reached or exceeded.

At low test levels compared to the amplifier noise, the inherent noise from the power amplifier can contribute the off-band level which can affect the spectrum validation. The frequency response of the amplifier can vary with the input level especially when approaching the compression point of the amplifier which can affect the result of the spectrum validation.

7 Test setup

The test setup requirements specified in IEC 61000-4-3:2020, Clause 7, apply, including applicable subclauses.

8 Test procedure

8.1 Step size and test signal bandwidth

Product committees may select the test signal bandwidth and corresponding step size in accordance with 5.3.

8.2 Test signal and level setting

Testing shall be performed with the same test setup as used for the saturation check (6.3.2.2). If the output power of the amplifier is controlled, the amplifier may be replaced by another suitable amplifier, but an additional saturation check and spectrum validation (see 6.3.2) is necessary.

For each frequency step according to 5.5 and 5.6, the level shall be adjusted to produce the forward power P_T necessary to achieve the required carrier equivalent electric field strength (see Table 1) with the RF generator unmodulated. After the required level is reached, the broadband and pulse modulations shall be switched on. If averaging sensors for the power meter are used, the amplifier output level can also be adjusted with modulations kept switched on. In this case the power reduction by for example 3 dB (for a duty cycle of 50 %) due to the pulse modulation shall be considered.

The dwell time of the modulated signal shall not be less than the time necessary for the EUT to be exercised and to respond, but shall in no case be less than 1 s.

NOTE The dwell time starts when the test condition has stabilized at each frequency step.

9 Evaluation of the test results

In order to evaluate test results, the EUT performance shall be examined during the dwell time and classified in terms of the loss of function or degradation of performance of the EUT relative to a performance level derived from the accompanying documents (specification sheets, manuals, user guides, etc.).

The recommended classification is as follows:

- a) Performance criterion A: normal performance within limits specified in the accompanying documents.
- b) Performance criterion B: temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the EUT recovers its normal performance, without operator intervention.
- c) Performance criterion C: temporary loss of function or degradation of performance, the correction of which requires operator intervention.
- d) Performance criterion D: loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

This classification may be used as a guide in formulating performance criteria, by committees responsible for generic, product and product-family standards, or as a framework for the agreement on performance criteria between the manufacturer and the purchaser, for example where no suitable generic, product or product-family standard exists.

10 Test report

The test report shall contain all the information necessary to reproduce the test. In particular, the following shall be recorded:

- identification of the EUT and any associated equipment, for example brand name, product type, serial number;
- representative operating conditions of the EUT;
- whether the EUT is tested as a single or multiple unit;
- the types of cables, including their length, and the interface port of the EUT to which they were connected;
- any specific conditions for use, for example shielding or grounding, or EUT operating conditions, which are required to achieve compliance;
- any additional information relevant to the EUT, AE(s) position with respect to the size and position of the UFA as well as the position of coupling and decoupling devices, if used;
- identification of the test equipment, for example brand name, product type, serial number;
- a description of the EUT exercising method;
- any specific conditions necessary to enable the test to be performed;
- the frequency range of application of the test;
- the dwell time and frequency steps;
- the test level set;
- test signal bandwidth;
- pulse modulation parameters;
- the specified performance level;
- the performance criteria that have been applied;
- any effects on the EUT observed during or after application of the test disturbance and the duration for which these effects persist;
- the rationale for the pass/fail decision based on the specified performance criterion.

Annex A (informative)

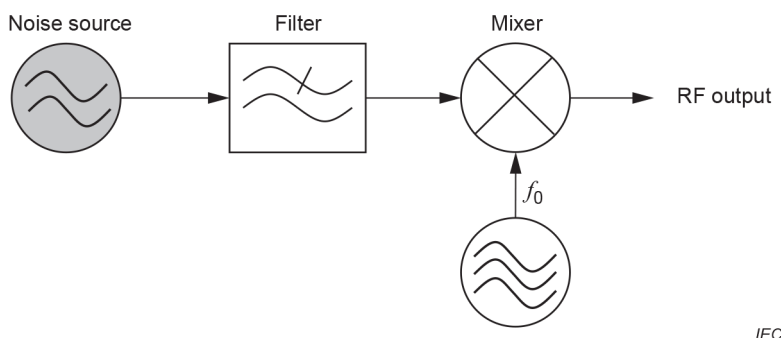
Information on test signal generation

A.1 General

This document specifies a band-limited broadband signal as test signal. Band-limited broadband signals can be generated in different ways. This annex provides some guidance on the realization of band-limited true noise signals and band-limited pseudo-random noise signals.

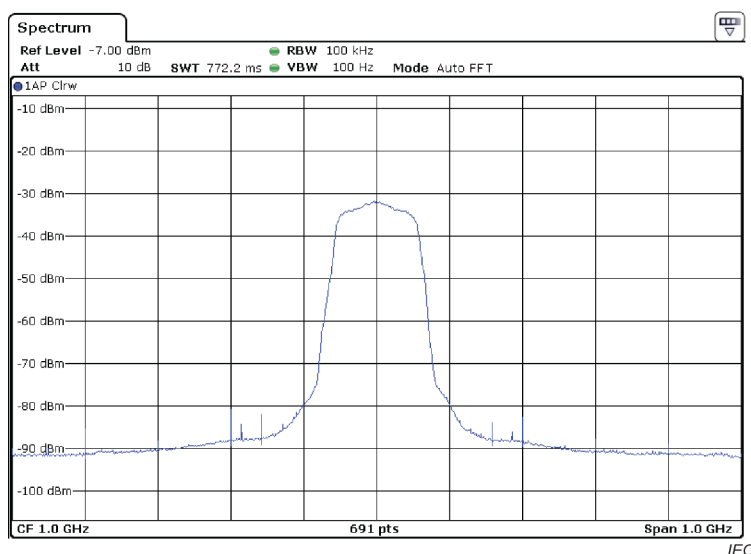
A.2 True noise generation

The true noise generation makes use of a white noise source (e.g. shot noise in a semiconductor diode). For band limitation a filter restricts the spectral content of the noise generator output to the required frequency band (see Figure A.1). The filter characteristics determine the generated signal spectrum. Higher order filters have to be realized in order to fulfil the requirements for the slopes at the limiting frequency edges. A mixing circuit will transform the baseband noise signal to the desired RF band (see Figure A.1). Figure A.2 shows an example of a 100 MHz wide band-limited true noise signal at a centre frequency of 1 GHz.



IEC

Figure A.1 – Principle of true noise generation



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Figure A.2 – Example of a 100 MHz wide band-limited true noise signal at a centre frequency of 1 GHz

A.3 Pseudo-random noise sequence

The true noise source can be replaced by a random number sequence uploaded into the memory of an arbitrary waveform generator (AWG). To allow an easier implementation of the band filter the sample sequence can be preconditioned. Thus, only an anti-alias-filter is physically necessary at the AWG output (see Figure A.3). The design of this filter is not as demanding as for the true noise generation, when a sufficiently large sampling frequency of the AWG is selected. The edge frequency of the anti-alias-filter is usually half of the sampling frequency.

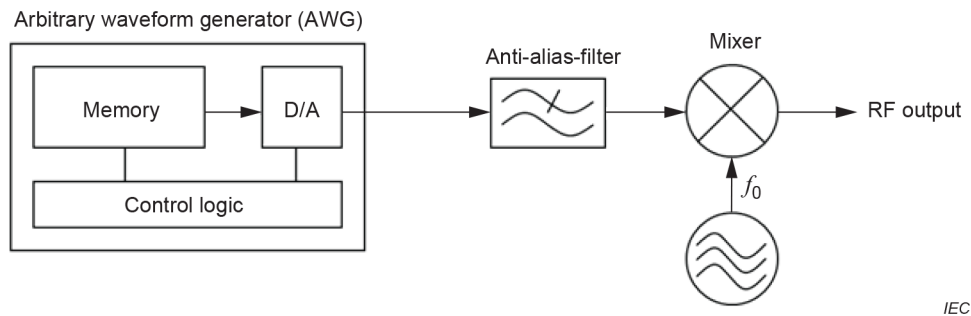


Figure A.3 – Principle of band-limited broadband signal generation with an arbitrary waveform generator

Let $s(t)$ be the sequence of random numbers. This signal is frequency independent (at least in a frequency interval up to half of the sampling frequency) and can be expressed in the frequency domain as $S(\omega)$. The filtering can be made in the frequency domain by multiplying $S(\omega)$ with a filter characteristic $H_F(\omega)$. A rectangular function $H_n(\omega)$ in the frequency domain:

$$H_n(\omega) = \begin{cases} 1 & \text{for } |\omega| < \omega_n \\ 0 & \text{else} \end{cases} \quad (\text{A.1})$$

corresponds to the function $h_n(t)$ in the time domain:

$$h_n(t) = \frac{\omega_n}{\pi} \cdot \text{sinc}(\omega_n \cdot t) \quad (\text{A.2})$$

with:

$$\text{sinc}(x) = \frac{\sin(x)}{x} \quad (\text{A.3})$$

The filter for the desired signal spectrum with the lower border frequency f_1 (corresponding transfer function $H_1(\omega)$) and with the upper border frequency f_2 (corresponding transfer function $H_2(\omega)$) is:

$$H_F(\omega) = H_2(\omega) - H_1(\omega) \quad (\text{A.4})$$

with the corresponding pulse response in the time domain:

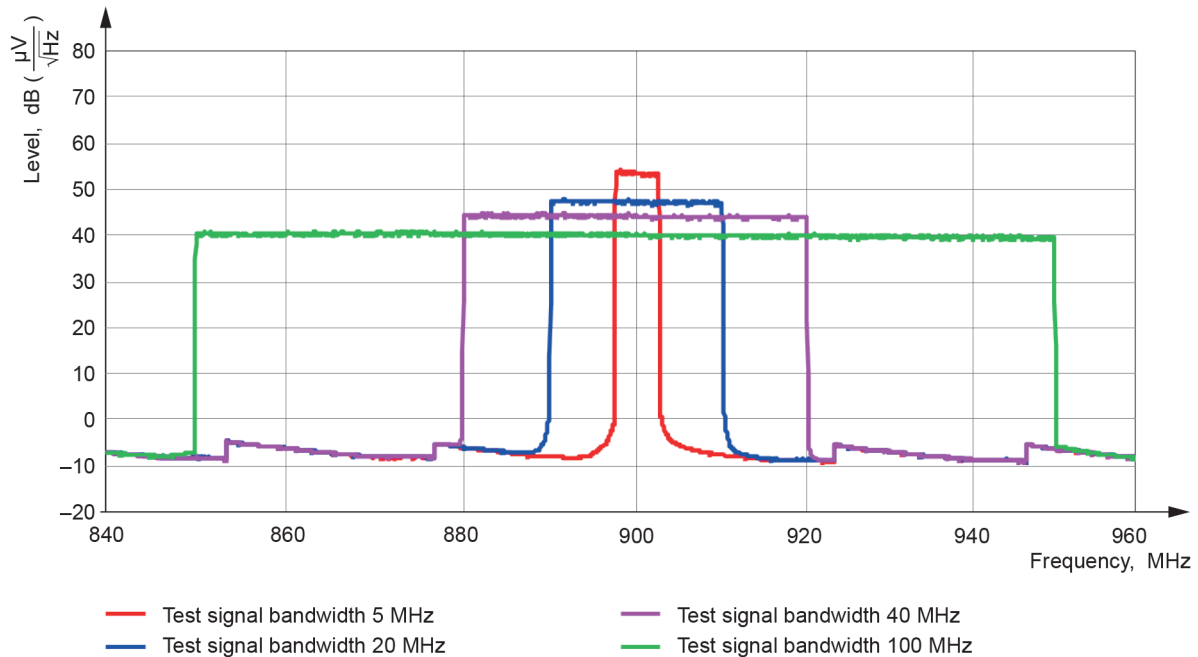
$$h_F(t) = \frac{\omega_2}{\pi} \text{sinc}(\omega_2 \cdot t) - \frac{\omega_1}{\pi} \text{sinc}(\omega_1 \cdot t) \quad (\text{A.5})$$

Applying the filter to the random number sequence in the frequency domain corresponds to a multiplication. In the time domain it becomes a convolution operation:

$$g(t) = h_F(t) * s(t) \quad (\text{A.6})$$

If this sequence $g(t)$ is loaded into the memory of an AWG, the corresponding spectrum is the spectrum specified in this document. Figure A.4 shows an example of a spectrum measured with a measuring receiver (AV detector, 120 kHz measurement bandwidth, frequency step 50 kHz) for a signal generated with an AWG with the parameters:

- sampling frequency of 150 megasamples per second;
- record length of 5 ms (750 000 points);
- 16-bit vertical resolution;
- test signal bandwidth of 5 MHz, 20 MHz, 40 MHz or 100 MHz.



IEC

NOTE The amplitude is normalized to 1 Hz bandwidth.

Figure A.4 – Example signal spectrum of a band-limited pseudo random noise signal (measured with 120 kHz bandwidth)

An extract of the output in time domain is shown in Figure A.5.

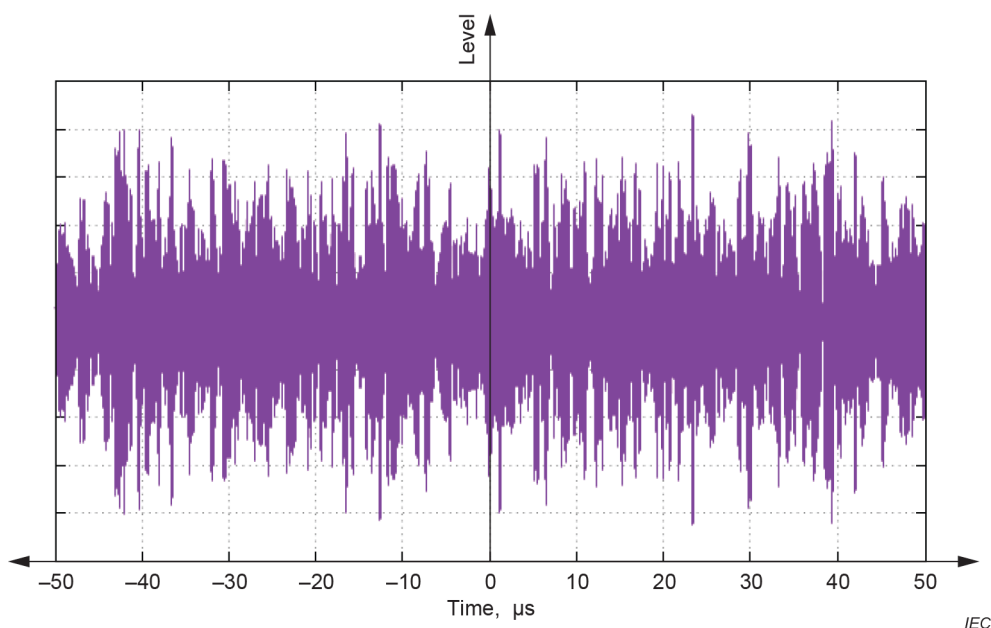


Figure A.5 – Extract of the band-limited pseudo random noise signal in time domain (measured with an oscilloscope)

There is a difference from the physically produced true noise signal specified in Clause A.2. Since the length of the sampling sequence is finite, it has to be successively repeated by the generator in order to produce a continuous signal. Mathematically this can be described by convolution of the sampling signal with finite length and a comb signal. In the frequency domain this means a multiplication between the signal spectrum obtained for the single sequence and a frequency comb, which yields to a comb spectrum. The comb frequency corresponds to the length of the sequence. With a sequence length of 5 ms a comb with a frequency spacing of 200 Hz will occur (see Figure A.6).

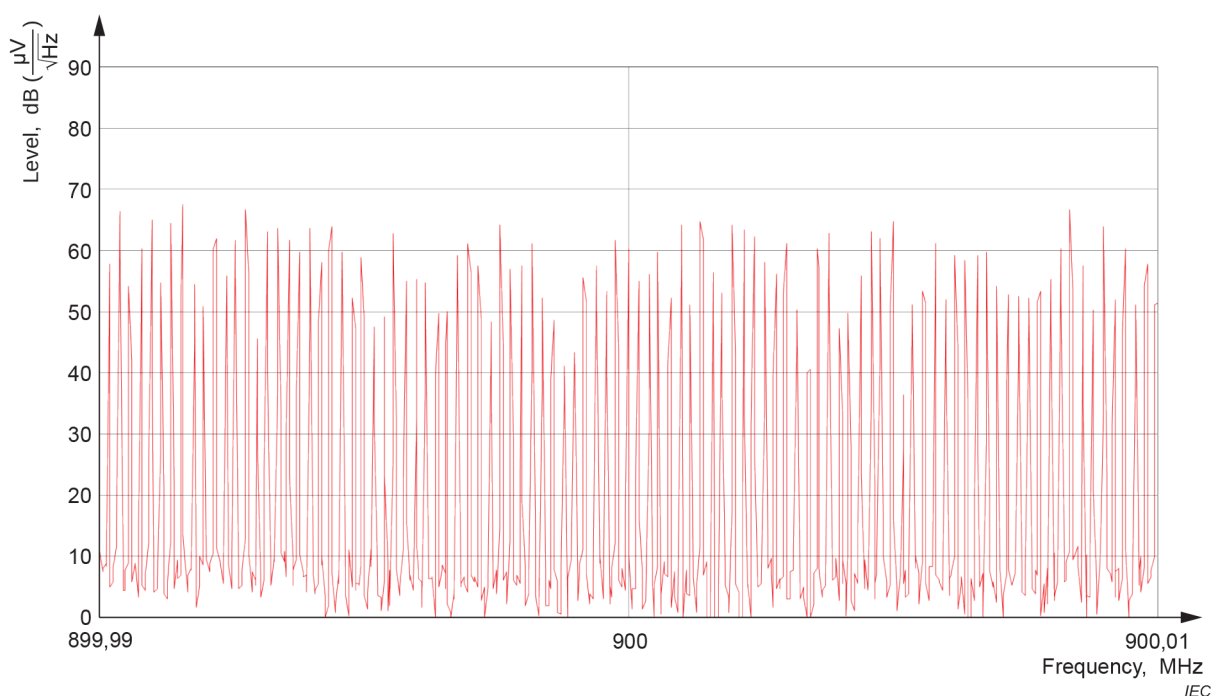


Figure A.6 – Extract of the signal spectrum of a band-limited pseudo random noise signal (measured with 10 Hz bandwidth, normalized to 1 Hz bandwidth)

Annex B (informative)

Field generating antennas

The field generating antennas specified in IEC 61000-4-3:2020, Annex B, apply, including applicable subclauses.

Annex C (informative)

4G and 5G signals

C.1 Overview of the radio interface technology of 4G and 5G

C.1.1 General

The International Mobile Telecommunications (IMT)-2020 (Recommendation ITU-R M.2150-1 and Recommendation ITU-R M.2150-2), known as 5G, have been developed by the 3rd Generation Partnership Project (3GPP) and consist of Long-Term Evolution (LTE) and New Radio (NR) releases 15 and beyond. In 3GPP terminology, the term Evolved-Universal mobile telecommunication system Terrestrial Radio Access (E-UTRA) is also used to signify the LTE radio interface. See also Bibliography for more sources.

5G is a set of radio interface technologies (RITs) consisting of E-UTRA/LTE as one component RIT and NR as the other component RIT. Both components are designed for operation in the IMT spectrum.

5G fulfills all technical performance requirements in all five selected test environments: Indoor Hotspot – enhanced Mobile BroadBand (eMBB), dense urban – eMBB, rural – eMBB, urban macro – Ultra Reliable Low Latency Communication (URLLC) and urban macro – massive Machine Type Communication (mMTC). Also, 5G fulfills the service and spectrum requirements. Both component RITs, NR and E-UTRA/LTE, utilize the frequency bands below 7,125 GHz including frequency bands identified for International Mobile Telecommunication (IMT) in the ITU Radio Regulations. In addition, the NR component RIT can also utilize the frequency bands above 7,125 GHz, i.e. above 24,25 GHz, including frequency bands identified for IMT in the ITU Radio Regulations.

The complete set of standards for the terrestrial radio interface of IMT-2020 identified as 5G includes not only the key characteristics of IMT-2020 but also the additional capabilities of 5G, both of which are continuing to be enhanced.

C.1.2 Overview of the component RIT: E-UTRA/LTE

The E-UTRA/LTE Component RIT is based on releases 15 and 16 of LTE, and it is the evolution of the previous releases, encompassing both frequency division duplexing (FDD) and time division duplexing (TDD). The E-UTRA/LTE RIT uses either 1) FDD operation and therefore is applicable for the operation with paired spectrum, or 2) TDD operation and therefore is applicable for the operation with unpaired spectrum. Both full-duplex and half-duplex FDD are supported. Aggregation of TDD and FDD spectrum is supported.

The E-UTRA/LTE RIT can operate in both FDD and TDD modes as illustrated in Figure C.1. Although the time-domain structure is, in most respects, the same for FDD and TDD there are some differences between the two duplex modes, most notably the presence of a special subframe in the case of TDD. The special subframe is used to provide the necessary guard time for downlink-to-uplink switching.

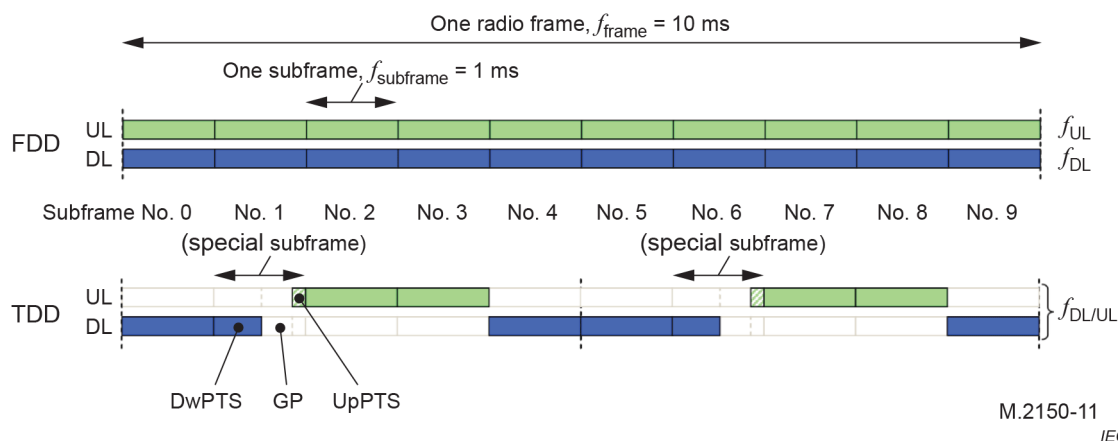


Figure C.1 – Uplink/downlink time/frequency structure for FDD and TDD

For FDD operation (upper part of Figure C.1), there are two carrier frequencies for each component carrier, one for uplink transmission (f_{UL}) and one for downlink transmission (f_{DL}). During each frame, there are thus ten uplink subframes and ten downlink subframes, and uplink and downlink transmission can occur simultaneously within a cell. Half-duplex operation at the user equipment (UE) side is supported by the scheduler ensuring non-simultaneous reception and transmission at the UE.

For TDD operation (lower part of Figure C.1), there is only a single carrier frequency per component carrier and uplink and downlink transmissions are always separated in time also on a cell basis. As shown in Figure C.1, some subframes (UpPTS: Uplink Pilot TimeSlot) are allocated for uplink transmissions and some subframes (DwPTS: Downlink Pilot TimeSlot) for downlink transmission with a Guard Period (GP) where the switch between downlink and uplink occurs in the special subframe. The DwPTS, GP, and UpPTS have configurable individual lengths to support different deployment scenarios, and a total length of 1 ms.

Different asymmetries in terms of the number of resources allocated for uplink and downlink transmission, respectively, are provided through seven different downlink/uplink configurations as shown in Figure C.2. Where carrier aggregation is employed, the downlink/uplink configuration is identical across component carriers in the same band and can be the same or different across component carriers in different bands.

Transmission bandwidths up to 640 MHz are supported, yielding to peak data rates up to roughly 32 Gbit/s in the downlink (DL) and 13,6 Gbit/s in the uplink (UL).

The downlink transmission scheme is based on conventional orthogonal frequency division multiplexing (OFDM) to provide a high degree of robustness against channel frequency selectivity while still allowing for low-complexity receiver implementations also at very large bandwidths.

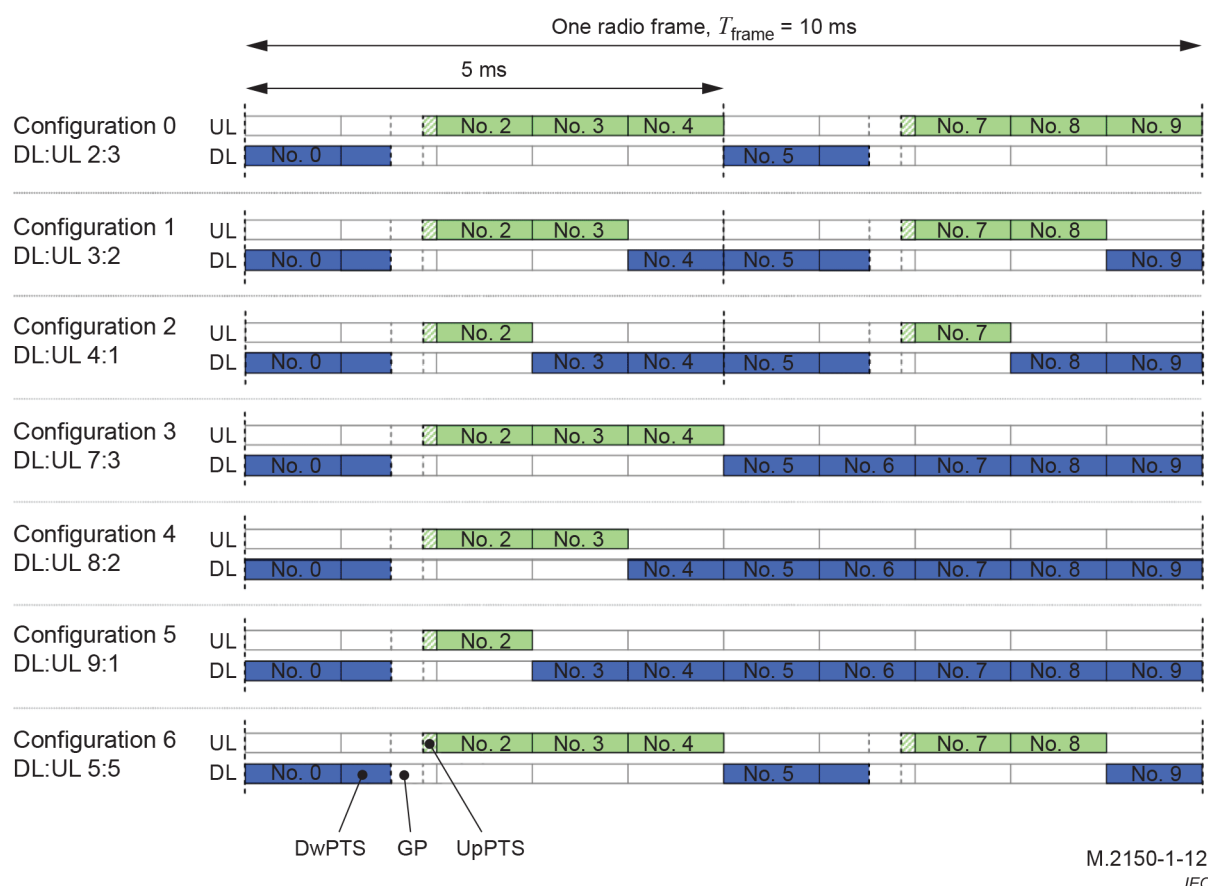


Figure C.2 – Uplink-downlink asymmetries supported by the E-UTRA/LTE RIT (TDD)

The uplink transmission scheme is based on discrete Fourier transform spread-OFDM (DFTS-OFDM). The use of this transmission scheme for the uplink is motivated by the lower peak-to-average power ratio (PAPR) of the transmitted signal compared to conventional OFDM. This allows for more efficient usage of the power amplifier in the UE, which translates into an increased coverage or reduced terminal power consumption, or both. The uplink numerology (subcarrier spacing and symbol duration) is aligned with the downlink numerology. The narrow band-Internet of Things (NB-IoT) UL allows the allocation of a single-tone in addition to multi-tone DFTS-OFDM with the possibility of a lower subcarrier spacing in addition to the normal subcarrier spacing.

Channel coding is based on a rate of 1/3 turbo coding and is complemented by Hybrid-Automatic Repeat reQuest (HARQ) with soft combining to handle decoding errors at the receiver side.

Data modulation supports quadrature phase shift keying (QPSK), 16 quadrature amplitude modulation (QAM), 64 QAM and 256 QAM for both the downlink and the uplink. In downlink, 1024 QAM is supported. NB-IoT supports QPSK on DL and UL, and additionally $\pi/2$ -binary phase shift keying (BPSK), and $\pi/4$ -quadrature phase shift keying (QPSK) are supported in uplink when a single-tone is allocated. NB-IoT DL channel coding is based on tail biting convolutional code. For eMTC (enhanced MachineType Communication), $\pi/2$ -BPSK is supported when two tones are allocated.

The E-UTRA/LTE RIT supports bandwidths from approximately 1,4 MHz to 640 MHz. NB-IoT supports a 200 kHz bandwidth. Carrier aggregation, i.e. the simultaneous transmission of multiple component carriers in parallel to/from the same terminal/eNB, is used to support bandwidths greater than 20 MHz. Component carriers do not have to be contiguous in frequency and can even be located in different frequency bands in order to enable exploitation of fragmented spectrum allocations by means of spectrum aggregation.

Carrier aggregation (CA) supports the functionality to aggregate TDD bands with different uplink and downlink allocations as well as the functionality to support multiple timing advances. Carrier aggregation also supports aggregating FDD and TDD component carriers. Dual connectivity allows aggregating component carriers of different eNBs that are connected via a non-ideal backhaul.

Channel-dependent scheduling in both the time and frequency domains is supported for both downlink and uplink with the base-station scheduler being responsible for (dynamically) selecting the transmission resource as well as the data rate. The basic operation is dynamic scheduling, where the base-station scheduler takes a decision for each 1 ms transmission time interval (TTI), but there is also a possibility for semi-persistent scheduling.

C.1.3 Overview of the component RIT: NR

The NR RIT as one component RIT represents the releases 15 and 16 of NR, which uses either

- 1) FDD operation and therefore is applicable for operation with paired spectrum, or
- 2) TDD operation and therefore is applicable for operation with unpaired spectrum. Channel bandwidths up to 400 MHz and carrier aggregation over 16 component carriers are supported, yielding peak data rates up to roughly 140 Gbit/s in the downlink and 65 Gbit/s in the uplink.

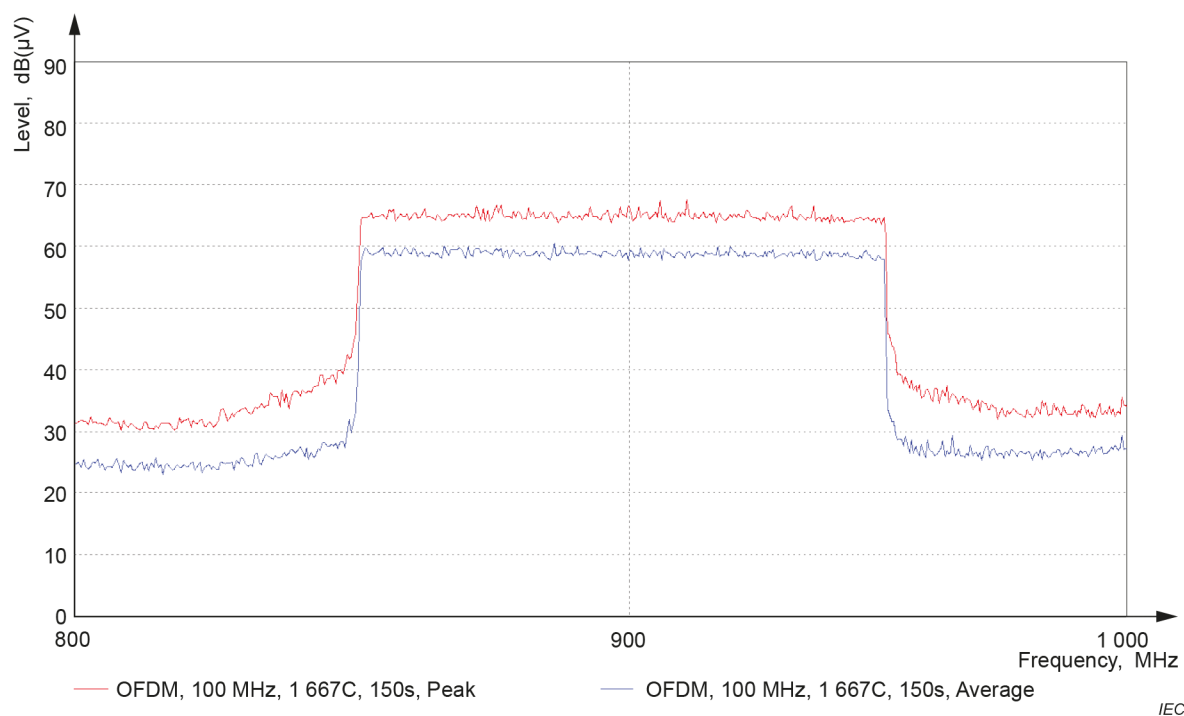
C.2 Simulation of the 5G signal

Classically, signal power has been considered a fundamental hazard in radiated immunity testing. Moreover, the up and down ratio of the TDD frame has been additionally considered. On the other hand, the signal modulation scheme and signal fluctuation within the test signal bandwidth were not considered important.

In this document, the 5G signal was also simulated from the same technical point of view.

In terms of signal power, the case where the signal spectrum is fully utilized by using all resource blocks is the one where the power is the greatest.

Figure C.3 shows an example of a spectrum measured by a spectrum analyser for an OFDM signal with 100 MHz test signal bandwidth generated by a vector signal generator.



OFDM numerology: 100 MHz BW, 1 667 sub-carriers, and 150 symbols.

Generator setting: 900 MHz and -20 dBm.

Spectrum analyser setting: 120 kHz resolution bandwidth and max-hold, red trace peak detector, blue trace average detector.

Figure C.3 – Example of an OFDM spectrum

The test signal for this document is modeled using band-limited white noise instead of OFDM in order to ensure independence from modulation schemes, as a basic standard. Additionally, a 100 Hz pulse modulation (PM) with 50 % duty cycle is added to this model to simulate the TDD scheme of 5G.

Figure C.4 and Figure C.5 show examples of a spectrum of the test signal using a white noise in the frequency domain and time domain. This signal with a bandwidth of 100 MHz was also generated by using a vector signal generator and then measured by using a spectrum analyser.