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TECHNICAL SPECIFICATION

**ElectroMagnetic Compatibility (EMC)
standard for radio equipment and services;
Study into extending the upper limit of the range of
radiated emissions requirements up to 40 GHz**

Reference
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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

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Introduction

The present document defines requirements for radiated emissions from 6 GHz to 40 GHz. It includes limits and test methodologies.

With the need for faster digital communications, at higher bandwidths, means that today's internet technologies have to use Gbps (Gigabyte per second) signals in TNE (including MME, ICT and IMT equipment) to satisfy the growing demand. In addition to traditional wired communication, wireless devices (radio base stations, Wi-Fi® systems, NR) also operate at, and use these higher frequencies. Hence there is need to protect the spectrum to allow efficient communication. Consequently, the risk of wireless systems being disturbed electromagnetically by unintentional digital noise has increased significantly over the last few years in the frequency band above 6 GHz.

1 Scope

The aim of the present document is to control unintentional radiated emissions generated by digital devices to protect radio services operating at frequencies up to 40 GHz.

The upper frequency limit of 6 GHz for unintentional radiated electric field emissions within current ETSI EMC standards is insufficient to protect these higher frequencies. Therefore, there is a need to develop requirements to control higher frequency digital noise to improve EMC. Within the present document, the upper limit of the frequency range is extended to 40 GHz and includes the following main elements:

- radiated electric field emission limits for unintentional signals;
- test site specifications;
- measurement methods;
- uncertainty analysis.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

[1] EN 55032 (2015 + Amendment 1:2020): "Electromagnetic compatibility of multimedia equipment - Emission Requirements" (produced by CENELEC).

NOTE: When referencing to EN 55032, Table clause x.y, wx denotes the table and y denotes the referenced clause by row within the table. For example table clause 2.3 is Table 2, clause (row) 3.

[2] CISPR 16-1-4 (2019): "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements".

[3] CISPR 16-2-3 (2016 + Amendment 1:2019): "Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements".

[4] ANSI C63.2 (2016): "American National Standard For Specifications of Electromagnetic Interference and Field Strength Measuring Instrumentation in the Frequency Range 9 kHz to 40 GHz".

[5] CFR Title 47 Part 15 (2020): "Radio Frequency devices".

[6] EN 61000-4-22 (2010): "Electromagnetic compatibility (EMC) - Part 4-22: Testing and measurement techniques - Radiated emissions and immunity measurements in fully anechoic rooms (FARs)" (produced by CENELEC).

[7] CISPR 16-1-1 (2019): "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus".

[8] ANSI C63.4 (2014 + Amendment 1:2017): "American National Standard For Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz".

[9] CISPR 16-1-6 (2014 + Amendment 1:2017): "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-6: Radio disturbance and immunity measuring apparatus - EMC antenna calibration".

[10] ETSI EN 300 386 (V2.1.1) (07-2016): "Telecommunication network equipment; ElectroMagnetic Compatibility (EMC) requirements; Harmonised Standard covering the essential requirements of the Directive 2014/30/EU".

[11] CISPR 16-1-5 (2016): "Specification for radio disturbance and immunity measuring apparatus and methods -Part 1-5: Radio disturbance and immunity measuring apparatus - Antenna calibration sites and reference test sites for 5 MHz to 18 GHz".

[12] CISPR 32 (2015 + Amendment 1:2019): "Electromagnetic compatibility of multimedia equipment - Emission requirements".

[13] ISO/IEC 17025 (2017): "General requirements for the competence of testing and calibration laboratories".

[14] IEC 61000-4-21 (2011): "Electromagnetic compatibility (EMC) - Part 4-21: Testing and measurement techniques - Reverberation chamber test methods".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] CISPR 11 (2015 + Amendment 1:2016 + Amendment 2:2019): "Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement".

[i.2] EN 55011 (2016 + Amendment A1:2017): "Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement" (produced by CENELEC).

[i.3] Recommendation ITU-T K.136 (2018): "Electromagnetic compatibility requirements for radio telecommunication equipment".

[i.4] Recommendation ITU-T K.137 (2018): "Electromagnetic compatibility requirements and measurement methods for wireline telecommunication network equipment".

[i.5] ICES 003 (2016 + Updated:2019): "Information Technology Equipment (Including Digital Apparatus) - Limits and Methods of Measurement".

[i.6] CISPR 16-4-2 (2011 + Amendment 1:2014 + Amendment 2:2018): "Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-2: Uncertainties, statistics and limit modelling - Measurement instrumentation uncertainty".

[i.7] ETSI TR 102 273-1-1 (V1.2.1) (12-2001): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties Part 1: Uncertainties in the measurement of mobile radio equipment characteristics; Sub-part 1: Introduction".

[i.8] ETSI TR 102 273-1-2 (V1.2.1) (12-2001): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties; Part 1: Uncertainties in the measurement of mobile radio equipment characteristics; Sub-part 2: Examples and annexes".

[i.9] GB 4824 (2019): "Industrial, scientific and medical equipment - Radio frequency disturbance characteristics - Limits and methods of measurement".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

enclosure port: physical boundary of the EUT through which electromagnetic fields may radiate

Equipment Under Test (EUT): equipment being evaluated for compliance with the present document

formal measurement: measurement used to determine compliance

NOTE: This is often the final measurement performed. It may be carried out following a pre-scan measurement. It is the measurement recorded in the test report.

Full Anechoic Room (FAR): enclosure that has six internal surfaces which are lined with radio-frequency-energy absorbing material (i.e. RF absorber) that attenuates electromagnetic energy in the frequency range of interest

highest internal frequency f_x: highest fundamental frequency generated or used within the EUT or highest frequency at which it operates

NOTE: This includes frequencies which are solely used within an integrated circuit.

H_{max}: maximum antenna height scanned during measurements within a FSOATS, for example 4 m

H_{min}: minimum antenna height scanned during measurements within a FSOATS

NOTE: H_{min} is normally at 1 m.

measurement distance (d_2): distance within a FSOATS is the shortest horizontal distance between an imaginary circular periphery just encompassing the EUT arrangement and the calibration point of the antenna

mode of operation: set of operational states of all functions of an EUT during a test or measurement

port: physical interface through which electromagnetic energy enters or leaves the EUT

reference distance (d_1): distance within a FSOATS, at which a limit is specified

3.2 Symbols

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

f_x the highest fundamental frequency generated or used within the EUT or highest frequency at which it operates
λ the free space wavelength at the measurement frequency
θ_{3dB} polar angle of the antenna main beamwidth at 3 dB

NOTE: See Figure C.3.

φ_{3dB} azimuthal angle of the antenna main beamwidth at 3 dB

NOTE: See Figure C.2.

D_a the largest dimension of the antenna aperture

w_h maximum horizontal dimension of the 3 dB beamwidth of the receiving on the surface plane of the turntable

NOTE: See Figure C.2.

φ_h the arc angle of maximum horizontal dimension, w_h, on the surface plane of the turntable

NOTE: See Figure C.2.

Δ maximum vertical and horizontal dimension that covers the EUT within the 3 dB beamwidth of the receiving antenna

3.3 Abbreviations

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

10GE	10 Gigabit Ethernet
ADAS	Advanced Driver Assistance Systems
AF	Antenna Factor
AI	Artificial Intelligence
ANSI	American National Standardization Institute
AP	Access Point
AV	Average
CENELEC	European Committee for Electrotechnical Standardization
CFR	Code of Federal Regulations
CISPR	Comité International Spécial des Perturbations Radioélectriques (International Special Committee on Radio Interference)
C-V2X	Cellular Vehicle to Everything
EM	Electromagnetic
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
EN	European Norm
EUT	Equipment Under Test
FAR	Full Anechoic Room
FSOATS	Free Space Open Area Test Site
G.Fast	Type of Digital Subscriber Line
GPS	Global Positioning System
GRP	Ground Reference Plane
ICES	Interference-Causing Equipment Standard
ICT	Information and Communication Technology
IF	Intermediate Frequency
IMT	International Mobile Technology
LTE	Long Term Evolution
MME	Multi Media Equipment
NR	New Radio
OLT	Optical Line Terminal
PK	Peak
RBW	Resolution Bandwidth
RF	Radio Frequency
RVC	Reverberation Chamber
TDB	To Be Defined
TNE	Telecommunications Network Equipment
UE	User Equipment
VSWR	Voltage Standing Wave Ratio

4 Rationale

4.1 Background

With the need for faster digital communications, and higher bandwidths, today's internet technologies have to use Gigabit per second (Gbps) signals within TNE to satisfy the growing demand. The implications for equipment to enable these faster digital communications include:

- High speed clocks and data on internal PCBs, processors and ASICs.
- Extensive use of high speed optical modules, placed at the periphery of the equipment, which may have emissions at key frequencies (for example 10 GHz and 26 GHz).
- Extremely high capacity backplanes to support the numerous required interfaces, cards and the high volume of traffic.
- Unintentional emissions at frequencies above 6 GHz.

Meanwhile, from the perspective of wireless communications, the radio technology has been developing rapidly with AI services based on 4G LTE and 5G NR, with use cases such as the smart home, smart city and autonomous driving. These radio services are rapidly expanding and using the higher frequency spectrum above 6 GHz.

Hence the impact of the unintentional emissions may reduce the effectiveness of the radio services.

4.2 Risk scenarios for high frequency EMI

Three typical scenarios are outlined:

- Radiation disturbance from telecommunication centres (supporting cloud web services) to radio base station(s), Figure 1.
- Radiation disturbance from data access equipment in city streets to vehicles, UE, and radio base stations, Figure 2.
- Radiation disturbance between electronics in the home environment, Figure 3.

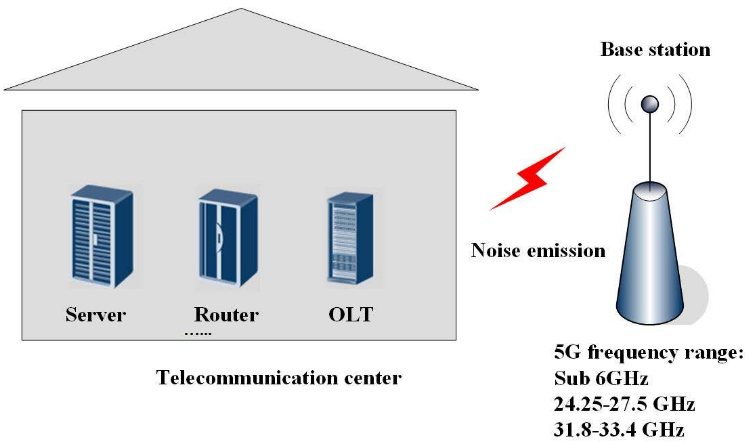

Figure 1: Disturbance from telecommunication to base station system

Figure 2: Disturbance to vehicles and base stations due to outside access equipment on the street

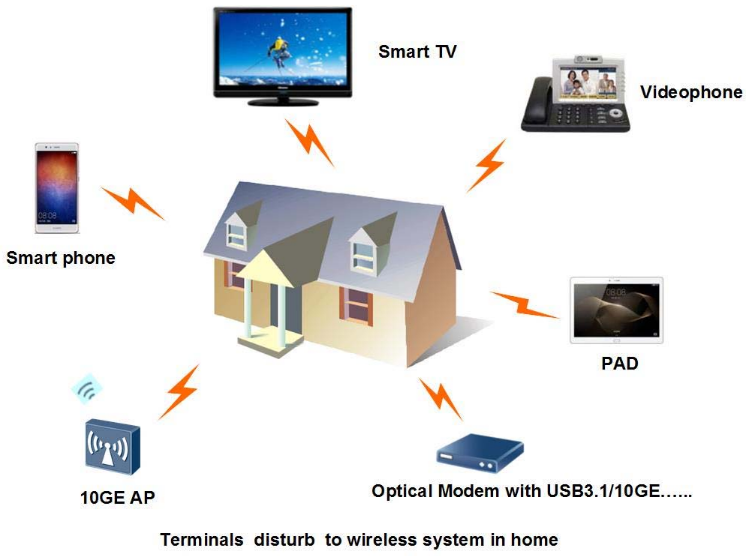

Figure 3: Disturbance to wireless systems in the home

5 Radiated emission limits

5.1 Overview of existing limits

CISPR, the international committee responsible for the establishing limits and methods to protect radio services, is at the very early stages of developing radiated electric field emission limits above 6 GHz, so the current proposal uses a combination of the requirements within the following standards to establish an interim solution:

- CFR Title 47 Part 15 [5]
- ANSI C63.2 [4]
- ANSI C63.4 [8]
- EN 55032 [1]
- ETSI EN 300 386 [10]
- CISPR 16 series [2], [3], [7], [9], [11], and [i.6]

According to the clause §15.109 (a) of CFR Title 47 Part 15 [5] the radiated emission limits, up to 40 GHz, for the class A and class B equipment are summarized in Table 1. Class B limits are for the protection of radio services in residential environments and class A limits are for the protection of radio services other than residential environments.

Table 1: Requirements for radiated electric field emission, in the range 6 GHz to 40 GHz

Frequency range (GHz)	Test site	Test distance (m)	Detector/ RBW	Class A Limit dB (µV/m)	Class B Limit dB (µV/m)
6 to 40	FSOATS FAR	3	Average/ 1 MHz	60	54
6 to 40	FSOATS FAR	3	Peak/ 1 MHz	80	74
NOTE: The limits at exactly 6 GHz in EN 55032 [1] are identical.					

Within Table 1, the class A limits are only relaxed by 6 dB compared to class B limits.

In the frequency range from 30 MHz to 1 GHz there is a 10 dB difference between class A limits and class B limits. As the frequency increases this differential needs to increase based upon the following:

- As the frequency increases the losses due to free space increase.
- As the frequency increases the losses due to structures, walls increase.

The impact of these elements will also mean that mitigation techniques become more effective, for example moving the offending device away from the radio receiver or the use of a barrier between the offending device and the radio receiver.

Hence the 10 dB differential between the class A and class B limits should be used at these higher frequencies. Some parties suggest that the 10 dB differential should be even larger. However, further analysis is required from both practice and theoretical perspectives to support such an increase.

EN 55032 [1] is identical to CISPR 32 [12] hence if a regulatory body or manufacturer wanted to use CISPR 32 [12] as the reference instead of EN 55032 [1] then the requirements within this publication would be equivalent.

5.2 Radiated emission requirements from 6 GHz to 40 GHz

The EUT classification (Class A or Class B) defined in EN 55032 [1] shall apply.

Radiated emission requirements defined in Table 2 shall be satisfied across the frequency range from 6 GHz up to the highest frequency derived from Table 3.

Measurements shall be performed using both peak and average detectors unless the limit defined for use with the average detector has been satisfied using a peak detector, in this case, no average measurement is required but the EUT is deemed to satisfy both limits.

Table 2: Electric field radiated emission requirements, in the frequency range 6 GHz to 40 GHz

Table clause	Frequency range (GHz)	Test site	Test distance (m)	Detector/ RBW	Class A Limit dB (µV/m)	Class B Limit dB (µV/m)
2.1	6 to 40	FSOATS FAR	3	Average/ 1 MHz	64	54
2.2	6 to 40	FSOATS FAR	3	Peak/ 1 MHz	84	74
2.3	6 to 18	RVC	n/a	Average/ 1 MHz	70	60
2.4	6 to 18	RVC	n/a	Peak/ 1 MHz	90	80
Apply Option 1 or Option 2. Option 1: apply Table clause 2.1 and 2.2 across the frequency range from 6 GHz to the highest frequency of measurement derived from Table 3. Option 2: apply Table clause 2.3 and 2.4 across the frequency range from 6 GHz to the highest frequency of measurement derived from Table 3 up to 18 GHz, whichever is the lower. Where the derived highest frequency is greater than 18 GHz, Option 1 shall be used from 18 GHz up to the highest frequency of measurement derived from Table 3. The minimum test distance is 1 m when using a FAR/FSOATS. See clause 6.1. The limits for RVC are based upon EUT measurements, rather than a direct calculation. The relaxation is based upon the fact that the total radiated power is measured, rather than the direct radiated electric field strength. Therefore, further analysis from both practice and theoretical perspectives is required to support the specified limit levels. These limits are provisional and may change as more experience is obtained. When using an RVC, including test site validation, test method and calibration method refer to IEC 61000-4-21 [14] and EN 55032 [1]. RVC is currently limited to 18 GHz [14], this frequency may be extended after further study. NOTE: In the present table, table clauses are referenced using an x.y format, where x denotes the table and y denotes the referenced clause by row within the table. For example Table clause 2.3 is Table 2, clause (row) 3.						

5.3 Frequency range of radiated measurements

The frequency range of radiated measurements shall be determined according to the highest fundamental frequency of EUT operation according to CFR Title 47 Part 15 [5] and EN 55032 [1], see Table 3. Radiated emission measurements shall be performed across the frequency range from 6 GHz to the highest measured frequency, based upon f_x.

Table 3: Frequency range requirement

Highest internal frequency (f_x)	Highest measured frequency (MHz)
$f_x \leq$ 108 MHz	1 000
108 MHz < $f_x \leq$ 500 MHz	2 000
500 MHz < $f_x \leq$ 1 GHz	5 000
Above 1 GHz	5th harmonic of the highest frequency or 40 GHz, whichever is lower
NOTE 1: For further information about *fx* see the definition. NOTE 2: The first three rows are included for completeness.	

Where *f*x is unknown, the radiated emission measurements shall be performed up to 40 GHz.

6 Test facilities

6.1 Test site validation

The preferable test site is a FSOATS for the measurement of radiated electric field emissions from 6 GHz to 40 GHz. A FSOATS is intended to simulate a free-space environment, such that only the direct ray from the EUT reaches the receive antenna. Other types of test sites based on the principle of reciprocity on ground reflection introduce an unacceptably high uncertainty. The reflection from the ground, walls, and ceilings shall be minimized by using absorber, see illustration in Figure 4.

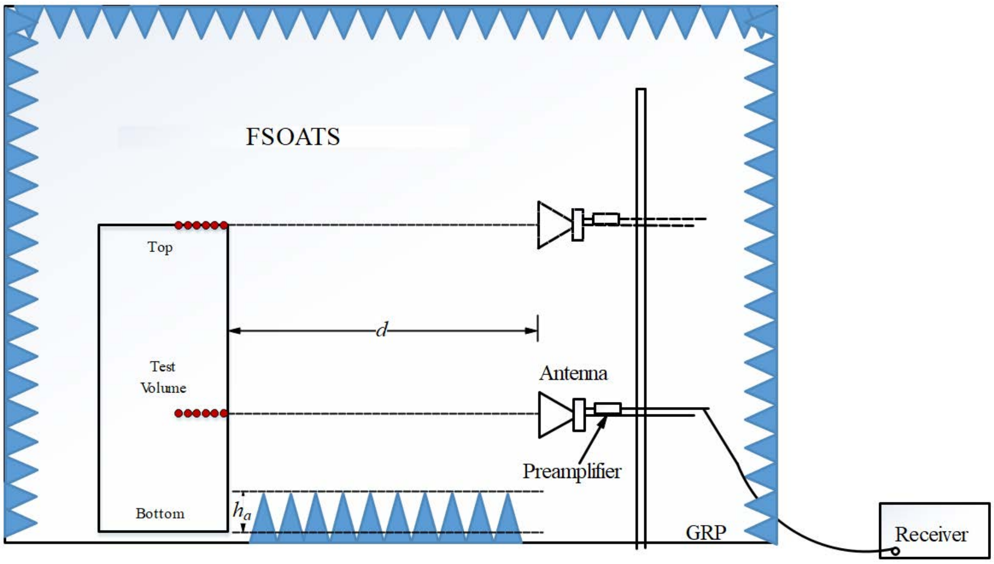

Figure 4: Illustration of site validation setup for radiated emission from 6 GHz to 40 GHz within a FSOATS

The FSOATS shall satisfy the requirements of clause 7.3.2 of CISPR 16-1-4 [2].

There is no defined specification of a FSOATS in the frequency range from 18 GHz to 40 GHz. In the frequency range 18 GHz to 40 GHz, a FSOATS is deemed acceptable if the FSOATS satisfies clause 7.3.2 of CISPR 16-1-4 [2] over the frequency range from 6 GHz to 18 GHz.

A FAR may be used provided it satisfies the FSOATS requirements defined in the present clause.

For measurements in an RVC the chamber shall be validated in accordance with Annexes B and C of IEC 61000-4-21 [14].

6.2 Ambient signal environment

The ambient signal level shall be at least 6 dB below the appropriate limit defined in Table 2.

6.3 Test Equipment

6.3.1 Measurement Receiver

In the frequency range from 6 GHz to 18 GHz the measurement receiver shall comply with the requirements of CISPR 16-1-1 [7].

In the frequency range from 18 GHz to 40 GHz the measurement receiver shall comply with the requirements of clause 4 of ANSI C63.2 [4]. See Table 4.

The receiver shall include both peak and average detectors. The measurement receiver may be a spectrum analyser or a test receiver, provided it satisfies the appropriate requirements within the present document.

Table 4: Test receiver requirements in the frequency range 18 GHz to 40 GHz

Specification	18 GHz to 26,5 GHz	26,5 GHz to 40 GHz
Input impedance	50 Ω	50 Ω
Input VSWR	3:1	3:1
Frequency accuracy	±2 %	±2 %
IF bandwidths (-6 dB)	100 kHz, 1 MHz	100 kHz, 1 MHz
Displayed average noise level (in a 1 Hz bandwidth) - with internal preamplifier turned on (if present)	-145 dBm	-140 dBm
Amplitude accuracy	±2 dB	±2 dB
Spurious free dynamic range	40 dBc	40 dBc
Peak detection	Per CISPR 16-1-1 [7] clause 5 for frequency range 1 GHz to 18 GHz	Per CISPR 16-1-1 [7] clause 5 for frequency range 1 GHz to 18 GHz
Average detection	Per CISPR 16-1-1 [7] clause 6 for frequency range 1 GHz to 18 GHz	Per CISPR 16-1-1 [7] clause 6 for frequency range 1 GHz to 18 GHz

6.3.2 Measurement Antenna

Any type of linearly polarized antenna may be used. These antennas include hybrid antennas, LPDAs, double-ridged waveguide horns, quadruple-ridged waveguide horns, rectangular waveguide horns, pyramidal horns, optimum-gain horns, octave-band horns, and standard-gain horns.

For standard gain horns the following may be calculated:

- 3 dB beamwidth
- Antenna factors

for all other antennas, or for standard gain horns where the calculation has not been performed:

- The antenna pattern and the 3 dB beamwidth shall be established in accordance with Annex I of CISPR 16-1-6 [9]. The same methods from 1 GHz to 18 GHz shall be used from 18 GHz to 40 GHz.
- Antenna factors shall be established using free space conditions defined in CISPR 16-1-6 [9] using facilities defined in CISPR 16-1-5 [11]. The same methods from 1 GHz to 18 GHz shall be used from 18 GHz to 40 GHz.

The antennas used for EUT measurements and site validation shall comply with clause 4.6 of CISPR 16-1-4 [2]. Where possible, the same antenna used for site validation shall be used for EUT measurements. This will reduce measurement uncertainty.

For frequencies up to 18 GHz, and at a receiving antenna height of 1 m, the 3 dB beamwidth shall be large enough to encompass the active elements within EUT, or system arrangement, when located at the measuring distance. For frequencies above 18 GHz the 3 dB beamwidth shall be recorded in the test report.

7 Test method

7.1 Overview

The measurement method in the frequency range between 6 GHz to 40 GHz shall be based upon either of the following standards:

- EN 55032 [1], Table clause A1.3
- CISPR 16-2-3 [3], clause 7.6

- IEC 61000-4-21 [14], Annex E for measurements up to 18 GHz in an RVC, in combination with EN 55032 [1].

For measurements using a FSOATS, some regulatory bodies require full height scanning from 1 m to 4 m, independent of the beamwidth of the antenna, hence they would require the use of methods of EN 55032 [1] or CISPR 32 [12]. The method chosen shall be recorded in the test report (see clause C.3 for further guidance).

7.2 Arrangement, Configuration, Mode of Operation of the EUT

The arrangement, configuration and mode of operation of the EUT shall be in accordance with ETSI EN 300 386 [10] for TNE and EN 55032 [1] for all other equipment.

For measurements using a FSOATS, where possible, the sources of radiation disturbance within the EUT should be above the height of the absorber positioned on the GRP.

NOTE: The absorber used within a FSOATS on the GRP is to block the reflected wave, but may also reduce EUT emissions.

7.3 Measurement distance using a FSOATS

The measurement distance is the shortest horizontal distance between an imaginary circular periphery just compassing the EUT arrangement and the calibration point of the antenna, see Figures C.1 and C.2 in EN 55032 [1]. Where a test facility has been validated for a different measurement distance other than 3 m, then the measurement may be performed at that distance. In that case, the limit L_2, corresponding to the selected measurement distance d_2 applying, shall be calculated by applying the following formula:

$$L_2 = L_1 + 20 \log (d_1/d_2) \quad (1)$$

Where L_1 is the specified limit in dBµV/m at the distance d_1; and, L_2 is the new limit for distance d_2. The distances d_1 and d_2 use the same unit, such as m.

7.4 Measurement Process

7.4.1 Frequency ranges

Based upon the antennas performance, test setup and characteristics of the measurement process it is logical to divide the measurement into 3 sub-ranges. See Table 5.

7.4.2 Test methods

7.4.2.1 Introduction

For measurements using a FSOATS, typically, there are two main methods of capturing data, continuous (see clause 7.4.2.2) and stepped (see clause 7.4.2.3).

For measurements using a RVC see IEC 61000-4-21 [14], clause E.4.

7.4.2.2 Continuous Method, using a FSOATS

In the continuous method, data is captured during movement of the antenna or rotation of the turntable. The following elements are critical:

a) Speed of tower movement (from H_{min} to H_{max}), when the tower is in motion during capture.

b) Rotation speed of the turntable (from 0 degrees to 360 degrees), when the turntable is in motion during capture.

c) Sweep time (or capture time) of the spectrum analyser. During prescan, when either of the tower or the turntable are in motion.

7.4.2.3 Stepped Method, using a FSOATS

In the stepped method, the tower and the turntable are set to fixed positions, whilst data is captured from the EUT typically using maximum hold mode on the spectrum analyser. So the turntable is stepped from (from 0 degrees to 360 degrees) and the tower is stepped (from H_{min} to H_{max}). The following elements are critical:

a) The size of the step of the tower, in height.

b) The size of the azimuth step of the turntable, in degrees.

c) Capture/Hold time of the spectrum analyser, in max hold.

Sometimes the continuous method and stepped method are used in combination. For example, during prescan, which uses a fixed height tower whilst continuously rotating the turntable.

7.4.3 Measurement process using a FSOATS

7.4.3.1 Introduction

Typically, there are two main measurement processes, prescan and formal (see clauses 7.4.3.2 and 7.4.3.3).

7.4.3.2 Prescan Process

An approximation process used to quickly investigate the EUT to establish the critical frequencies which need further evaluation.

7.4.3.3 Formal Process

A prescan process is typically performed after a prescan (see clause 7.4.3.2).

For each critical frequency found, during the prescan process, measure each emission, during full rotation of the turntable, whilst the receiving antenna height is changed to cover the range H_{min} to H_{max}. The tower (or turntable) is set to a fixed position (the maximum position if known), whilst the turntable (or tower) is changed to find the position of maximum response. When the maximum emission level is found for both tower and turntable, both the tower and turntable are reset to this maximum position and a final measurement is then performed. This process is repeated with the antenna in horizontal and vertical polarization.

In order to ensure that measurements are performed effectively Table 5 defines various values to be used in the above processes.

Table 5: Minimum step sizes during the measurement process

Range	**1**	**2**	**3**
Frequency Range	6 GHz - 18 GHz	18 GHz - 26,5 GHz	26,5 GHz - 40 GHz
Measurement distance	3 m	3 m	3 m
Test Method:	**CISPR 16-2-3 [3], clause 7.6**		
Prescan and Formal process, see note 2			
Stepped method Minimum Turntable Step, φ_h (in degrees)	< 6	< 6	< 3
Stepped method Minimum Tower Step, Δ (height in cm) See note 1	< 100	< 100	< 50
Others	*TDB*	*TDB*	*TDB*
Test Method:	**EN 55032 [1], Table clause A1.3**		
Prescan process			
Stepped method Minimum Turntable Step, φ_h (in degrees)	< 6	< 6	< 3
Stepped method Minimum Tower Step, Δ (height in cm) See note 1	< 100	< 100	< 50
Others	*TDB*	*TDB*	*TDB*

Range	1	2	3
Formal process			
Minimum Turntable Step	Continuous scan from 0 degrees to 360 degrees (see clause 7.4.2.2)	Continuous scan from 0 degrees to 360 degrees (see clause 7.4.2.2)	Continuous scan from 0 degrees to 360 degrees (see clause 7.4.2.2)
Minimum Tower Step	Continuous scan from H_{min} to H_{max} (1 m to 4 m) (see clause 7.4.2.2)	Continuous scan from H_{min} to H_{max} (1 m to 4 m) (see clause 7.4.2.2)	Continuous scan from H_{min} to H_{max} (1 m to 4 m) (see clause 7.4.2.2)
Others	*TDB*	*TDB*	*TDB*
NOTE 1: The calculated value is obtained from the antenna technical data given in Annex A and the formula (C.4). NOTE 2: Using the CISPR 16-2-3 [3], clause 7.6 test method, height scanning of the receiving antenna is based upon the height of the EUT. NOTE 3: Using the EN 55032 [1] table clause A1.3 test method, H_{min} = 1 m and H_{max} = 4 m.			

7.5 Other details using a FSOATS

As frequencies increase, signals become more directional in nature, hence careful consideration needs to be given to turntable speed and the capture time/sweep of the receivers/spectrum analysers. The turntable rotation needs to be sufficiently slow and the receivers/spectrum analysers capture time needs to very fast to ensure the maximum signals are recorded.

For automated measurement, if a large difference, i.e. greater than 3 dB, is observed between prescan and formal measurements, which is not related to the detector function or reasonable EUT operation, then the measurement result should be confirmed.

For time varying signals, measurements times will need to be increased to ensure that the maximum emission levels are recorded.

8 Uncertainty Analysis

The estimations of the uncertainty for emission measurements refer to the examples and methods in the clause part D1 for emission of EN 61000-4-22 [6], Annex D. In the frequency range from 1 GHz to 18 GHz, the results of Table D.2 of EN 61000-4-22 [6], Annex D applies, in which the expanded uncertainties are evaluated with the coverage factor $k = 2$, which is usually selected to indicate that the true value lies in a symmetric interval around the measurement value with a confidence level of 95 %.

NOTE 1: EN 61000-4-22 [6], Annex D states that in case of compliance statements with the same confidence level of 95 %, a single-sided evaluation may apply leading to a coverage factor $k = 1,64$.

Similarly, in the subranges of frequencies in 18 GHz to 26,5 GHz and 26,5 GHz to 40 GHz, the same method of the basic standard applies to estimate the uncertainty of emission measurement associating with measurement distance, antenna types, height scan steps, etc. The analysis results are listed in the tables 6 and 7.

NOTE 2: The measurement uncertainty in the range of 6 GHz to 18 GHz in CISPR 16-4-2 [i.6], Annex E provides a value of uncertainty.

The word "typical" for the tables 6 and 7 implies that the statistical data are measured at a number of EMC test sites being accredited against ISO/IEC 17025 [13].

The method of uncertainty calculation used is defined in ETSI TR 102 273-1-1 [i.7] and ETSI TR 102 273-1-2 [i.8].

For measurements in a RVC measurement uncertainty is defined in IEC 61000-4-21 [14], Annex K.

Table 6: The typical uncertainty budget for the frequency range 18 GHz to 26,5 GHz

No.	Uncertainty component	Symbol	Value (dB)	Probabilistic distribution	Coverage factor k	u_i (dB)
1	Receiver reading	V_r	0,31	Normal	1	0,31
2	Receiver sine wave voltage inaccuracy	δV_{sw}	0,12	Normal	2	0,06
3	Receiver pulse amplitude response	δV_{pa}	1,5	Rectangular	$\sqrt{3}$	0,87
4	Receiver pulse repetition rate response	δV_{pr}	1,58	Rectangular	$\sqrt{3}$	0,91
5	Antenna factor calibration inaccuracy	F_a	2	Normal	2	1
6	Attenuation between the receiver and antenna	a_c	0,9	Normal	2	0,45
7	The effect of the receiver noise floor	δV_{nf}	0,9	Rectangular	$\sqrt{3}$	0,52
8	Mismatch: antenna and amplifier	δM_1	0,83	U-shaped	$\sqrt{2}$	0,59
9	Mismatch: amplifier and receiver	δM_2	1,34	U-shaped	$\sqrt{2}$	0,95
10	Antenna factor frequency interpolation	δF_{af}	0,3	Rectangular	$\sqrt{3}$	0,17
11	Antenna factor variation with height	δF_{ah}	0,5	Rectangular	$\sqrt{3}$	0,29
12	Antenna directivity	δF_{adir}	0,5	Rectangular	$\sqrt{3}$	0,29
13	Antenna phase centre location	δF_{aph}	0,3	Rectangular	$\sqrt{3}$	0,17
14	Antenna cross-polarization response	δF_{acp}	0,9	Rectangular	$\sqrt{3}$	0,52
15	Antenna distance	δd	0,1	Rectangular	$\sqrt{3}$	0,06
16	Effect of setup table material	δA_{NT}	1,23	Rectangular	$\sqrt{3}$	0,71
17	The inaccuracy of Preamplifier gain	G_p	1,34	Rectangular	$\sqrt{3}$	0,77
18	Combined uncertainty	$u_c(E)$	-	-	-	2,45
19	Expanded uncertainty	$U(E)$	-	-	2	4,9

Table 7: The typical uncertainty budget for the frequency range 26,5 GHz to 40 GHz

No.	Uncertainty component	Symbol	Value (dB)	Probabilistic distribution	Coverage factor k	u_i (dB)
1	Receiver reading	V_r	0,31	Normal	1	0,31
2	Receiver sine wave voltage inaccuracy	δV_{sw}	0,11	Normal	2	0,055
3	Receiver pulse amplitude response	δV_{pa}	1,5	Rectangular	$\sqrt{3}$	0,87
4	Receiver pulse repetition rate response	δV_{pr}	1,75	Rectangular	$\sqrt{3}$	1,01
5	Antenna factor calibration inaccuracy	F_a	2	Normal	2	1
6	Attenuation between the receiver and antenna	a_c	3	Normal	2	1,5
7	The effect of the receiver noise floor	δV_{nf}	0,9	Rectangular	$\sqrt{3}$	0,52
8	Mismatch: antenna and amplifier	δM_1	0,89	U-shaped	$\sqrt{2}$	0,63
9	Mismatch: amplifier and receiver	δM_2	1,76	U-shaped	$\sqrt{2}$	1,24
10	Antenna factor frequency interpolation	δF_{af}	0,3	Rectangular	$\sqrt{3}$	0,17
11	Antenna factor variation with height	δF_{ah}	0,5	Rectangular	$\sqrt{3}$	0,29
12	Antenna directivity	δF_{adir}	0,5	Rectangular	$\sqrt{3}$	0,29
13	Antenna phase centre location	δF_{aph}	0,3	Rectangular	$\sqrt{3}$	0,17
14	Antenna cross-polarization response	δF_{acp}	0,9	Rectangular	$\sqrt{3}$	0,52
15	Test distance	δd	0,1	Rectangular	$\sqrt{3}$	0,06
16	Effect of setup table material	δA_{NT}	1,51	Rectangular	$\sqrt{3}$	0,87
17	The inaccuracy of Preamplifier gain	G_p	1	Rectangular	$\sqrt{3}$	0,58
18	Combined uncertainty	$u_c(E)$	-	-	-	2,99
19	Expanded uncertainty	$U(E)$	-	-	2	5,98

The results show that the uncertainty level *U(E)* becomes higher (5,98) in the frequency range of 26,5 GHz to 40 GHz. This is due mainly to the following 3 factors:

1) Attenuation between the receiver and antenna a_c.

2) Mismatch between amplifier and receiver δM_2.

3) Antenna factor calibration inaccuracy F_a.

Annex A (informative): Technical information of receiving antennas from 1 GHz to 40 GHz

The 3 dB beamwidth of typical receiving antennas in the three subranges from 1 GHz to 40 GHz are presented in the following tables from Table A.1 to A.3 at 3 m distance. The information is from the technical data of the typical antennas.

Table A.1: Technical information of receiving antenna in 1 GHz to 18 GHz

Manufacturer & Model	Brand 1	Brand 2	Brand 3	Brand 4
Frequency range	1 GHz - 18 GHz	1 GHz - 18 GHz	0,8 GHz - 18 GHz	0,7 GHz - 18 GHz
3 dB Beamwidth (E–Plane)	90° - 10°	40°@18GHz	100° - 40°	48°
3 dB Beamwidth (H–Plane)	60° - 10°	20°@18GHz	90° - 30°	30°
Antenna Factor (AF) (dB/m)	24 - 50	28 - 42	23,5 - 44	22 - 44

Table A.2: Technical information of receiving antenna in 18 GHz to 26,5 GHz

Manufacturer & Model	Brand 1	Brand 2	Brand 3
Frequency range	15 GHz - 26,5 GHz	18 GHz - 40 GHz	18 GHz - 26,5 GHz
3 dB Beamwidth (E–Plane)	13° - 21°	18°	20°@22GHz
3 dB Beamwidth (H–Plane)	14° - 23°	20°	20°@22GHz
Antenna Factor (AF) (dB/m)	38 - 45	40,3 - 41,1	40,3

Table A.3: Technical information of receiving antenna in 26,5 GHz to 40 GHz

Manufacturer & Model	Brand 1	Brand 2	Brand 3
Frequency range	26,5 GHz - 40 GHz	18 GHz - 40 GHz	26,5 GHz - 40 GHz
3 dB Beamwidth (E–Plane)	14,5° - 22,5°	18°	20°@33GHz
3 dB Beamwidth (H–Plane)	14,5° - 22,5°	20°	20°@33GHz
Antenna Factor (AF) (dB/m)	41 - 41,4	40,3 - 41,1	43,55

Annex B (informative): Limits of radiated emission above 6 GHz in other standards

The limits for radiated emission above 6 GHz specified by other international standards have been summarized in Table B.1.

Table B.1: Radiated emission requirements above 6 GHz

Region	Standard	Frequency range	Limits (above 6 GHz) dB (μV/m)	
			Class A	Class B
International	CISPR 11 [i.1]	up to 18 GHz (group 2)	Peak detector: 82 (within harmonic frequency bands); Peak detector: 70 (outside harmonic frequency bands)	Peak detector: 70
Europe	EN 55011 [i.2]	up to 18 GHz (group 2)	Peak detector: 82 (within harmonic frequency bands); Peak detector: 70 (outside harmonic frequency bands)	Peak detector: 70
International	Recommendation ITU-T K.136 [i.3]	up to 40 GHz	PK: 80 AV: 60	PK: 74 AV: 54
International	Recommendation ITU-T K.137 [i.4]	up to 40 GHz	PK: 80 AV: 60	PK: 74 AV: 54
United States of America	CFR Title 47 Part 15 [5]	up to 40 GHz	PK: 80 AV: 60	PK: 74 AV: 54
Canada	ICES 003 [i.5]	up to 40 GHz	PK: 80 AV: 60	PK: 74 AV: 54
China	GB 4824 [i.9]	up to 18GHz (group 2)	Peak detector: 82 (within harmonic frequency bands); Peak detector: 70 (outside harmonic frequency bands)	Peak detector: 70

Annex C (informative): Supporting information

C.1 Far field conditions

In application, the following condition should be satisfied to ensure the 3 dB beamwidth of the antenna is in the far-field zone, i.e.:

$$d \geq \frac{2{D_a}^2}{\lambda} \quad \text{(C.1)}$$

Where *d* is the measurement distance (m); D_a is the largest dimension of the aperture of the antenna (m); and λ is the free space wavelength at the frequency of measurement (m). In addition, the EUT itself is a type of antenna and its size is relevant to the measurement distance. The EUT size, for example 2 m in height, is an electrically long antenna at 3 m distance in the frequency band from 6 GHz to 40 GHz.

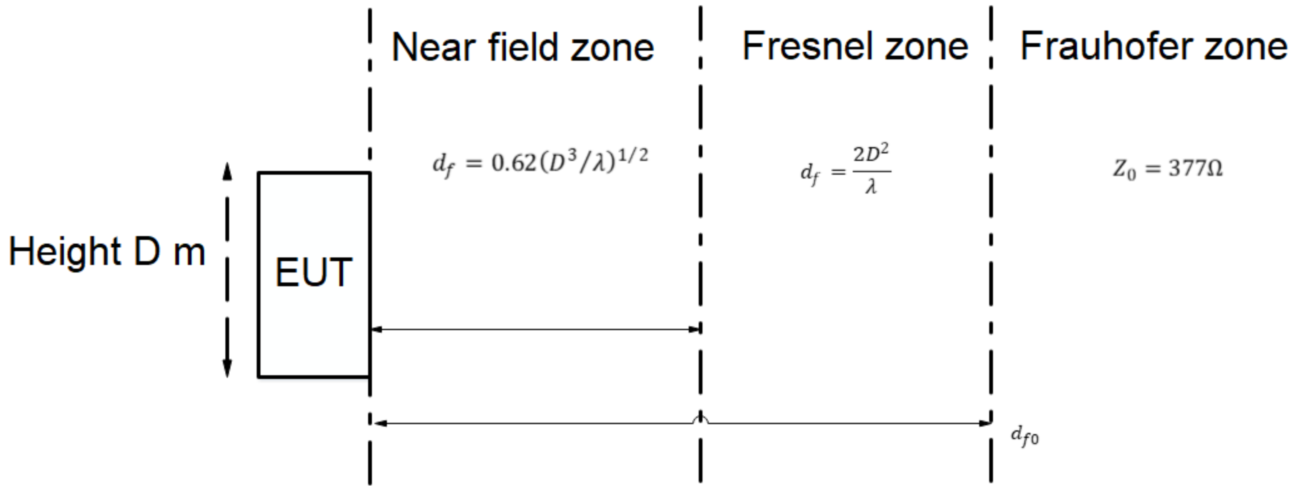

Figure C.1: Illustration of radiation by EUT whose dimension (D) is considered as an electrically long antenna

As shown in Figure C.1, the measured radiation field is distributed within Fresnel zone and the near field zone by the EUT at 3 m distance over the frequency range from 6 GHz to 40 GHz. There is no or very weak radiation in the near field zone of EUT. The condition of Fraunhofer zone is impossible for a test distance over 10 m. The azimuth angle and vertical scan of the near field radiation generated by EUT equivalent to a large size antenna therefore need to be controlled in fine steps in order to capture the maximum amplitude of the EUT radiation field.

C.2 Azimuth angle scan and movement of turntable

EM noise radiation from EUT behaves more as a narrow-beam lobe at higher frequencies in both horizontal and vertical polarization. Therefore, the azimuth angle scan for the receiving antenna shall be selected to be a small enough step in order not to miss the detection of EUT-EMI-narrow beams at higher frequencies. To achieve the uncertainty of minimum 95 % coverage of measuring narrow beam EMI in each of the sub-frequency ranges, the azimuth-angle-scan step needs to be specified. The smaller step of azimuth-angle scan takes a longer measurement time than the time for measurements below 6 GHz.

Figure C.2 illustrates that the turning angle of the EUT table shall not be larger than the dimension covered by the azimuth-angle φ_{3dB} corresponding to the main-beam lobe width, the horizontal dimension w_h, of the receiving antenna at the frequencies of 18 GHz in range 1, 26,5 GHz in the range 2, and 40 GHz in range 3, respectively.

$$w_h = 2d\tan(0{,}5\varphi_{3dB}) \quad \text{(C.2)}$$

$$\varphi_{h=} 2\arctan\left(\frac{w_h}{2a}\right) \qquad (C.3)$$

Where w_h is also the horizontal dimension at the arc angle φ_h on the surface plan of test turntable, a is the radius of EUT imaginary periphery circular. The turntable angle and the number of steps are summarized in Table 5. When the test distance is adjustable the arc angle φ_h changes too for the same φ_{3dB} of receiving antenna 3 dB lobe. When the test distance is 1 m, the angle scan step, φ_h, of tunable becomes smaller than that for a 3 m test distance according to the formula above. In the test a smaller angular step is necessary to ensure the maximum emission level is measured. For the continuous moving turntable a slow rotating speed is preferred to ensure the sweep time and number of scans are sufficient to ensure the maximum emission level is measured.

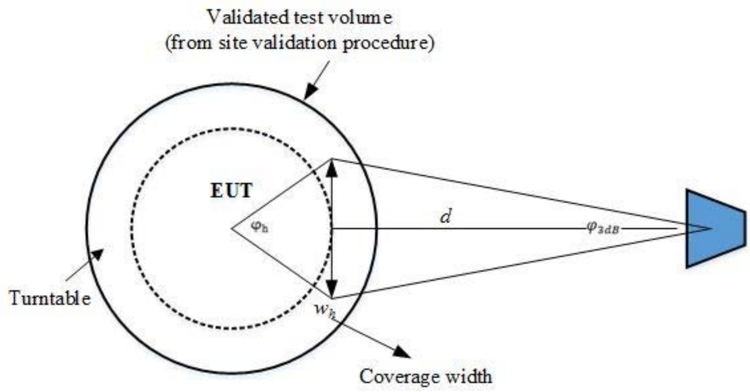

Figure C.2: Illustration (top view) of Rx antenna coverage range *Wh* on turntable surface at distance *d*

C.3 Vertical scan step

The requirement for height scanning as given in CISPR 16-2-3 [3] is based on the concept that if the beamwidth of the antenna encompasses the EUT then height scanning is not required. This is shown in Figure C.3, the θ_{3dB} is the polar angle of the 3 dB lobe width of the receiving antenna along the vertical axis. *d* is the measurement distance. *w* is the maximum range that covers the part of EUT within the 3 dB lobe width of the receiving antenna. At the measuring the distance *d*, *w* can be calculated by the following formula:

$$\Delta = 2d \tan 0{,}5\theta_{3dB} \qquad (C.4)$$

As shown in Figure C.3, *h* is the height of receiving antenna, which is the distance from the antenna reference point to ground.

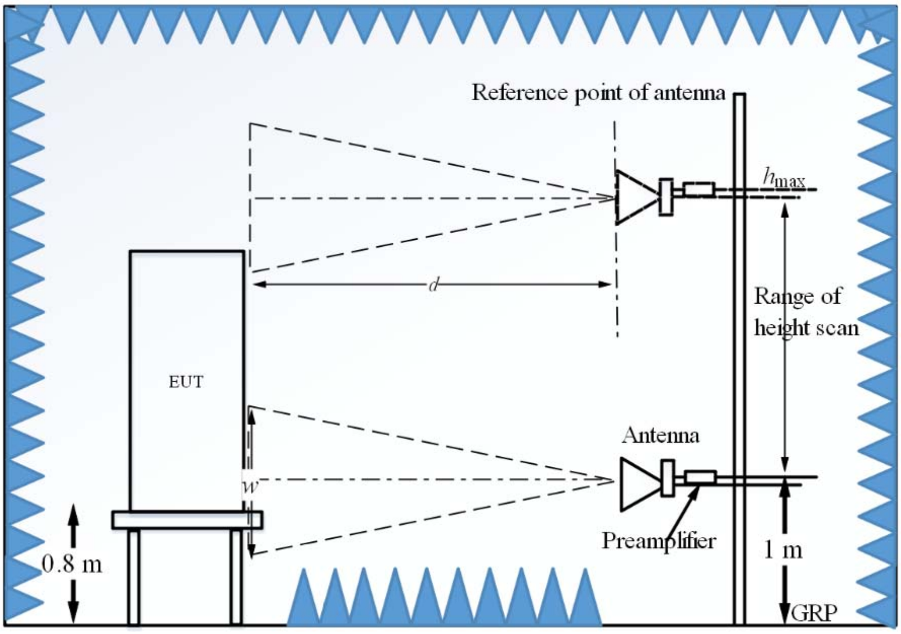

Figure C.3: *w* does not encompass EUT height (height scan required)

With using the linearly polarized antennas, the lobe width of polar angle θ_{3dB} along the vertical axis becomes smaller so to cause the dimension Δ smaller with increasing frequency. General information of different antennas commonly used in 6 GHz - 40 GHz test are showed in Annex A. At a measuring distance *d*, the height scan step of the receiving antenna shall be less or equal Δ.

The requirement for height scanning as given in EN 55032 [1] is based on the concept that the EUT emissions are directional in nature and the receiving antenna has to move to ensure the it captures such emissions.

As stated earlier as frequencies increase the radiation lobes from the EUT become narrower and can be highly directional therefore the concept of the antenna beamwidth encompassing the EUT is not valid for determining the need to height scan the measurement antenna. It is in fact the reverse of this. It is the beamwidth and direction of the EUT emission that is the determining factor and these are unknown.

For example, if the beamwidth of an EUT emission is 10 degrees, has a directional angle of +45 degrees above horizontal from the centre of the EUT then at a measurement distance of 3 m the measurement antenna will need to be raised by at least 2,5 m before the measurement antenna will capture the main lobe of the emission. The 3 dB width in height of the emission at a distance of 3 m will be approximately 1 m so a fine step will be required to capture the peak level of the lobe or an error of up to 3 dB may occur. See Figure C.4. Equally the beamwidth of the measurement antenna will also need to be sufficiently large otherwise boresighting of the antenna may also be required, however boresighting complicates the measurement process. The height scan of measurement antenna shall be from 1 m to 4 m.

These factors become more significant as frequencies increase above 6 GHz and the measurement antenna beamwidths reduce as shown in Annex A.

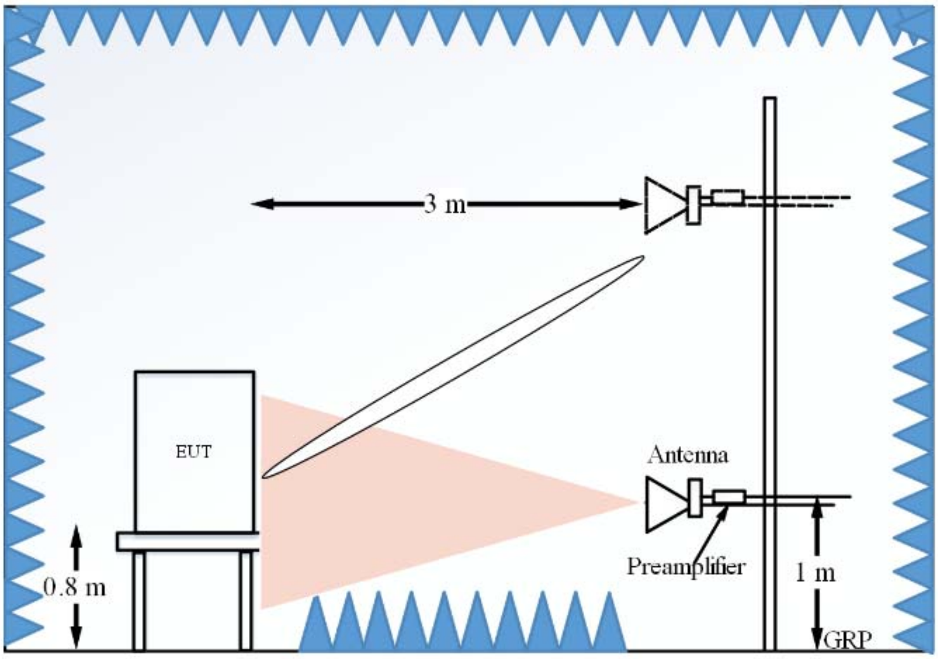

Figure C.4: Height scanning

History

Document history		
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