

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE



INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE  
COMITÉ INTERNATIONAL SPÉCIAL DES PERTURBATIONS RADIOÉLECTRIQUES

BASIC EMC PUBLICATION  
PUBLICATION FONDAMENTALE EN CEM

**Specification for radio disturbance and immunity measuring apparatus and methods –  
Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements**

**Spécifications des méthodes et des appareils de mesure des perturbations radioélectriques et de l'immunité aux perturbations radioélectriques –  
Partie 2-3: Méthodes de mesure des perturbations et de l'immunité – Mesures des perturbations rayonnées**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION  
INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

**SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY  
MEASURING APPARATUS AND METHODS –**

**Part 2-3: Methods of measurement of disturbances and immunity –  
Radiated disturbance measurements**

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International Standard CISPR 16-2-3 has been prepared by CISPR subcommittee A: Radio-interference measurements and statistical methods.

This third edition of CISPR 16-2-3 cancels and replaces the second edition published in 2006. It is a technical revision.

This edition includes the following significant technical changes with respect to the previous edition: addition of the measurand for radiated emissions measurements in an OATS and a SAC in the range of 30 MHz to 1 000 MHz, and addition of a new normative annex on the determination of suitability of spectrum analysers for compliance tests. Also, numerous maintenance items are addressed to make the standard current with respect to other parts of the CISPR 16 series.

It has the status of a basic EMC publication in accordance with IEC Guide 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*.

The text of this standard is based on the following documents:

|                  |                  |
|------------------|------------------|
| FDIS             | Report on voting |
| CISPR/A/886/FDIS | CISPR/A/892/RVD  |

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the CISPR 16 series, published under the general title *Specification for radio disturbance and immunity measuring apparatus and methods*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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## SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

### Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements

#### 1 Scope

This part of CISPR 16 specifies the methods of measurement of radiated disturbance phenomena in the frequency range of 9 kHz to 18 GHz. The aspects of measurement uncertainty are specified in CISPR 16-4-1 and CISPR 16-4-2.

NOTE In accordance with IEC Guide 107, CISPR 16-2-3 is a basic EMC publication for use by product committees of the IEC. As stated in Guide 107, product committees are responsible for determining the applicability of the EMC standard. CISPR and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular EMC tests for specific products.

#### 2 Normative references

The following referenced documents are indispensable for the application 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.

CISPR 14-1:2005, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

CISPR 16-1-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

CISPR 16-1-2:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Conducted disturbances*  
Amendment 1 (2004)  
Amendment 2 (2006)

CISPR 16-1-4:2010, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Radiated disturbances*

CISPR 16-2-1:2008, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements*

CISPR 16-4-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-1: Uncertainties, statistics and limit modelling – Uncertainties in standardized EMC tests*

CISPR 16-4-2, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Uncertainty in EMC measurements*

CISPR 16-4-5, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-5: Uncertainties, statistics and limit modelling – Conditions for the use of alternative test methods*

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

Amendment 1 (1997)

Amendment 2 (1998)

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*  
Amendment 1 (2007)

IEC 61000-4-20, *Electromagnetic compatibility (EMC) – Part 4-20: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161, as well as the following apply.

#### 3.1

##### **absorber-lined OATS/SAC**

OATS or SAC with ground plane partially covered by RF-energy absorbing material

#### 3.2

##### **ancillary equipment**

transducers (e.g. current and voltage probes and artificial networks) connected to a measuring receiver or (test) signal generator and used in the disturbance signal transfer between the EUT and the measuring or test equipment

#### 3.3

##### **antenna beam**

main lobe of the antenna pattern (gain pattern) of the receive antenna (usually the direction with maximum sensitivity or lowest antenna factor) that is directed towards the EUT

#### 3.4

##### **antenna beamwidth**

angle between the half-power (3 dB) points of the main lobe of the antenna beam, when referenced to the maximum power of the main lobe. It may be expressed for the *H* plane or for the *E* plane of the antenna

NOTE Antenna beamwidth is expressed in degrees.

#### 3.5

##### **associated equipment**

##### **AE**

apparatus, that is not part of the system under test, but needed to help exercise the EUT

#### 3.6

##### **auxiliary equipment**

##### **AuxEq**

peripheral equipment that is part of the system under test

#### 3.7

##### **basic standard**

standard that has a wide-ranging coverage or contains general provisions for one particular field

NOTE A basic standard may function as a standard for direct application or as a basis for other standards.

[ISO/IEC Guide 2, definition 5.1]

### 3.8

#### **coaxial cable**

cable containing one or more coaxial lines, typically used for a matched connection of ancillary equipment to the measuring equipment or (test-) signal generator providing a specified characteristic impedance and a specified maximum allowable cable transfer impedance

### 3.9

#### **common-mode absorption device**

##### **CMAD**

device that may be applied on cables leaving the test volume in radiated emission measurements to reduce the compliance uncertainty

[CISPR 16-1-4, 3.1.4]

### 3.10

#### **conformity assessment**

demonstration that specified requirements relating to a product, process, system, person or body are fulfilled

NOTE The subject field of conformity assessment includes activities defined elsewhere in ISO/IEC 17000:2004, such as testing, inspection and certification, as well as the accreditation of conformity assessment bodies.

[ISO/IEC 17000:2004, 2.1, modified]

### 3.11

#### **continuous disturbance**

RF disturbance with duration of more than 200 ms at the IF-output of a measuring receiver that causes a deflection on the meter of a measuring receiver in quasi-peak detection mode, and that does not decrease immediately

[IEC 60050-161:1990, 161-02-11, modified]

### 3.12

#### **(electromagnetic) emission**

phenomenon by that electromagnetic energy emanates from a source

[IEC 60050-161:1990, 161-01-08]

### 3.13

#### **emission limit** (from a disturbing source)

specified maximum emission level of a source of electromagnetic disturbance

[IEC 60050-161:1990, 161-03-12]

### 3.14

#### **equipment-under-test**

##### **EUT**

equipment (devices, appliances and systems) subjected to EMC (emission) compliance (conformity assessment) tests

### 3.15

#### **fully-anechoic room**

##### **FAR**

shielded enclosure, the internal surfaces of which are lined with radio-frequency-energy absorbing material (i.e. RF absorber) that absorbs electromagnetic energy in the frequency range of interest

**3.16****loop-antenna system****LAS**

antenna system consisting of three orthogonally-oriented loop antennas that are used to measure the three orthogonal magnetic dipole moments of an EUT located in the centre of the three loops

**3.17****measurement, scan and sweep times****3.17.1****measurement time** $T_m$ 

effective, coherent time for a measurement result at a single frequency (in some areas also called dwell time)

- for the peak detector, the effective time to detect the maximum of the signal envelope
- for the quasi-peak detector, the effective time to measure the maximum of the weighted envelope
- for the average detector, the effective time to average the signal envelope
- for the rms detector, the effective time to determine the rms of the signal envelope

**3.17.2****scan**

continuous or stepped frequency variation over a given frequency span

**3.17.3****span** $\Delta f$ 

difference between stop and start frequencies of a sweep or scan

**3.17.4****sweep**

continuous frequency variation over a given frequency span

**3.17.5****sweep or scan rate**

frequency span divided by the sweep or scan time

**3.17.6****sweep or scan time** $T_s$ 

time between start and stop frequencies of a sweep or scan

**3.17.7****observation time** $T_o$ 

sum of measurement times  $T_m$  on a certain frequency in case of multiple sweeps; if  $n$  is the number of sweeps or scans, then  $T_o = n \times T_m$

**3.17.8****total observation time** $T_{tot}$ 

effective time for an overview of the spectrum (either single or multiple sweeps); if  $c$  is the number of channels within a scan or sweep, then  $T_{tot} = c \times n \times T_m$

### 3.18

#### **measuring receiver**

instrument such as a tunable voltmeter, an EMI receiver, a spectrum analyzer or an FFT-based measuring instrument, with or without preselection, that meets the relevant parts of CISPR 16-1-1

### 3.19

#### **number of sweeps per time unit** (e.g. per second)

$n_s$

reciprocal of the sum of sweep time and retrace time, i.e.  $1 / (\text{sweep time} + \text{retrace time})$

### 3.20

#### **open-area test site**

##### **OATS**

facility used for measurements of electromagnetic fields the intention for which is to simulate a semi-free-space environment over a specified frequency range that is used for radiated emission testing of products. An OATS typically is located outdoors in an open area, and has an electrically-conducting ground plane.

### 3.21

#### **product standard**

standard that specifies requirements to be fulfilled by a product or group of products, to establish its fitness for purpose

NOTE 1 A product standard may include, in addition to the fitness-for-purpose requirements, directly or by reference, aspects such as terminology, sampling, testing, packaging and labelling and, sometimes, processing requirements.

NOTE 2 A product standard can either be complete or not, according to whether it specifies all or only a part of the necessary requirements. In this respect, one may differentiate between standards such as dimensional, material and technical delivery standards.

[ISO/IEC Guide 2, definition 5.4]

### 3.22

#### **semi-anechoic chamber**

##### **SAC**

shielded enclosure in which five of the six internal surfaces are lined with radio-frequency-energy absorbing material (i.e. RF absorber) that absorbs electromagnetic energy in the frequency range of interest, and the bottom horizontal surface is a conducting ground plane for use with OATS test set

### 3.23

#### **test configuration**

combination that gives the specified measurement arrangement of the EUT in which an emission level is measured

### 3.24

#### **weighting** (of e.g. impulsive disturbance)

pulse-repetition-frequency (PRF) dependent conversion (mostly reduction) of a peak-detected impulse voltage level to an indication that corresponds to the interference effect on radio reception

NOTE 1 For the analogue receiver, the psychophysical annoyance of the interference is a subjective quantity (audible or visual) usually not a certain number of misunderstandings of a spoken text

NOTE 2 For the digital receiver, the interference effect is an objective quantity that may be defined by the critical bit error ratio (BER) or bit error probability (BEP) for that perfect error correction can still occur or by another, objective and reproducible parameter

**3.24.1****weighted disturbance measurement**

measurement of disturbance using a weighting detector

**3.24.2****weighting characteristic**

peak voltage level as a function of PRF for a constant effect on a specific radiocommunication system, i.e. the disturbance is weighted by the radiocommunication system itself

**3.24.3****weighting detector**

detector that provides an agreed weighting function

**3.24.4****weighting factor**

value of the weighting function relative to a reference PRF or relative to the peak value

NOTE Weighting factor is expressed in dB.

**3.24.5****weighting function or weighting curve**

relationship between input peak voltage level and PRF for constant level indication of a measuring receiver with a weighting detector, i.e. the curve of response of a measuring receiver to repeated pulses

**4 Types of disturbance to be measured****4.1 General**

This clause describes the classification of different types of disturbance and the detectors appropriate for their measurement.

**4.2 Types of disturbance**

For physical and psychophysical<sup>1</sup> reasons, dependent on the spectral distribution, measuring receiver bandwidth, the duration, rate of occurrence, and degree of annoyance during the assessment and measurement of radio disturbance, distinction is made between the following types of disturbance:

- a) *narrowband continuous disturbance*, i.e. disturbance on discrete frequencies as, for example, the fundamentals and harmonics generated with the intentional application of RF energy with ISM equipment, constituting a frequency spectrum consisting only of individual spectral lines whose separation is greater than the bandwidth of the measuring receiver so that during the measurement only one line falls into the bandwidth in contrast to b);
- b) *broadband continuous disturbance*, which normally is unintentionally produced by the repeated impulses of, for example, commutator motors, and which have a repetition frequency that is lower than the bandwidth of the measuring receiver so that during the measurement more than one spectral line falls into the bandwidth; and
- c) *broadband discontinuous disturbance* is also generated unintentionally by mechanical or electronic switching procedures, for example by thermostats or programme controls with a repetition rate lower than 1 Hz (click-rate less than 30/min).

The frequency spectra of items b) and c) are characterized by having a continuous spectrum in the case of individual (single) impulses and a discontinuous spectrum in case of repeated impulses, both spectra being characterized by having a frequency range that is wider than the bandwidth of the measuring receiver specified in CISPR 16-1-1.

<sup>1</sup> Psychophysical means psychological relationship between physical stimuli and sensory response.

### 4.3 Detector functions

Depending on the types of disturbance, measurements may be carried out using a measuring receiver with:

- a) an average detector generally used in the measurement of narrowband disturbance and signals, and particularly to discriminate between narrowband and broadband disturbance;
- b) a quasi-peak detector provided for the weighted measurement of broadband disturbance for the assessment of audio annoyance to a radio listener, but also usable for narrowband disturbance;
- c) an rms-average detector provided for the weighted measurement of broadband disturbance for the assessment of the effect of impulsive disturbance to digital radio communication services but also useable for narrowband disturbance;
- d) a peak detector that may be used for either broadband or narrowband disturbance measurement.

Measuring receivers incorporating these detectors are specified in CISPR 16-1-1.

## 5 Connection of measuring equipment

Concerning the connection of measuring equipment, measuring receivers and ancillary equipment such as antennas: the connecting cable between the measuring receiver and the ancillary equipment shall be shielded and its characteristic impedance shall be matched to the input impedance of the measuring receiver. The output of the ancillary equipment shall be terminated with the prescribed impedance.

## 6 General measurement requirements and conditions

### 6.1 General

Radio disturbance measurements shall be:

- reproducible, i.e. independent of the measurement location and environmental conditions, especially ambient noise; and
- free from interactions, i.e. the connection of the EUT to the measuring equipment shall influence neither the function of the EUT nor the accuracy of the measurement equipment.

These requirements may be met by observing the following conditions:

- a) existence of a sufficient signal-to-noise ratio at the desired measurement level, e.g. the level of the relevant disturbance limit;
- b) having a defined measuring set-up, termination and operating conditions of the EUT;
- c) when using a spectrum analyzer or scanning receiver, due considerations shall be given to its particular operating and calibration requirements.

### 6.2 Disturbance not produced by the equipment under test

#### 6.2.1 General

The measurement signal-to-noise ratio with respect to ambient noise shall meet the following requirements. If the spurious noise level exceeds the required level, it shall be recorded in the test report.

#### 6.2.2 Compliance (conformity assessment) testing

A test site shall permit emissions from the EUT to be distinguished from ambient noise. The ambient noise level should preferably be 20 dB, but at least be 6 dB below the desired

measurement level. For the 6 dB condition, the apparent disturbance level from the EUT is increased by up to 3,5 dB. The suitability of the site for required ambient level may be determined by measuring the ambient noise level with the test unit in place but not operating.

In the case of compliance measurement according to a limit, the ambient noise level is permitted to exceed the preferred -6 dB level provided that the level of both ambient noise and source emanation combined does not exceed the specified limit. The EUT is then considered to meet the limit. Other actions can also be taken; for example, reduce the bandwidth for narrowband signals and/or move the antenna closer to the EUT.

NOTE If both the ambient field strength and field strength of ambient and EUT are measured separately, it may be possible to provide an estimate of the EUT field strength to a quantifiable level of uncertainty. Reference is made in this respect in Annex C of CISPR 11.

### **6.3 Measurement of continuous disturbance**

#### **6.3.1 Narrowband continuous disturbance**

The receiver shall be kept tuned to the discrete frequency under investigation, and re-tuned if the frequency fluctuates.

#### **6.3.2 Broadband continuous disturbance**

For the assessment of broadband continuous disturbance the level of which is not steady, the maximum reproducible measurement value shall be found. See 6.5.1 for further details.

#### **6.3.3 Use of spectrum analyzers and scanning receivers**

Spectrum analyzers and scanning receivers are useful for disturbance measurements, particularly in order to reduce measuring time. However, special consideration must be given to certain characteristics of these instruments, which include overload, linearity, selectivity, normal response to pulses, frequency scan rate, signal interception, sensitivity, amplitude accuracy and peak, average and quasi-peak detection. These characteristics are considered in Annex B.

### **6.4 Operating conditions of the EUT**

The EUT shall be operated under the following conditions:

#### **6.4.1 Normal load conditions**

The normal load conditions shall be as defined in the manufacturer's product specification relevant to the EUT, and for EUTs not so covered, as indicated in the manufacturer's instructions.

#### **6.4.2 The time of operation**

The time of operation shall be, in the case of EUTs with a given rated operating time, in accordance with the marking; in all other cases, the time is not restricted.

#### **6.4.3 Running-in time**

No specific running-in time, prior to testing, is given, but the EUT shall be operated for a sufficient period to ensure that the modes and conditions of operation are typical of those during the life of the equipment. For some EUTs, special test conditions may be prescribed in the relevant equipment publications.

#### 6.4.4 Supply

The EUT shall be operated from a supply having the rated voltage of the EUT. If the level of disturbance varies considerably with the supply voltage, the measurements shall be repeated for supply voltages over the range of 0,9 times to 1,1 times the rated voltage. EUTs with more than one rated voltage shall be tested at the rated voltage that causes maximum disturbance.

#### 6.4.5 Mode of operation

The EUT shall be operated under practical conditions that cause the maximum disturbance at the measurement frequency.

### 6.5 Interpretation of measuring results

#### 6.5.1 Continuous disturbance

- a) If the level of disturbance is not steady, the reading on the measuring receiver is observed for at least 15 s for each measurement; the highest readings shall be recorded, with the exception of any isolated clicks, which shall be ignored (see 4.2 of CISPR 14-1).
- b) If the general level of the disturbance is not steady, but shows a continuous rise or fall of more than 2 dB in the 15 s period, then the disturbance voltage levels shall be observed for a further period and the levels shall be interpreted according to the conditions of normal use of the EUT, as follows:
  - 1) if the EUT is one that may be switched on and off frequently, or the direction of rotation of which can be reversed, then at each frequency of measurement the EUT should be switched on or reversed just before each measurement, and switched off just after each measurement. The maximum level obtained during the first minute at each frequency of measurement shall be recorded;
  - 2) if the EUT is one that in normal use runs for longer periods, then it should remain switched on for the period of the complete test, and at each frequency the level of disturbance shall be recorded only after a steady reading (subject to the provision that item a) has been obtained).
- c) If the pattern of the disturbance from the EUT changes from a steady to a random character part way through a test, then that EUT shall be tested in accordance with item b).
- d) Measurements are taken throughout the complete spectrum and are recorded at least at the frequency with maximum reading and as required by the relevant CISPR publication.

#### 6.5.2 Discontinuous disturbance

There is currently no requirement for the measurement of radiated discontinuous disturbances.

### 6.6 Measurement times and scan rates for continuous disturbance

#### 6.6.1 General

For both manual measurements and automated or semi-automated measurements, measurement times and scan rates of measuring and scanning receivers shall be set so as to measure the maximum emission. Especially, where a peak detector is used for pre-scans, the measurement times and scan rates have to take the timing of the emission under test into account. More detailed guidance about performing automated measurements can be found in Clause 8.

### 6.6.2 Minimum measurement times

Clause B.7 provides a table of the minimum sweep times or the fastest – practically achievable – scan rates. From that table, the minimum scan times for measurements over a complete CISPR band have been derived in the following Table 1.

**Table 1 – Minimum scan times for the three CISPR bands with peak and quasi-peak detectors**

| Frequency band |                     | Scan time $T_s$ for peak detection | Scan time $T_s$ for quasi-peak detection |
|----------------|---------------------|------------------------------------|------------------------------------------|
| A              | 9 kHz to 150 kHz    | 14,1 s                             | 2 820 s = 47 min                         |
| B              | 0,15 MHz to 30 MHz  | 2,985 s                            | 5 970 s = 99,5 min = 1 h 39 min          |
| C and D        | 30 MHz to 1 000 MHz | 0,97 s                             | 19 400 s = 323,3 min = 5 h 23 min        |

The scan times in Table 1 apply to the measurement of CW signals. Depending on the type of disturbance, the scan time may have to be increased – even for quasi-peak measurements. In extreme cases, the measurement time  $T_m$  at a certain frequency may have to be increased to 15 s, if the level of the observed emission is not steady (see 6.5.1). However isolated clicks are excluded.

Scan rates and measurement times for use with the average detector are given in Annex C.

Most product standards call out quasi-peak detection for compliance measurements, which can be very time-consuming if time-saving procedures are not applied (see Clause 8). Before timesaving procedures can be applied, the emission has to be detected using a pre-scan. To ensure that, e.g. intermittent signals are not missed during an automated scan, the considerations in 6.6.3 to 6.6.5 shall be accounted for.

### 6.6.3 Scan rates for scanning receivers and spectrum analyzers

One of two conditions needs to be met to ensure that signals are not missed during automated scans over frequency spans:

- for a single sweep: the measurement time at each frequency must be larger than the intervals between pulses for intermittent signals;
- for multiple sweeps with maximum hold: the observation time at each frequency should be sufficient for intercepting intermittent signals.

The frequency scan rate is limited by the resolution bandwidth of the instrument and the video bandwidth setting. If the scan rate is chosen too fast for the given instrument state, erroneous measurement results will be obtained. Therefore, a sufficiently long sweep time needs to be chosen for the selected frequency span. Intermittent signals may be intercepted by either a single sweep with sufficient observation time at each frequency or by multiple sweeps with maximum hold. Usually for an overview over unknown emissions, the latter will be highly efficient: as long as the spectrum response changes, there may still be intermittent signals to discover. The observation time shall be selected according to the periodicity at which interfering signals occur. In some cases, the sweep time may have to be varied in order to avoid synchronization effects.

When determining the minimum sweep time for measurements with a spectrum analyzer or scanning EMI receiver, based on a given instrument setting and using peak detection, two different cases have to be distinguished. If the video bandwidth is selected to be **wider** than the resolution bandwidth, the following expression can be used to calculate the minimum sweep time:

$$T_{s \min} = k \times \frac{\Delta f}{B_{\text{res}}^2} \quad (1)$$

where

- $T_{s \min}$  is the minimum sweep time,
- $\Delta f$  is the frequency span,
- $B_{\text{res}}$  is resolution bandwidth, and
- $k$  is a constant of proportionality, related to the shape of the resolution filter; this constant assumes a value between 2 and 3 for synchronously-tuned, near-Gaussian filters. For nearly rectangular, stagger-tuned filters,  $k$  has a value between 10 and 15.

If the video bandwidth is selected to be equal to or smaller than the resolution bandwidth, the following expression can be used to calculate the minimum sweep time:

$$T_{s \min} = k \times \frac{\Delta f}{B_{\text{res}} B_{\text{video}}} \quad (2)$$

where  $B_{\text{video}}$  is the video bandwidth.

Most spectrum analyzers and scanning EMI receivers automatically couple the sweep time to the selected frequency span and the bandwidth settings. Sweep time is adjusted to maintain a calibrated display. The automatic sweep time selection can be overridden if longer observation times are required, e.g. to intercept slowly varying signals.

In addition, for repetitive sweeps, the number of sweeps per second will be determined by the sweep time  $T_{s \min}$  and the retrace time (time needed to retune the local oscillator and to store the measurement results, etc.).

#### 6.6.4 Scan times for stepping receivers

Stepping EMI receivers are consecutively tuned to single frequencies using predefined step sizes. While covering the frequency range of interest in discrete frequency steps, a minimum dwell time at each frequency is required for the instrument to accurately measure the input signal.

For the actual measurement, a frequency step size of roughly 50 % of the resolution bandwidth used or less (depending on the resolution filter shape) is required to reduce measurement uncertainty for narrowband signals due to the step-width. Under these assumptions the scan time  $T_{s \min}$  for a stepping receiver can be calculated using the following equation:

$$T_{s \min} = T_{m \min} \times \frac{\Delta f}{0,5 B_{\text{res}}} \quad (3)$$

where  $T_{m \min}$  is the minimum measurement (dwell) time at each frequency

In addition to the measurement time, some time has to be taken into consideration for the synthesizer to switch to the next frequency and for the firmware to store the measurement result, which in most measuring receivers is automatically done so that the selected measurement time is the effective time for the measurement result. Furthermore, the selected detector, e.g. peak or quasi-peak, determines this time period as well.

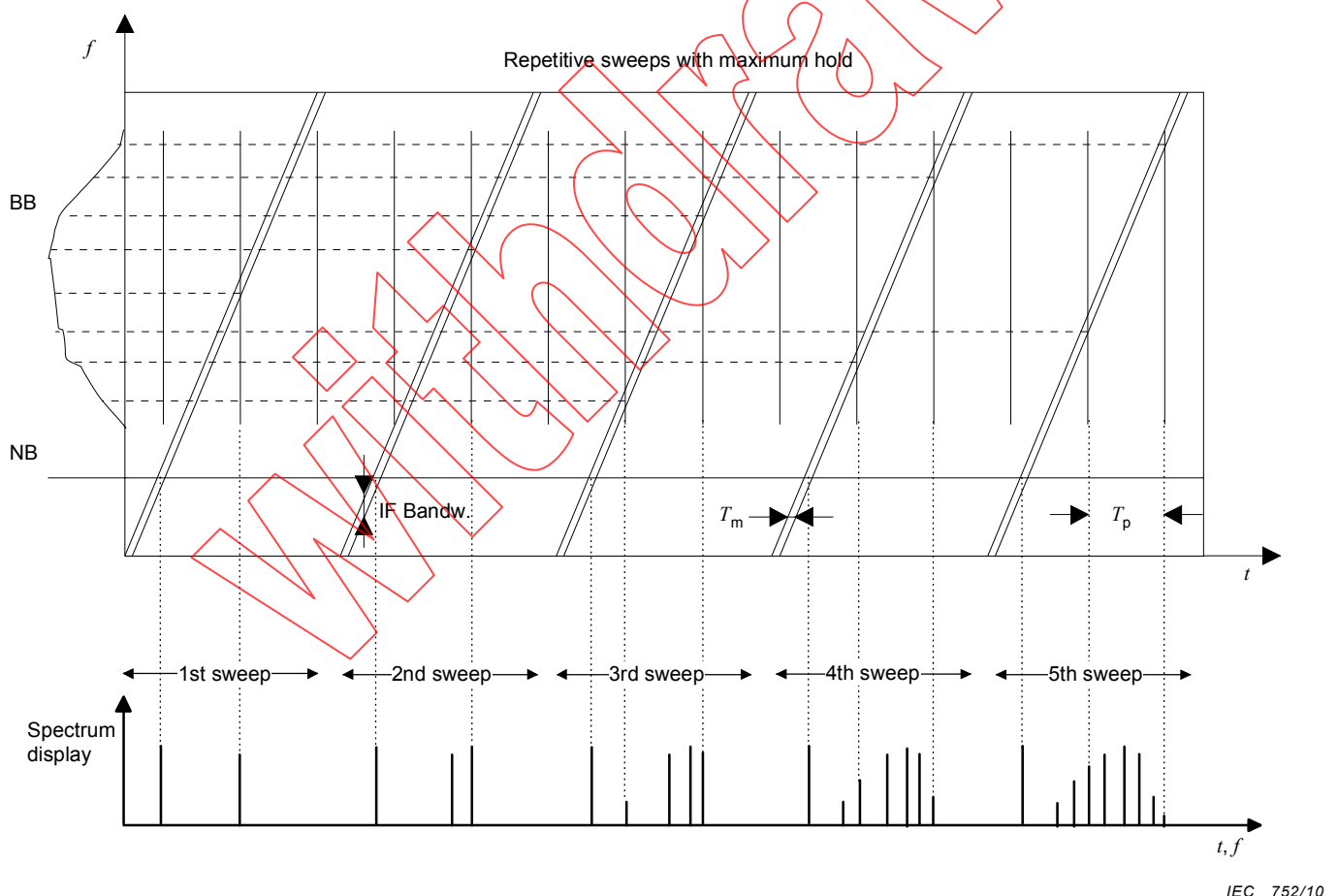
For purely broadband emissions, the frequency step size may be increased. In this case, the objective is to find the maxima of the emission spectrum only.

### 6.6.5 Strategies for obtaining a spectrum overview using the peak detector

For each pre-scan measurement, the probability of intercepting all critical spectral components of the EUT spectrum shall be equal to 100 % or as close to 100 % as possible. Depending on the type of measuring receiver and the characteristics of the disturbance, that may contain narrowband and broadband components, two general approaches are proposed:

- stepped scan: the measurement (dwell) time shall be long enough at each frequency to measure the signal peak, e.g. for an impulsive signal the measurement (dwell) time should be longer than the reciprocal of the repetition frequency of the signal.
- swept scan: the measurement time must be larger than the intervals between intermittent signals (single sweep) and the number of frequency scans during the observation time should be maximized to increase the probability of signal interception.

Figure 1, Figure 2, and Figure 3 show examples of the relationship between various time-varying emission spectra and the corresponding display on a measuring receiver. In each case, the upper part of the figure shows the position of the receiver bandwidth as it either sweeps or steps through the spectrum.

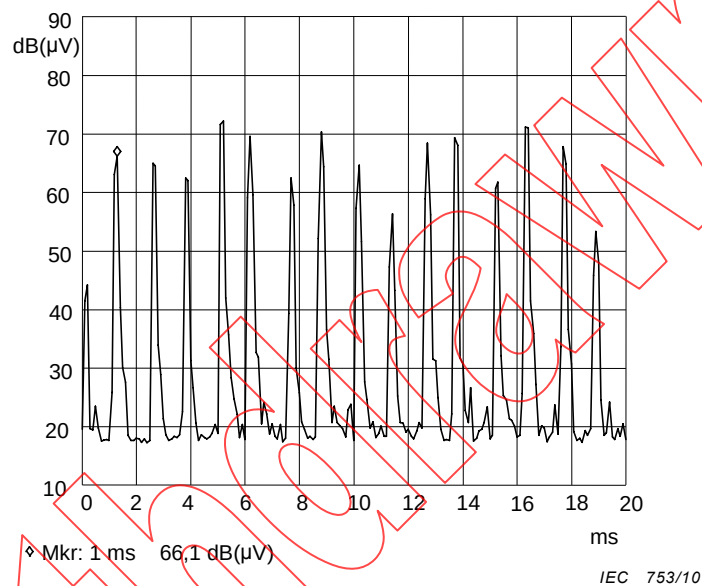


$T_o$  is the pulse-repetition interval of the impulsive signal. A pulse occurs at each vertical line of the spectrum-vs.-time display (upper part of the figure).

**Figure 1 – Measurement of a combination of a CW signal (NB) and an impulsive signal (BB) using multiple sweeps with maximum hold**

If the type of emission is unknown, multiple sweeps with the shortest possible sweep time and peak detection facilitate determining the spectrum envelope. A short single sweep is sufficient to measure the continuous narrowband signal content of the EUT spectrum. For continuous broadband and intermittent narrowband signals, multiple sweeps at various scan rates using a “maximum hold” function may be necessary to determine the spectrum envelope. For low repetition impulsive signals, many sweeps will be necessary to fill up the spectrum envelope of the broadband component.

The reduction of measurement time requires a timing analysis of the signals to be measured. This can be done either with a measuring receiver that provides a graphical signal display, used in zero-span mode or using an oscilloscope connected to the IF or video output of the receiver, and with an example shown in Figure 2.

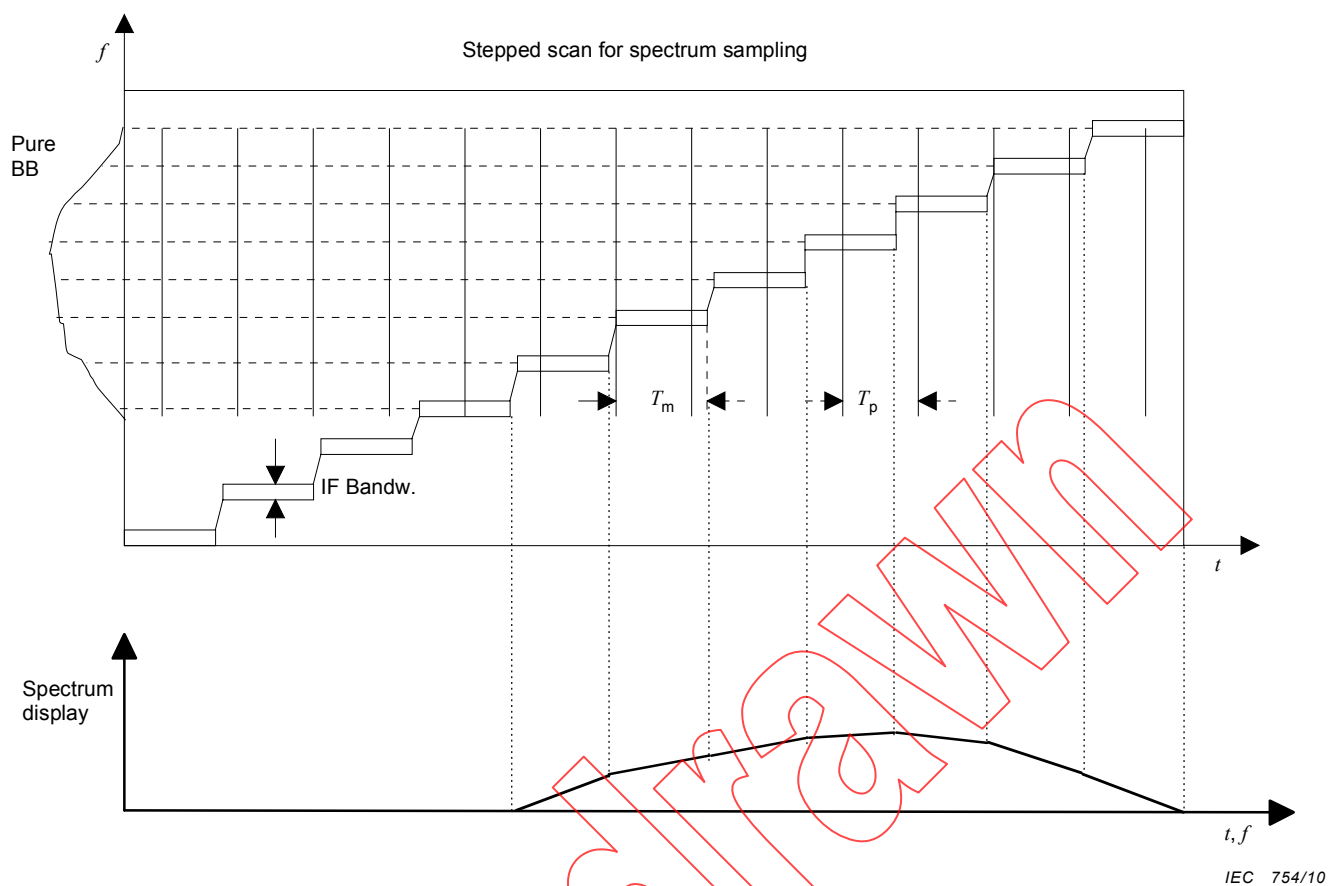


NOTE Disturbance from a d.c. collector motor; due to the number of collector segments, the pulse repetition frequency is high (approximately 800 Hz) and the pulse amplitude varies considerably. Therefore for this example, the recommended measurement (dwell) time with the peak detector is > 10 ms.

**Figure 2 – Example of a timing analysis**

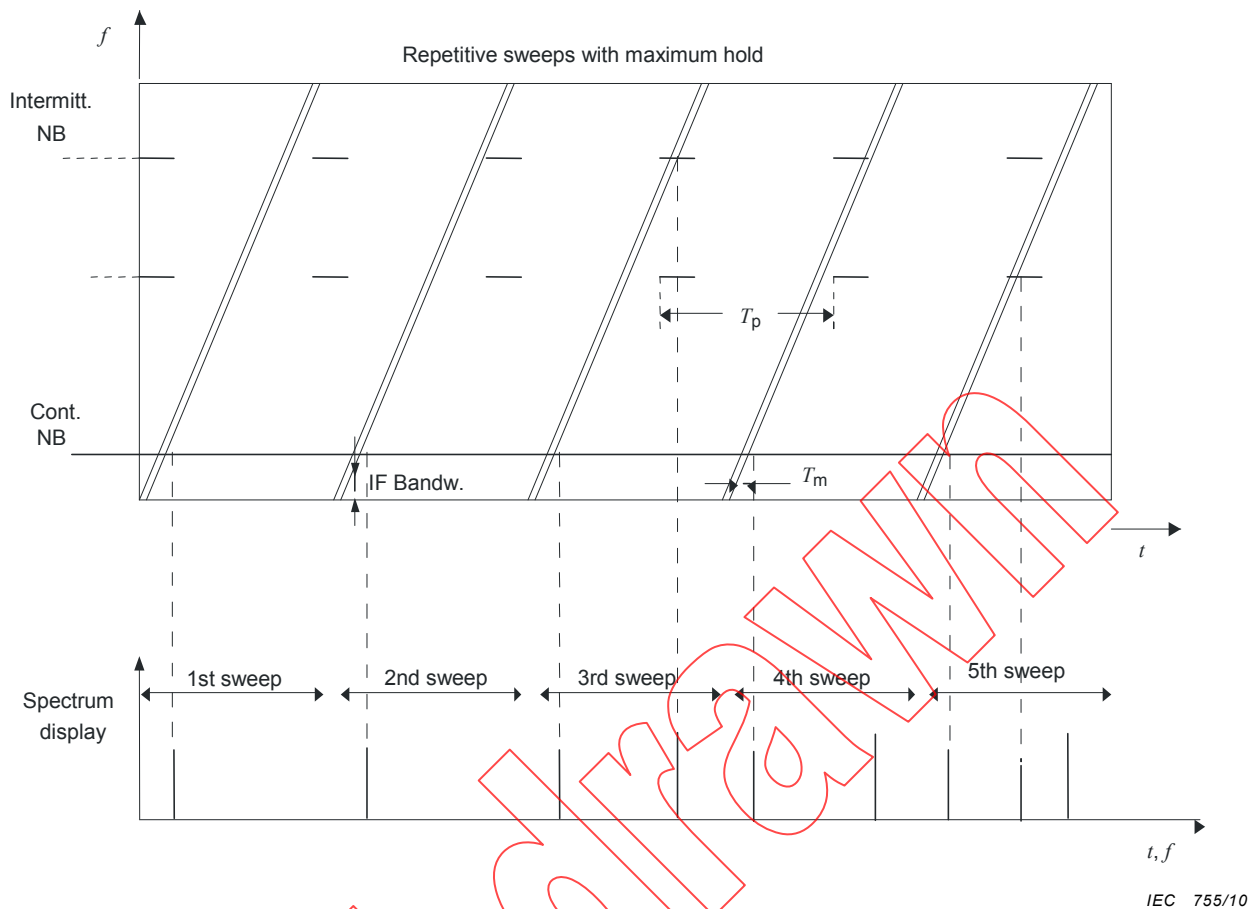
From such a timing analysis, pulse durations and pulse repetition frequencies can be determined and scan rates or dwell times selected, and according to the following:

- for **continuous unmodulated narrowband** disturbances, the fastest scan time possible for the selected instrument settings may be used;
- for **pure continuous broadband** disturbances, e.g. from ignition motors, arc welding equipment, and collector motors, a stepped scan (with peak or even quasi-peak detection) for sampling of the emission spectrum may be used. In this case the knowledge of the type of disturbance is used to draw a polyline (piecewise) curve as the spectrum envelope (see Figure 3). The step size shall be chosen so that no significant variations in the spectrum envelope are missed. A single swept measurement, if performed slowly enough, will also yield the spectrum envelope;
- for **intermittent narrowband** disturbances with unknown frequencies either fast short sweeps involving a “maximum hold” function (see Figure 4) or a slow single sweep may be used. A timing analysis may be required prior to the actual measurement to ensure proper signal interception.
- **intermittent broadband** disturbances shall be measured with discontinuous disturbance analysis procedures, as described in CISPR 16-1-1.



NOTE The measurement (dwell) time  $T_m$  shall be longer than the pulse repetition interval  $T_p$ , which is the inverse of the pulse repetition frequency.

**Figure 3 – A broadband spectrum measured with a stepped receiver**



NOTE 1 The number of sweeps required or the sweep time may have to be increased, depending on pulse duration and pulse repetition interval.

NOTE 2 In this example, five sweeps are required for all spectral components to be intercepted.

**Figure 4 – Intermittent narrowband disturbances measured using fast short repetitive sweeps with maximum hold function to obtain an overview of the emission spectrum**

## 7 Measurement of radiated disturbances

### 7.1 Introductory remarks

This clause sets forth the general procedures for the measurement of the field strength of radio disturbance produced by devices and systems. Experience with radiated disturbance measurements is less extensive than that of voltage measurements. The radiated disturbance measurement procedures are therefore open to revision and extension as knowledge and experience are accumulated. In particular, attention shall be given to the effect of leads and cables associated with the EUT. Table 2 provides a summary list of CISPR radiated emission test sites and test methods and the related cross-references to subclauses within this document or to other documents.

For some products, it may be required to measure the electric, the magnetic, or both components of the radiated disturbance. Sometimes a measurement of a quantity related to radiated power is more appropriate. Normally measurements should be made of both the horizontal and vertical components of the disturbance with respect to the reference ground plane. The results of measurements of either the electric or magnetic components may be expressed in peak, quasi-peak, average or rms values.

The magnetic component of the disturbance is normally measured at frequencies up to 30 MHz. In magnetic field measurements only the horizontal component of the field at the position of the receiving antenna is measured when using the distant antenna procedure. If the loop antenna system (LAS) is used, the three orthogonal magnetic dipole moments of the EUT are measured. (Note that in the single antenna method, the horizontal component of the field at the position of the antenna is determined by the horizontal and vertical dipole moments of the EUT because reflection plays a part.)

**Table 2 – Applicable frequency ranges and document references for CISPR radiated emission test sites and test methods**

| Site / method         | 9 kHz to 30 MHz | 30 MHz to 1 000 MHz      | 1 GHz to 18 GHz |
|-----------------------|-----------------|--------------------------|-----------------|
| Outdoor site          | tbd             | 7.3.8                    | n/a             |
| LAS                   | 7.2             | n/a                      | n/a             |
| OATS or SAC           | tbd             | 7.3                      | n/a             |
| FAR                   | n/a             | 7.4                      | 7.6             |
| Common RE/RI          | n/a             | 7.5<br>(RI start 80 MHz) | n/a             |
| Absorber-lined OATS   | n/a             | n/a                      | 7.6             |
| In-situ               | 7.7.2           | 7.7.3, 7.7.4.2           | 7.7.3, 7.7.4.3  |
| Substitution          | n/a             | 7.8                      | 7.8             |
| Reverberation chamber | n/a             | 7.9<br>(Start 80 MHz)    | 7.9             |
| TEM waveguide         | IEC 61000-4-20  | 7.10                     | 7.10            |

n/a = not applicable; tbd = to be determined or is under consideration

## 7.2 Loop-antenna system measurements (9 kHz to 30 MHz)

### 7.2.1 General

The loop antenna system (LAS) considered in this subclause is suitable for indoor measurement of the magnetic field strength emitted by a single EUT in the frequency range 9 kHz to 30 MHz. The magnetic field strength is measured in terms of the currents induced into the LAS by the magnetic disturbance field of the EUT. The LAS shall be validated regularly using the method described in CISPR 16-1-4. CISPR 16-1-4 also gives a complete description of the LAS and a relation between the measuring results obtained with the LAS and those obtained as described in this subclause.

### 7.2.2 General measurement method

Figure 5 shows the general concept of measurements made with the LAS. The EUT is placed in the centre of the LAS. The current induced by the magnetic field from the EUT into each of the three large loop antennas of the LAS is measured by connecting the current probe of the large loop antenna to a measuring receiver (or equivalent). During the measurements, the EUT remains in a fixed position.

The currents in the three large loop antennas, originating from the three mutually orthogonal magnetic field components, are measured in sequence. Each current level measured shall comply with the emission limit, expressed in dB(μA), as specified in the product standard. The emission limit shall apply for an LAS having large loop antennas with the standardized diameter of 2 m.

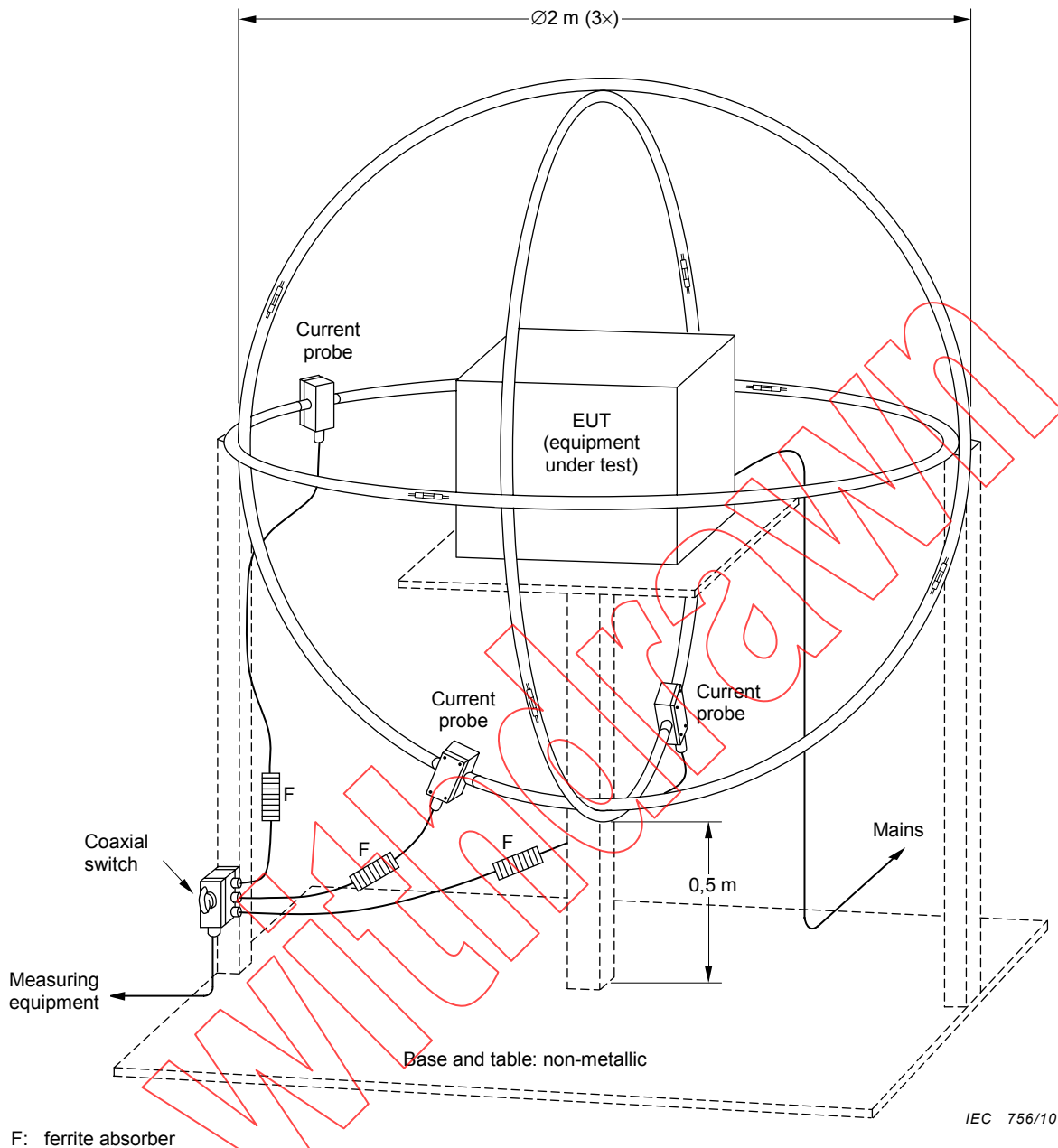


**Figure 5 – Concept of magnetic field induced current measurements made with the loop antenna system**

### 7.2.3 Test environment

The distance between the outer perimeter of the LAS and nearby objects, such as floor and walls, shall be at least 0,5 m. The currents induced in the LAS by an RF ambient field shall be judged in accordance with CISPR 16-1-4.

### 7.2.4 Configuration of the equipment under test

To avoid unwanted capacitive coupling between the EUT and the LAS, the maximum dimensions of the EUT shall allow a distance of at least 0,20 m between the EUT and the standardized 2 m large loop antennas of the LAS.

The position of the mains lead shall be optimized for maximum current induction. In general, this position will not be critical when the EUT complies with the conducted emission limit.

In case of a large EUT, the diameter of the loop antennas of the LAS may be increased up to 4 m. In that case:

- a) the current values measured shall be corrected in accordance with B.6 of CISPR 16-1-2; and
- b) the maximum dimensions of the EUT shall allow a distance between the EUT and the large loops of at least  $(0,1 \times D)$  m, where  $D$  is the diameter of the non-standardized loop.

### 7.2.5 Measurement uncertainty for LAS

General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1.

## 7.3 Open-area test site or semi-anechoic chamber measurements (30 MHz to 1 GHz)

### 7.3.1 Measurand

The quantity to be measured is the maximum electric field strength emitted by the EUT as a function of horizontal and vertical polarization and at heights between 1 m and 4 m, and at a horizontal distance of 10 m from the EUT, over all angles in the azimuth plane. This quantity shall be determined with the following provisions:

- a) the frequency range of interest is 30 MHz to 1 000 MHz;
- b) the quantity shall be expressed in terms of field strength units that correspond with the units used to express the limit levels for this quantity;
- c) a SAC/OATS measurement site and positioning table shall be used that complies with the applicable CISPR validation requirements;
- d) a measuring receiver compliant with CISPR 16-1-1 shall be used;
- e) the use of alternative measurement distances, such as 3 m or 30 m instead of 10 m, shall be considered as alternative measurement methods;
- f) the measurement distance is the horizontal projection of the distance between the boundary of the EUT and the antenna reference point to the ground plane;
- g) the EUT is configured and operated in accordance with the CISPR specifications;
- h) free-space antenna factors shall be used.

The measurand  $E$  is derived from the maximum voltage reading  $V_r$  by using the free-space antenna factor  $F_a$ :

$$E = V_r + A_c + F_a \quad (4)$$

where

- $E$  is the field strength in dB( $\mu$ V/m) as in the measurand description;
- $V_r$  is the maximum received voltage in dB( $\mu$ V) using the procedure as in the measurand description;
- $A_c$  is the loss in dB of the measuring cable between antenna and receiver;
- $F_a$  is the free-space antenna factor of the receive antenna in dB( $m^{-1}$ ).

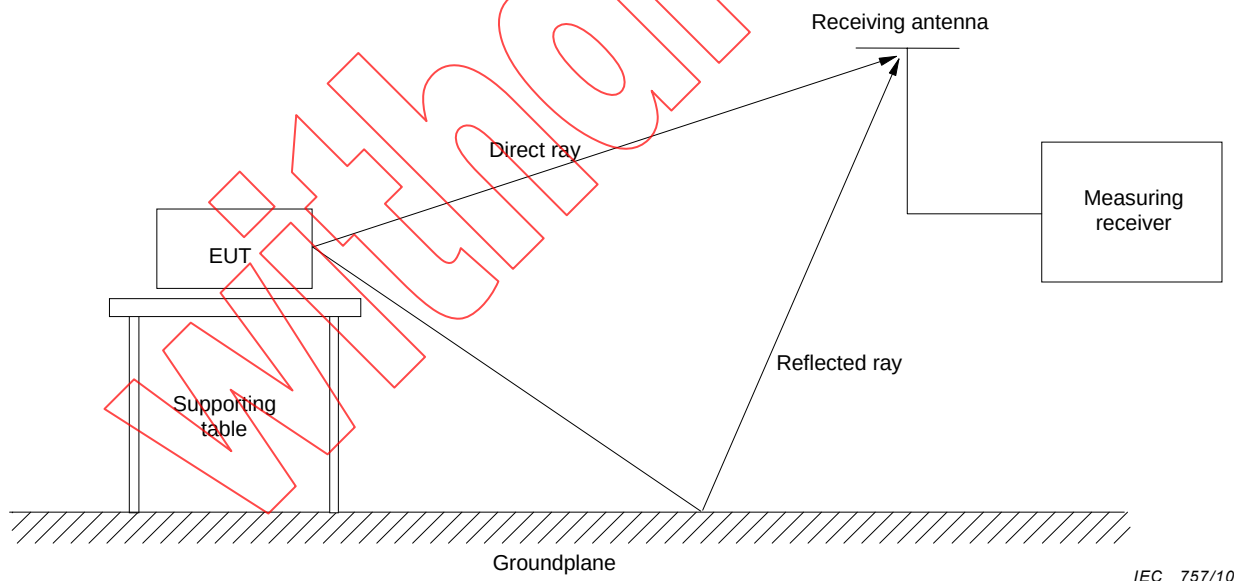
NOTE Free-space antenna factors are used as a figure of merit for the antenna. It should be noted the field strength is measured above a ground plane, not in a free-space environment.

### 7.3.2 Test site requirements

The test site shall conform to the relevant specifications of CISPR 16-1-4 for its physical and electrical properties, and for its validation.

### 7.3.3 General measurement method

Figure 6 shows the concept of measurements made on an open-area test site (OATS) or in a semi-anechoic chamber (SAC) with the direct and ground reflected rays arriving at the receiving antenna.



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**Figure 6 – Concept of electric field strength measurements made on an open-area test site (OATS) or semi-anechoic chamber (SAC) showing the direct and reflected rays arriving at the receiving antenna**

The EUT is configured at a specified height above the ground plane and configured to represent normal operating conditions. The antenna is positioned at the specified separation distance. The EUT is rotated in the horizontal plane and the maximum reading noted. The height of the antenna is adjusted so that the direct and reflected rays approach or meet in-phase addition. The procedural steps may be interchanged and may need to be repeated to find the maximum disturbance. For practical reasons, the height variation is restricted, and, therefore, perfect in-phase addition may not be achieved.

### 7.3.4 Measurement distance

An EUT subject to a radiated disturbance limit at a specified distance should be measured at that distance unless to do so would be impractical because of equipment size, etc. The measurement distance is the distance between the projection of closest point of the EUT to the antenna and the projection of the calibration reference point of the antenna on the ground plane. If the antenna reference point is not specified in the antenna calibration report, for log-periodic antennas the reference point is a point along the horizontal antenna boom midway between the dipole elements that correspond to a half wavelength at the centre frequency of antenna frequency range.

NOTE The centre frequency is defined by:  $\log(f_{\text{centre}}) = (\log f_{\text{min}} + \log f_{\text{max}})/2$ ;  $f_{\text{centre}} = 10^{\log(f_{\text{centre}})}$ .

A distance of 10 m is preferred at most outdoor sites since at this distance the expected level of the disturbance being measured is sufficiently above the general ambient noise level to permit useful testing. Distances of less than 3 m or greater than 30 m are not generally used. If a measurement distance other than the specified distance is necessary, the results should be extrapolated using the procedures specified in the product standards. If no guidance is given, suitable justification for extrapolation shall be provided. In general, extrapolation does not follow a simple inverse distance law.

Where possible, measurement should be made in the far field. The far-field region may be defined by the following conditions. The measurement distance  $d$  is selected so that:

- $d \geq \lambda/6$ . At this distance  $E/H = Z_0 = 120 \pi \approx 377 \Omega$ , that is electrical and magnetic field strength components are perpendicular to each other, and the measurement error is in the order of 3 dB if the EUT is regarded as being a tuned dipole antenna; or
- $d \geq \lambda$ , a condition for a plane wave, where the error is in the order of 0,5 dB if the EUT is regarded as a tuned dipole antenna; or
- $d \geq 2D^2 / \lambda$ , where  $D$  is the largest dimension of either the EUT or the antenna determining the minimum aperture for the illumination of the EUT, which applies to cases, where  $D \gg \lambda$ .

### 7.3.5 Antenna height variation

For electric field-strength measurements, the antenna height above the ground plane shall be varied within a specified range to obtain the maximum reading that will occur when the direct and reflected rays are in phase. As a general rule, for measurement distances up to and including 10 m, the antenna height for electric field strength measurements shall be varied between 1 m and 4 m. At greater distances of up to 30 m, preferably the height shall be varied between 2 m and 6 m. It may be necessary to adjust the minimum antenna height above ground down to 1 m in order to maximize the reading. These height scans apply for both horizontal and vertical polarization, except that for vertical polarization, the minimum height shall be increased so that the lowest point of the antenna clears the site ground surface by at least 25 cm.

### 7.3.6 Product specification details

#### 7.3.6.1 General

In addition to specifying the detailed measurement method and the disturbance parameters to be measured, the product standards shall include other relevant details as outlined below.

#### 7.3.6.2 Test environment

The influence of the test environment shall be considered so as to ensure correct functioning of the EUT. Important parameters in the physical environment shall be specified, e.g. temperature and humidity.

The electromagnetic environment needs special consideration to ensure accurate disturbance measurements. The ambient radio noise and signal levels measured at the test site with the EUT de-energized should be at least 6 dB below the limit. It is recognized that this is not always realizable at all frequencies. However, in the event that the measured levels of the ambient plus EUT radio noise emissions are not above the limit, the EUT shall be considered to be in compliance with the limit. See 6.2.2 and Annex A for further guidance about ambient levels and resulting measurement errors.

If the ambient field-strength level at frequencies within the specified measurement ranges exceeds the limit(s), the following alternatives may be used:

- a) perform measurements at a closer distance and extrapolate results to the distance at which the limit is specified. The extrapolation formula shall be as recommended by the product standard, or shall be verified by measurements at no less than three different distances;
- b) perform measurements in critical frequency bands during hours when broadcast stations are off the air and the ambients from industrial equipment are lower;
- c) compare the amplitude of the EUT disturbance at the frequency under investigation with the amplitude of the disturbance on adjacent frequencies, in a shielded room or absorber-lined shielded room. The amplitude of the EUT disturbance at the frequency under investigation can be estimated by measuring the amplitude of the adjacent frequency disturbance and making a comparison;
- d) consider the directions of strong ambient signals in orienting the axis of an open field area test site, so that the orientation of the receiving antenna on the site discriminates against such signals as far as possible;
- e) use a narrower instrument bandwidth for narrowband disturbances from the EUT occurring near an RF ambient when both are within the standard bandwidth.

### 7.3.6.3 Configuration of equipment under test

The operating conditions of the EUT shall be specified, e.g. the characteristics of the input signals, the modes of operation, the arrangement of components, the lengths and types of interconnecting cables, etc.

The testing of individual and multi-component systems shall satisfy the following two conditions:

- a) the system is configured for use in a typical manner;
- b) the system is configured in a manner that will maximize disturbances.

The term **system** refers to the EUT in combination with the components that are connected to the EUT and all required connecting cables.

The term **configuration** refers to the orientation of the EUT, the other components of the system, the interconnecting cables, and the power mains leads that comprise the system. During all measurements, the configuration of the system shall be adjusted so that the above two conditions, the condition a) being satisfied first and followed by condition b), are fulfilled, within the guidelines described in the following paragraphs.

The term **typical** is used to describe the arrangement of how the EUT will actually be used. Guidelines for setting up a typical configuration are outlined below.

For equipment designed to be part of a multi-unit system, the EUT shall be installed in a typical system and configured in accordance with the manufacturer's instructions. It shall also be operated in a manner that is representative of the typical usage for that EUT. During all tests, the EUT and all system components shall be manipulated within the confines of typical usage to maximize each disturbance.

Interface cables shall be connected to each interface port on the EUT. The effect of varying the position of each cable shall be investigated to find the configuration that maximizes each disturbance as constrained by its typical configuration in actual use. The number of manipulations may be limited if a few such cable configurations will lead to maximum disturbances over the frequency range investigated.

Interface cables shall be of the type and length specified by the equipment manufacturer. Any excess length of each cable shall be separately bundled in a serpentine fashion at the approximate centre of the cable with the bundle 30 cm to 40 cm in length. If it is impractical to do so because of cable bulk or stiffness, or because the testing is being done at a user installation, disposition of the excess cable length is left to the discretion of the test engineer and should be noted in the test report. Different requirements for excess cabling may be specified in the product standard.

Cables shall not be placed underneath, on top of the EUT, or on system components, unless it is appropriate to do so, e.g. a cable is normally routed through overhead cable racks or under the ground plane. Cables shall be positioned adjacent to the exterior cabinets of the EUT and all system components only if typically used in that manner. The EUT should be investigated in different modes of operation.

For an EUT normally operated on top of a table, radiated emission tests should be performed with the EUT on a non-conducting table, the top of which is of suitable size. The table should be placed on a remotely controlled rotating platform constructed with non-conducting materials. The top of the rotating platform should normally be less than 0,5 m above the ground plane and the height of the table and platform together 0,8 m above the ground plane. If the rotating platform is at the same elevation as the ground plane, its surface shall be of conducting material and the 0,8 m height shall be measured with respect to the top of the rotating platform. An EUT normally placed on the floor will be tested on the floor. A flush-mounted rotating platform (turntable) is useful in this situation. An EUT that may normally be placed either on the floor or table-top shall be tested as a table-top device.

The EUT shall be grounded in accordance with the manufacturer's requirements and conditions of intended use. If the EUT is operated without a ground connection, it shall be tested ungrounded. When the EUT is furnished with a grounding terminal or internally grounded lead that is to be connected in actual installation conditions, the ground lead or connection shall be connected to a ground plane (or facility for earth ground), simulating actual installation conditions. Any internally grounded lead included in the plug end of the a.c. mains cord of the EUT shall be connected to ground through the mains power service. Except at the manufacturer's intended grounding locations, a floor standing EUT shall be insulated from the ground plane by a dielectric material with thickness of up to 15 cm.

### **7.3.7 Measurement instrumentation**

The measurement instrumentation, including antennas, shall conform to the relevant requirements in CISPR 16-1-1 and CISPR 16-1-4.

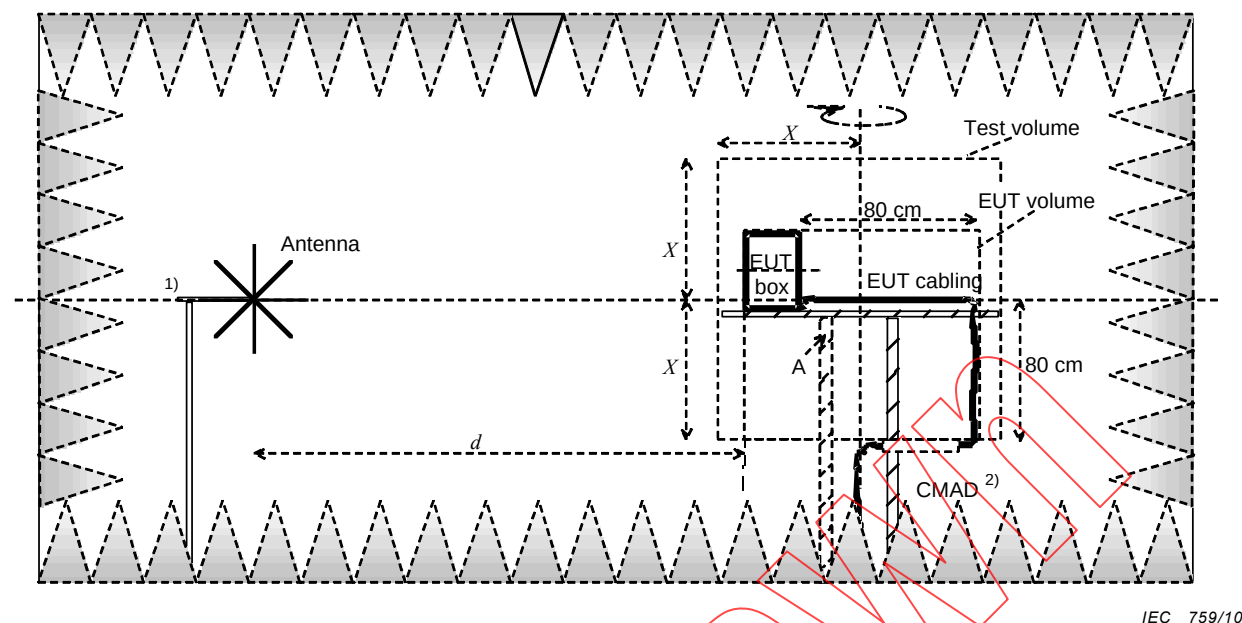
### **7.3.8 Field-strength measurements on other outdoor sites**

Outdoor test sites similar to an open-area test site but without any metal ground plane may be prescribed for some products, for practical reasons, e.g. ISM equipment and motor vehicles. The provisions given in 7.3.4 to 7.3.7 shall remain applicable.

### **7.3.9 Measurement uncertainty for OATS and SAC**

General and basic considerations about uncertainties for emission measurements are given in CISPR 16-4-1. Uncertainty aspects specific to radiated emission measurements on an OATS or SAC (30 MHz to 1 GHz) are given in CISPR 16-4-2.





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A turntable and EUT support fixture;

2X 1,5 m, 2,5 m, 5 m;

d 3 m; 5 m, or 10 m (for 3 m, 5 m, or 10 m test distance, respectively).

1) The antenna cable layout shall be the same as in the site validation procedure (see Figure 7).

2) CMADs shall be used in accordance with the applicable product standard; use (if required) shall be documented in the test report.

**Figure 8 – Typical test set-up for table-top equipment within the test volume of a FAR**

The test distance is measured from the reference point of the antenna to the boundary of the EUT. In the case of a difference between the reference point on an antenna and the phase centre, a correction factor may be applied to obtain the field strength at the test distance.

The correction factor,  $C_{dr}$ , in dB, in Equation (5), may be added to the field strength in order to reduce its uncertainty. In the calibration procedure for the antenna a phase correction factor  $C_{dr}$  is measured for each frequency. The measurement procedure is defined within the antenna calibration, or calculated from the mechanical spacing of the log-periodic elements along with the antenna factor  $F_a$ . The two factors ( $C_{dr}$ , and  $F_a$ ) in dB are added to the output voltage of the antenna to get the field strength, per Equation (6). If a phase centre correction is not included, an additional term must be included in the uncertainty budget.

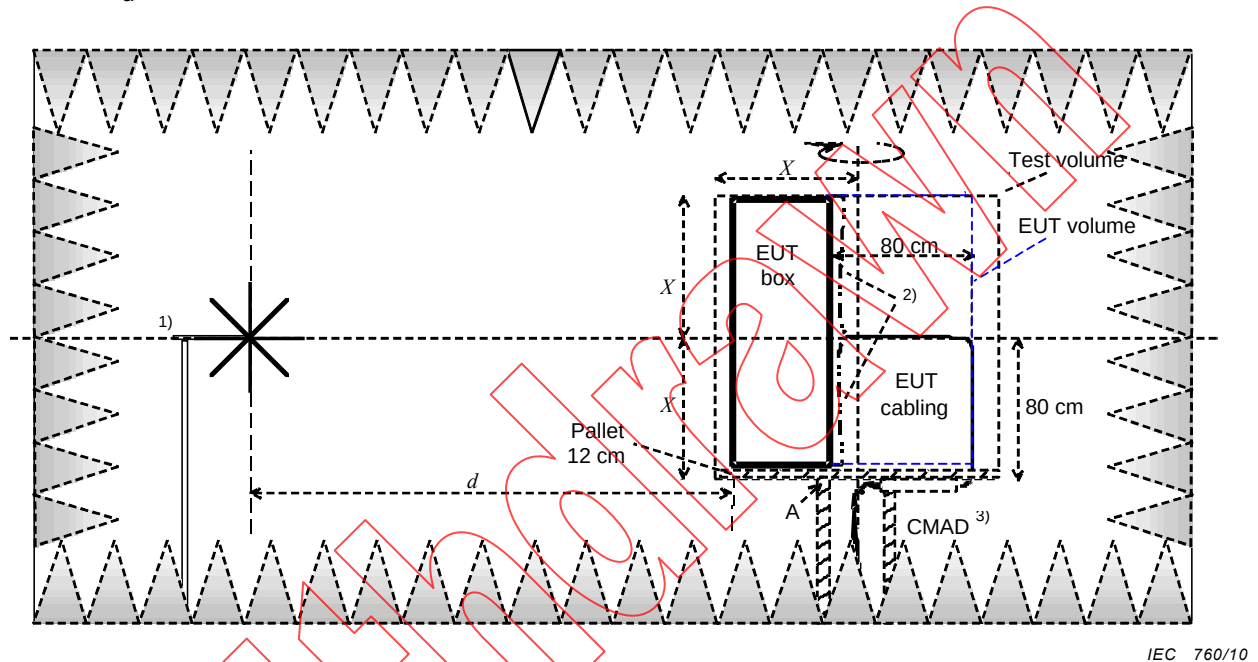
$$C_{dr} = 20 \log \left[ (d + P_f - r) / d \right] \quad (5)$$

The field strength is given by:

$$E_f = V_f + F_a + C_{dr} \quad (6)$$

where

- $f$  is the frequency (MHz);
- $d$  is the required separation point from the EUT boundary to the reference point on the antenna (m);
- $P_f$  is the phase centre position as a function of frequency, (m from tip of antenna);
- $r$  is the distance of the reference point on the antenna from the antenna tip (m);
- $E_f$  is the  $E$ -field at distance  $d$  from the source [dB( $\mu$ V/m)];
- $V_f$  is the voltage at the output of the antenna at frequency  $f$  [dB( $\mu$ V)];
- $C_{dr}$  is the phase centre correction factor (dB);
- $F_a$  is the antenna factor (free space) for the  $E$ -field at the phase centre [dB(m<sup>-1</sup>)].



- A turntable and EUT support fixture
- 2X 1,5 m, 2,5 m, 5 m
- d 3 m, 5 m or 10 m for 3 m, 5 m, or 10 m test distance, respectively

Pallet of 12 cm (10 cm to 14 cm) is a compromise between metal- and wooden ground plane.

- 1) The antenna cable layout shall be the same as in the validation procedure (see Figure 7).
- 2) The cable layout depends on the location of the cable outlets and shall be close to the surface of the housing.
- 3) CMADs are to be used in accordance with the applicable product standard; use (if required) must be documented in the test report.

**Figure 9 – Typical test set-up for floor-standing equipment within the test volume of a FAR**

#### 7.4.2 EUT position

Figure 8 and Figure 9 illustrate test set-ups in a FAR for typical table-top and floor-standing EUTs, respectively. The EUT shall be configured, installed, arranged and operated in a manner consistent with typical applications. The entire EUT shall fit in the test volume. Associated equipment that is required to exercise the EUT but does not form part of the EUT shall be located outside the screened room.

Interface cables shall be connected to each type of interface port of the EUT. If the EUT consists of separate devices, the space between the devices shall be in the normal

configuration, but with 10 cm separation if possible. Interconnecting cables shall be bundled. The bundle shall be of length 30 cm to 40 cm and longitudinal to the cable.

To improve the measurement repeatability, the following guidelines shall be applied:

- a) The EUT (including the cables laid out according to 7.4.3) shall be placed so that its centre is at the same height as the centre of the test volume. A non-conductive support of a suitable height may be used to achieve this.
- b) Where it is not physically possible to elevate a large EUT to the centre of the test volume (Figure 7 and Figure 8), the EUT may remain on a non-conductive transport pallet during the test (Figure 9). The height of the pallet shall be recorded in the test report.

The installation specifications for some floor-standing equipment require the unit to be installed and bonded directly to a conductive floor. The following considerations apply for testing of floor-standing equipment in a FAR: if FAR test results for floor-standing equipment intended to be installed and bonded directly to a conductive floor show non-compliance with an emissions limit applicable to FAR sites, actual emissions may be lower if the EUT were tested on a ground plane that better simulates the final installation environment. This is particularly true if the emissions are at a frequency below 200 MHz, horizontal polarization, and the source of emissions is from a location on the equipment that would correspond to a height above ground of 0,4 m or less in a typical installation. The reader is advised that prior to a determination of non-compliance based on FAR measurements, additional investigation in a ground plane test environment (i.e. an open-area test site or semi-anechoic chamber) is recommended, to better simulate the final intended installation condition for the equipment.

#### 7.4.3 Cable layout and termination

In EMC testing, the reproducibility of measurement results is often poor due to differences in cable layout and termination, when one single EUT is measured at various test-sites. The following listed items are general conditions for the test set-up in order to provide good reproducibility (see Figure 8 and Figure 9). Ideally all radiation to be measured should only be emitted from the test volume. The cables used during the test shall be in accordance with manufacturer's specifications. The EUT may employ non-terminated cables if cable terminations are not available. The specifications of the cables and terminations used during testing shall be clearly described in the test report.

- a) The cables that are connected to the EUT and auxiliary equipment or power supply shall include a length of 0,8 m run horizontally and 0,8 m run vertically (without any bundling) inside the test volume (see Figure 8 and Figure 9). Any cable length in excess of 1,6 m with a relative tolerance of  $\pm 5\%$  shall be routed outside the test volume.
- b) If the manufacturer specifies a shorter length than 1,6 m, then where possible, it shall be oriented such that half of its length is horizontal and half is vertical in the test volume.
- c) Cables that are not exercised through associated equipment during the test must be appropriately terminated:
  - 1) coaxial (shielded) cables with coaxial terminator with correct impedance (50  $\Omega$  or 75  $\Omega$ );
  - 2) shielded cables with more than one inner wire must have common mode (line to reference earth/ground) and differential-mode (line to line) termination in accordance with the manufacturer's specifications;
  - 3) unshielded cables must have differential mode termination as well as common-mode termination in accordance with the manufacturer's specifications.
- d) If the EUT needs associated equipment in order to be operated properly, special care shall be taken that no emission of that equipment can influence the radiation measurement. associated equipment shall be located outside the screened room wherever possible. Measures against RF-leakage into the FAR through the interconnection cables must be taken.

- e) The test set-up including cable layout, specifications of attached cables and terminations, and measures taken to suppress the emission influence of the cable length outside the test volume (for instance the use of ferrite clamps) are specified in the different product standards.

Due to the different nature of the many possible EUTs, product standards may deviate considerably from the requirements of this subclause (e.g. 10.5 of CISPR 22 [3])<sup>2</sup>.

#### 7.4.4 Measurement uncertainty for FAR

General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1. Conditions for the use of alternative test methods are given in CISPR 16-4-5. An example of an uncertainty budget for an emission measurement at a 3 m distance in a FAR is given in CISPR 16-4-2.

### 7.5 Radiated emission measurement method (30 MHz to 1 GHz) and radiated immunity test method (80 MHz to 1 GHz) with common test set-up in semi-anechoic chamber

#### 7.5.1 Applicability

As an alternative to different test set-ups for radiated emissions and radiated immunity testing, at the discretion of product committees, testing to both requirements may be performed using a common EUT arrangement in accordance with the provisions of this clause. The test arrangement described in this clause is applicable when radiated emissions and immunity testing of the EUT using the same configuration and test set-up is technically justified. This test arrangement is considered to be most applicable to EUTs of simple configuration, e.g. single enclosure, combination of small enclosures, less than five cables connected to the EUT. This alternative test arrangement is allowed for EUTs whose product emissions standards permit radiated emission tests at 3 m separation distance.

The radiated immunity test may be performed with absorbing material covering portions of the ground plane between the EUT and the transmitting antenna, if necessary to achieve field uniformity, as described in IEC 61000-4-3 (i.e. absorber-lined SAC, analogous to absorber-lined OATS). For emission measurements, the normalized site attenuation characteristics of the SAC without the ground-plane absorber shall satisfy the requirements of CISPR 16-1-4.

#### 7.5.2 EUT perimeter definition and antenna-to-EUT separation distance

Radiated emission and immunity tests shall be made with the receive or transmit antenna located at a horizontal distance of 3 m plus half of the maximum width of the EUT being tested, measured from the centre of the EUT. The antenna reference point used when determining its distance from the EUT is the identified reference point. However, if the reference point is not specified, the reference point is a point along the horizontal antenna boom midway between the dipole antenna elements that correspond to a half wavelength of the upper and lower frequency limits to be evaluated.

NOTE For a log-periodic antenna, the manufacturer may specify the reference point.

The EUT perimeter is defined by the smallest virtual (imaginary) rectangle encompassing the EUT. All intersystem cables shall be included within this perimeter (see Figure 10). Each edge of this perimeter shall lie in one of the four face planes of the EUT, co-planar with (and possibly residing within) the uniform field areas (UFAs) calibrated for immunity tests, depending upon the horizontal test distance.

<sup>2</sup> Figures in square brackets refer to the Bibliography.

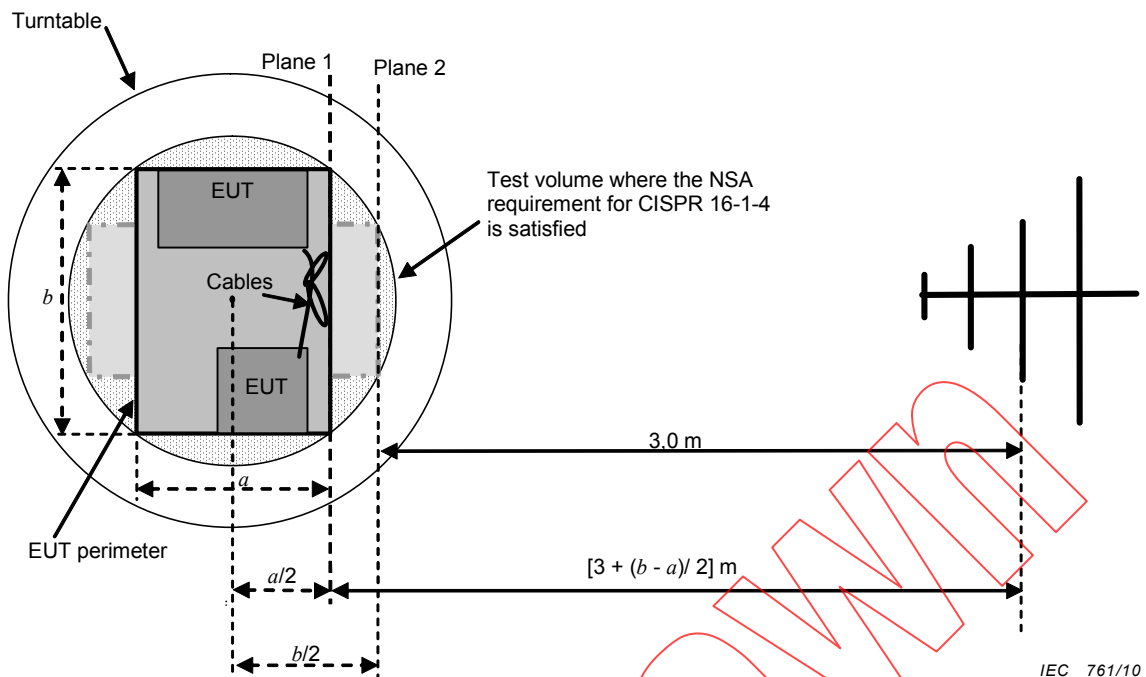


**Figure 10 – Positions of reference planes for uniform field calibration (top-view)**

### 7.5.3 Uniform test volume

The uniform test volume is defined by the following conditions.

- The EUT and its auxiliary equipment (AuxEq) (e.g. peripherals and cables) shall fit into a test volume where the site validation requirements of CISPR 16-1-4 are fulfilled. Refer to the site validation procedure for alternative test sites for use in emission measurements of CISPR 16-1-4;
- The EUT and its AuxEq shall fit into a test volume that allows each of the faces of the EUT and its AuxEq to be aligned with the uniform field area according to the requirements of IEC 61000-4-3 and as described in this subclause.

Evaluation of EUTs having unequal or non-symmetric boundaries at two antenna separation distances necessitate uniform field area calibrations according to the requirements of IEC 61000-4-3. In the example shown in Figure 10, this is at the plane with length  $b$  along the front face of the EUT ( $0^\circ$  azimuth) and the plane with length  $a$  along the side face of the EUT ( $90^\circ$  azimuth).

To accommodate EUTs with a maximum width of 1,5 m, the uniform field area may be calibrated for the two conditions:

- in a plane orthogonal to the axis of the antenna through the centre of the turntable;
- in a plane orthogonal to the axis of the antenna 0,75 m in front of the centre of the turntable, perpendicular to the measurement axis.

A linear interpolation can be performed to test any EUT whose exposed front is between the two calibrated UFAs. It is presumed that:

- the -0 dB to +6 dB criteria complies at the number of points defined by IEC 61000-4-3 for each of the two surfaces, and
- the average field strengths of the points satisfying the -0 dB to +6 dB criterion in the two UFAs are inversely proportional to the antenna-to-UFA distance when applying a constant forward power to the antenna.

Designate  $P_{c1}$  as the forward power (logarithmic scale) for the UFA at the centre of the turntable, evaluated by either the calibration with constant field strength or the calibration method with constant power, and  $P_{c2}$  as the corresponding forward power for the UFA at 0,75 m in front of the centre of the turntable. The required forward power to illuminate an EUT surface can be calculated by linear interpolation from  $P_{c1}$  and  $P_{c2}$  and the corresponding distances (also in logarithmic scale) to the antenna. For other measurement details and descriptions, refer to 6.2 of IEC 61000-4-3 calibration of field.

For EUT perimeter dimensions that differ by 20 % or less of the 3 m separation distance (that is, 0,6 m or less), only a single uniform field area calibration is required at the separation distance corresponding to Plane 1 in Figure 10 (the widest face of the EUT).

NOTE When using the method described in the preceding paragraph, two faces of the EUT will be tested at a higher immunity field-strength level due to their closer distance to the transmitting antenna.

The EUT perimeter, including the connecting cables, shall fit within the test volume where the site validation requirement is satisfied. For the common emission/immunity set-up, the facility must be calibrated at two vertical planes corresponding to the minimum and maximum dimensions of the EUT perimeter at 0°, 90°, 180° and 270° to the EUT faces. The types of equipment to be tested in the facility may be considered for selection of the two plane locations.

If floor absorbers are used to achieve the field uniformity criterion, these absorbers shall be placed between the transmitting antenna and Plane 2. If only one plane is calibrated (that is, an EUT with a difference of the two boundary dimensions being less than 0,6 m), the floor absorbers, when used, shall be placed between the transmitting antenna and the calibrated plane.

#### 7.5.4 Specifications for EUT set-up in common emissions/immunity test setup

The tests shall be performed with the equipment configured as closely as possible to its typical, practical operation. Unless stated otherwise, cables and wiring shall be as specified by the manufacturer and the equipment shall be in its housing (or cabinet) with all covers and access panels in place. Any deviation from normal EUT operating conditions shall be included in the test report. The specifications of 7.3.6.3 apply. The EUT (on a non-conductive support structure, where applicable) shall be placed on a remotely operated turntable, as specified in 7.3.6.3, to allow the EUT to be rotated.

The height of the EUT above the ground plane shall be in accordance with the following requirements.

- Table-top equipment is placed on a non-conductive setup table with height  $0,8 \text{ m} \pm 0,01 \text{ m}$ , see 7.3.6.3. CISPR 16-1-4 specifies the method to determine the impact of the non-conductive set-up table on test results.
- Floor-standing equipment is placed on a non-conductive support, as specified in the applicable product standard. If there are no EUT height placement requirements in the product standard, the EUT shall be placed on a non-conductive support at a height of 5 cm to 15 cm above the ground plane.

Equipment designed for wall-mounted operation shall be tested as table-top equipment. The orientation of the EUT shall be consistent with that of normal operation (that is, positioned as normally installed).

Interface cables, loads, and devices should be connected to at least one of each type of the interface ports of the EUT and, where practical, each cable shall be terminated in a device typical for its actual use. Where there are multiple interface ports of the same type, a typical number of these devices shall be connected to devices or loads. It is sufficient to connect only one of the loads, provided that it can be shown, for example by preliminary testing, that the connection of further ports would not significantly increase the level of disturbance (that is,

more than 2 dB) or significantly degrade the immunity level. The rationale for the configuration and loading of ports shall be documented in the test report.

The number of additional cables should be limited to the condition where the addition of another cable does not decrease the margin by a significant amount (for example, 2 dB) with respect to the limit. In some cases the optimum arrangement of features, loads, interface types, and cables for emissions and immunity tests are different, which may result in the need for some reconfiguration of the EUT within the confines of the uniform EUT arrangement.

The cable layout and termination shall be according to the following requirements.

- The cables shall be oriented so that vertically- and horizontally-polarized radiation fields are not excluded. The cable layout rules and cable lengths defined in the applicable product emission and immunity standards shall be applied. However, in case of conflicting requirements, the layout and maximum cable lengths defined in the product emission standard must take precedence. Fulfilling the rules can be accomplished by applying the cable placement rules of the emissions standard and exposing a minimum length of 1 m of cable, with a mix of horizontal or vertical parts, to the electromagnetic field during immunity testing (unless the manufacturer's specifications require shorter cables). Excess cable lengths should be bundled in the approximate centre of the length of the cable to form a bundle 30 cm to 40 cm in length. If no information is provided about cable layout in the product emission standard, the following arrangement is applied:
- For a table-top EUT (Figure 11 and Figure 12), the cables leaving the uniform test volume (that is, those that connect the EUT to the outside world) shall be exposed to the electromagnetic field according to Figure 11 and Figure 12 for a total length of 1 m ( $\pm 0,1$  m), and then extended vertically down towards the floor (with a minimum length of 0,8 m imposed by the EUT table height). Interconnecting cables that hang from the table shall be at a minimum distance of 0,4 m ( $\pm 0,04$  m) from the ground plane. If cables that hang closer than 40 cm to the ground plane cannot be shortened to the appropriate length, the excess cable shall be folded back and forth to form a bundle 30 cm to 40 cm long. If the maximum length declared by the manufacturer for certain cables does not allow a one meter horizontal cable layout, including a length to get to the ground plane for table-top products (placed on the 0,8 m height table), the horizontal layout shall depend on the length of cable in excess of 0,8 m. Bundling is not required.
- For a floor-standing EUT (Figure 13 and Figure 14), cables leaving the uniform test volume shall be arranged with a length of at least 0,3 m run horizontally within the test volume and with a vertical run according to typical, normal use (depending on the height above the floor of the I/O port). Horizontal cables shall be insulated from the ground planes by a minimum height of 10 cm for the entire length of the cable that is intended to be laid out along the floor.

Cabling between enclosures of the EUT shall be treated as follows:

- The manufacturer's specified cabling types and connectors shall be used.
- If the manufacturer's specification requires a cable length of less than or equal to 3 m, then the specified length shall be used. The cables shall be exposed for a length of 1 m ( $\pm 0,1$  m) and the excess shall be folded back and forth, forming a bundle 30 cm to 40 cm long, for table-top equipment (see Figures 11 and 12) and approximately 1 m for floor-standing equipment (see Figures 13 and 14).
- If the specified length is greater than 3 m or is not specified, then the illuminated length shall be 1 m. The excess cables shall be extended outside the test volume.
- EUT combinations of table-top equipment and floor-standing equipment shall be arranged according to the set-up of each individual equipment configuration and the interconnecting cables between table-top equipment and floor-standing equipment shall be according to these rules.

- For the cables not terminated into auxiliary equipment, differential- and common-mode terminations should be simulated to represent the auxiliary equipment that would be connected to the cables and represent the required functional impedance.
- Cables not connected to another device may be terminated as follows (see also 7.3.6.3).
  - Coaxial shielded cables shall be terminated with a coaxial termination (usually 50  $\Omega$  or 75  $\Omega$ )
  - Shielded cables with more than one inner wire should have common- and differential-mode termination according to the EUT manufacturer's specifications. This common-mode termination is to be connected appropriately between the inner wires or their differential-mode termination and cable shield. If no information is available about the common-mode terminations, 150  $\Omega$  common-mode terminations should be used.
  - Unshielded cables must have differential-mode termination according to the manufacturer's specifications.
  - All cables that have been shortened in respect to their maximum lengths declared by the manufacturer and provided with artificial terminations for testing convenience, according to this paragraph, should also be provided with additional 150  $\Omega$  common-mode terminations to the test chamber wall or floor.

The following items should be considered with 7.3.6.3.

- If the EUT needs associated equipment (AE) to operate properly, special care must be taken to ensure that AE does not affect the radiated emissions measurements or the radiated immunity tests. AE may be located outside the anechoic chamber during testing if proper connecting interfaces are available on the chamber shielding. Measures to prevent RF-leakage into or out of the anechoic chamber through the interconnection cable may be necessary.
- Other methods or equipment used to suppress unwanted emissions from AE shall be located outside the test chamber or beneath the raised floor.
- The test set-up, including cable layout, specifications of attached cables and terminations, use of CMAD(s) on cables leaving the test volume, and other measures taken to suppress emissions from AE outside the test volume, shall be clearly described in the test report.

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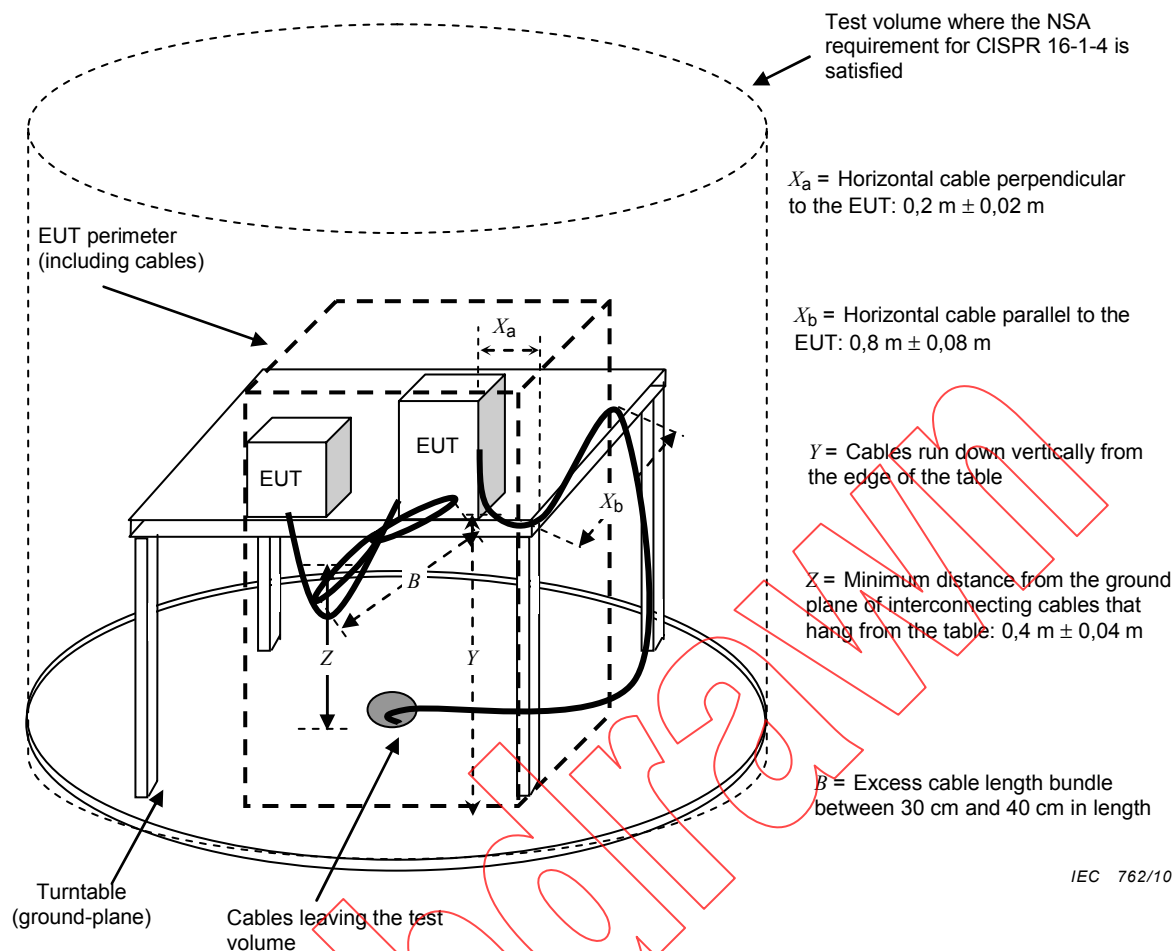


Figure 11 – Test set-up for table-top equipment

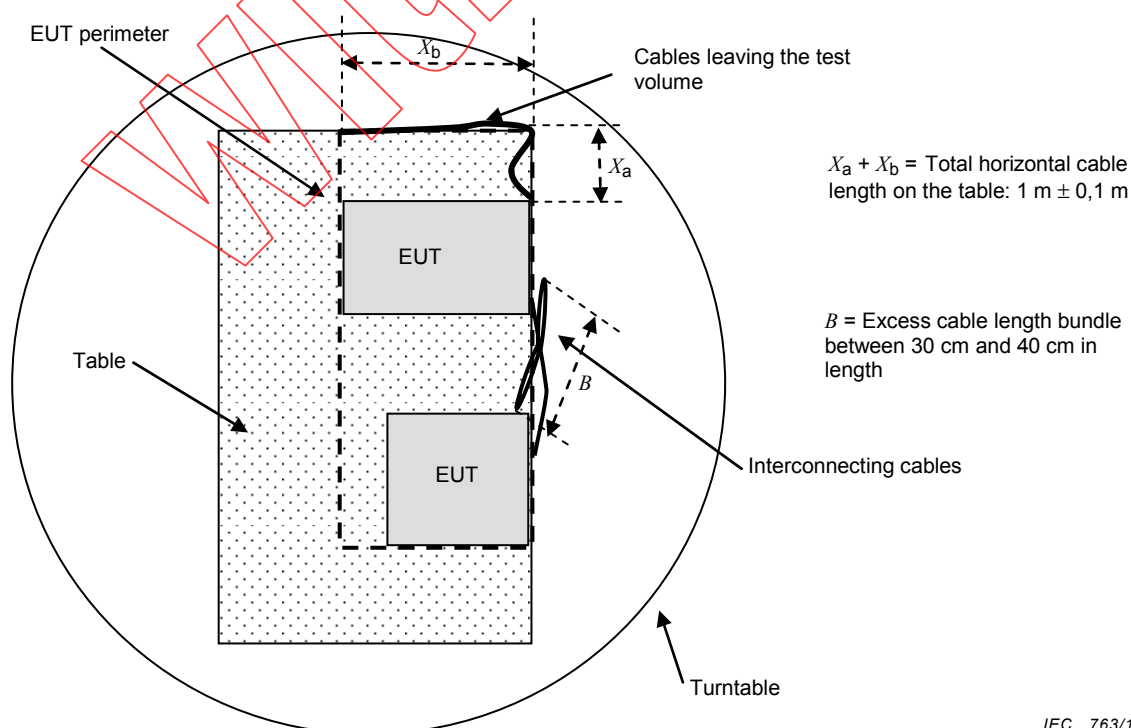
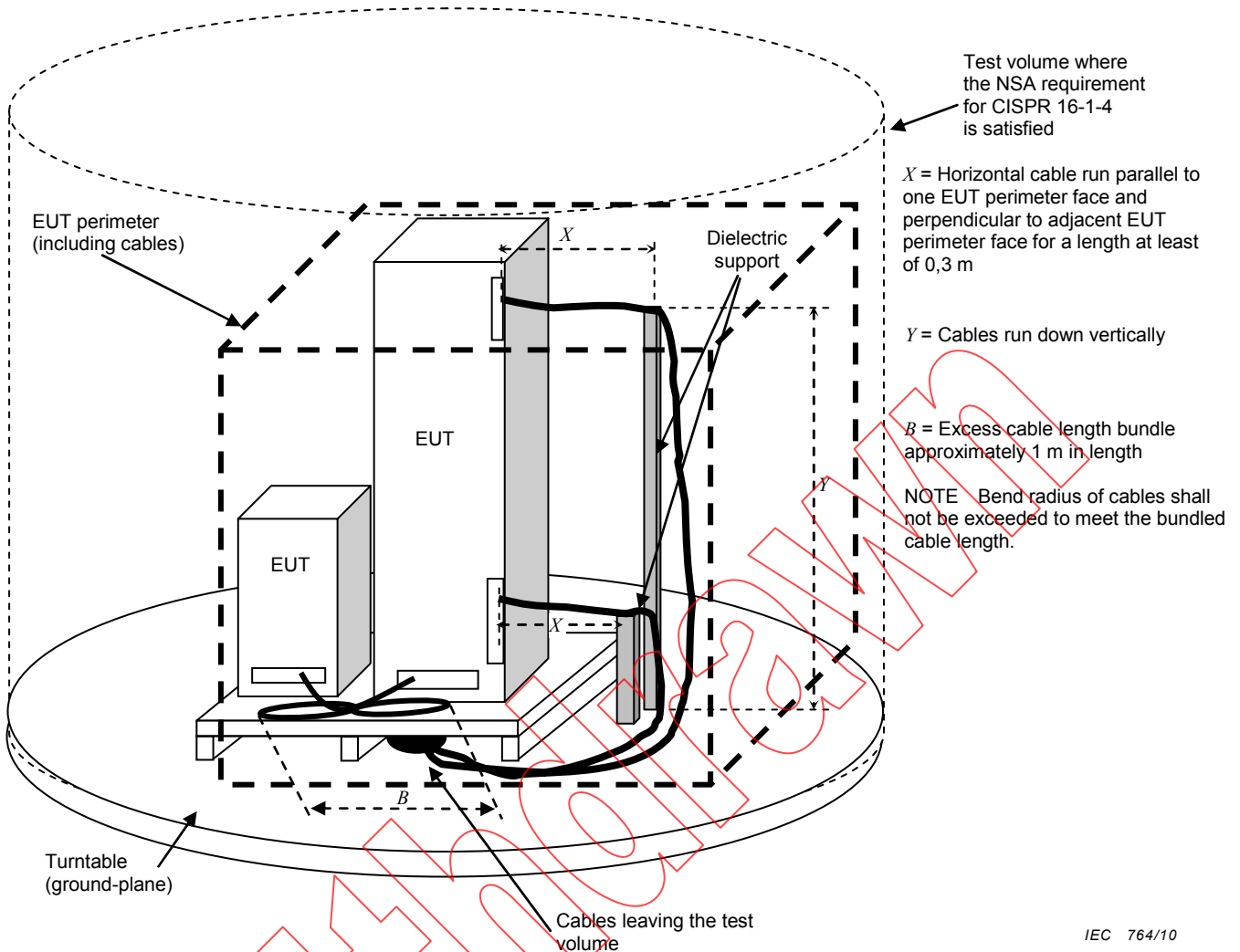
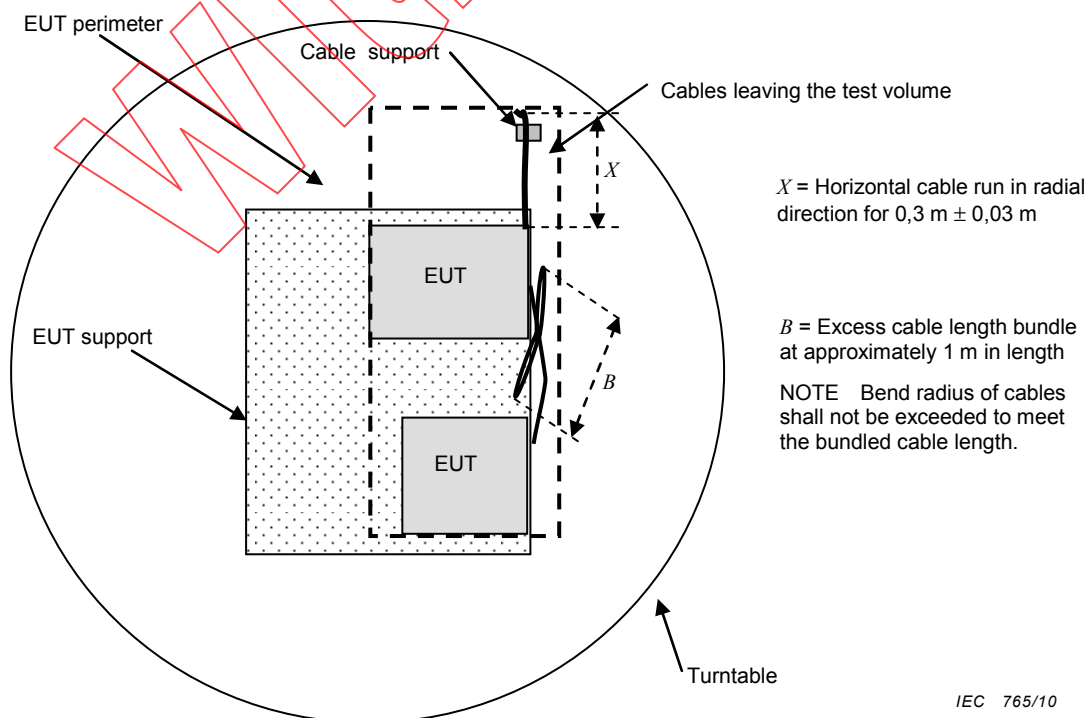


Figure 12 – Test set-up for table-top equipment – Top view



IEC 764/10

Figure 13 – Test set-up for floor-standing equipment



IEC 765/10

Figure 14 – Test set-up for floor-standing equipment – Top view

### 7.5.5 Measurement uncertainty for common emission/immunity set-up and method

General and basic considerations about uncertainties of emission measurements are given in CISPR 16-4-1.

## 7.6 Fully-anechoic room and absorber-lined OATS/SAC measurements (1 GHz to 18 GHz)

### 7.6.1 Quantity to measure

The electric field strength emitted by the EUT at the measuring distance is the quantity to be measured. The result shall be expressed in terms of field strength.

In some standards, emission limits above 1 GHz for equipment are expressed in terms of effective radiated power ( $P_{RE}$ ) in dB(pW). Under free-space far-field conditions, the equation to convert  $P_{RE}$  into field strength, in dB(μV/m), at a 3 m distance is:

$$E_{3m} = P_{RE} + 7,4 \quad (7)$$

For distances  $d$ , in m, other than 3 m:

$$E_d = P_{RE} + 7,4 + 20 \log\left(\frac{3}{d}\right) \quad (8)$$

### 7.6.2 Measurement distance

The field strength emitted by the EUT is measured at a preferred distance of 3 m. The measurement distance,  $d$ , is the horizontal distance between the periphery of the EUT and the receive antenna reference point (see Figure 15). The EUT encompasses all portions of the EUT, including cable racks and support equipment and a minimum cable length of 30 cm.

Other distances may be used in practical situations, i.e.:

- shorter distances in the case of high ambient noise, or to reduce the effect of unwanted reflections, but care should be taken to ensure the measurement distance is greater than or equal to  $D^2/(2\lambda)$ ;
- greater distances for large EUTs to allow the antenna beam to encompass the EUT.

NOTE Because dominant components of the EUT disturbance signals may be assumed to be incoherent and radiated from a point source, the minimum distance mentioned above, i.e.  $D^2/(2\lambda)$ , is to be established using the measuring antenna dimensions, and not the EUT dimensions.

If measurements are made at a distance other than 3 m (see note above), the measurement distance shall be greater than or equal to 1 m and less than or equal to 10 m. In such a case, the measurement data is to be adjusted to a 3 m distance, assuming free-space propagation. Users are advised that comparison of measurements at different distances and extrapolation of results typically will not correlate as well as measurements made at the same distance. Standards or specifications that reference this test method should identify a preferred measurement distance.

### 7.6.3 Set-up and operating conditions of the equipment under test (EUT)

As a general guideline, test set-ups and operating conditions of the EUT shall be the same as those used below 1 GHz. Whenever possible, the test set-up should be representative of the most typical configuration of the EUT (table-top, floor-standing, rack-mounted, wall-mounted, etc.).

The test set-up should also consider that for measurements above 1 GHz absorbers are typically required on the floor between the antenna and EUT. Whenever practical, for emission measurements above 1 GHz the EUT should be raised above the height of the absorbers. If it is not possible to raise the entire EUT above the absorbers (i.e. for rack-mounted or floor-standing equipment), efforts should be made to configure the EUT (within a rack or chassis, for example) such that the radiating elements are located above the absorbers. The EUT shall be located in the test volume established during site validation, as described in CISPR 16-1-4. If it is not practical and safe to raise the EUT or its radiating elements above the absorber height, the maximum extent of the EUT that is permitted to be located below the highest point of the absorbers is 30 cm (see 7.6.6.1 and Figure 15).

The actual EUT configuration and set-up used shall be documented in the test report with photographs or diagrams clearly showing the location of the EUT with respect to the facility floor or turntable surface, absorber placement on the floor (height and location) and receive antenna location.

#### **7.6.4 Measurement site**

The measurement site shall comply with the requirements described in CISPR 16-1-4.

#### **7.6.5 Measurement instrumentation**

The measurement instrumentation shall comply with the requirements described in CISPR 16-1-1 and CISPR 16-1-4.

Measurements to verify compliance with a peak limit shall be conducted with the peak measuring spectrum analyzer or receiver using a measurement bandwidth of 1 MHz (impulse bandwidth) as defined CISPR 16-1-1.

Measurements to verify compliance with an average limit shall be conducted with a peak measuring spectrum analyzer using a measurement bandwidth of 1 MHz (impulse bandwidth) and a reduced video bandwidth, set as defined in CISPR 16-1-1. The value of video bandwidth required for an average measurement shall be less than the lowest spectral component of the input signals to be measured.

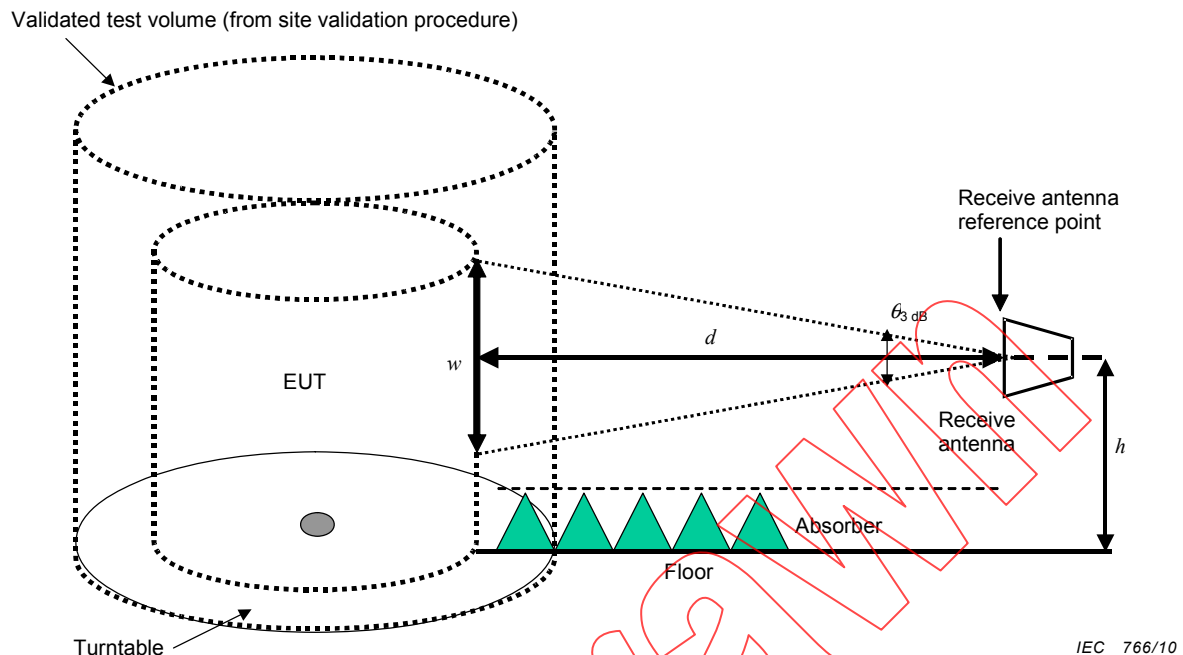
NOTE A spectrum analyzer can be used to perform average measurements by setting the display mode to linear and the video bandwidth to a value that is lower than the lowest spectrum component of the input signal to be measured. For example, if the input signal has a 1 kHz pulse repetition frequency (PRF), for a video bandwidth less than 1 kHz, only the d.c. component of the signal (i.e. the average value) will pass through the video filter.

The use of other types of linear average detectors that comply with these requirements is allowed. In general, the spectrum analyzer shall be set to linear display mode when performing average measurements, not logarithmic display mode. The sweep time of the spectrum analyzer shall be increased, due to the use of narrower video bandwidths, to ensure accurate measurement results. The logarithmic mode is permitted for average measurements when the specification limits assume a logarithmic detector will be used.

#### **7.6.6 Measurement procedure**

##### **7.6.6.1 General description of the radiated field measurement method above 1 GHz**

The radiated field measurement method above 1 GHz is based on measurement of the maximum electric field emitted from the EUT, with a set-up as shown in Figure 15.



NOTE The anechoic material placed on the ground plane is for illustration purposes only. Consult CISPR 16-1-4 for more detailed guidance about placement of absorber to comply with the site validation requirements.

**Figure 15 – Measurement method above 1 GHz, receive antenna in vertical polarization**

The following descriptions apply to the parameters and terms given in Figure 15.

- Validated test volume: the volume evaluated during the site validation procedure (see CISPR 16-1-4). Typically, this determines the largest diameter EUT that can be tested in the facility.
- EUT (volume): the smallest diameter cylinder that will fully encompass all portions of the actual EUT, including cable racks and a minimum length of 30 cm of cables. The EUT that is located within this cylinder must be capable of rotating about its centre (typically by a remotely controlled turntable). The EUT must be located within the validated test volume. A maximum of 30 cm of  $w$  (see definition of  $w$  below) may be below the height of absorbers on the floor only when the EUT is floor-standing and cannot be raised above the height of the absorbers (see 7.6.3).
- $\theta_{3\text{ dB}}$ : The minimum 3 dB beamwidth of the receive antenna at each frequency of interest.  $\theta_{3\text{ dB}}$  is the minimum of both the  $E$ -plane and  $H$ -plane values at each frequency.  $\theta_{3\text{ dB}}$  may be obtained from manufacturer-provided data for the receive antenna.
- $d$ : The measurement distance (in meters). This is measured as the horizontal distance between the periphery of the EUT and the reference point of the receive antenna.
- $w$ : The dimension of the line tangent to the EUT formed by  $\theta_{3\text{ dB}}$  at the measurement distance  $d$ . Equation (9) shall be used to calculate  $w$  for each actual antenna and measurement distance used. The values of  $w$  shall be included in the test report. This calculation may be based on the manufacturer-provided receive-antenna beamwidth specifications:

$$w = 2d \tan(0,5 \theta_{3\text{ dB}}) \quad (9)$$

$w$  shall be of the minimum dimension as specified in Table 3.

- $h$ : The height of the receive antenna, measured from its reference point to the floor.

Table 3 specifies the minimum acceptable dimension of  $w$  ( $w_{\min}$ ). The minimum requirements shown in Table 3 are calculated from Equation (9) based on testing at the minimum permitted measurement distance of 1 m specified in 7.6.2, and the values of  $\theta_{3\text{ dB}(\min)}$  shown. The selection of measurement distance  $d$  and antenna type shall be made such that  $w$  is equal to or greater than the values shown in Table 3 at any frequency where the field is measured. At frequencies not shown in Table 3, the limit of  $w_{\min}$  shall be linearly interpolated between the nearest two frequencies listed. Table 4 gives example values of  $w$  calculated using Equation (9) for three antenna types, at measurement distances of 1 m, 3 m, and 10 m.

The maximum emission is measured by moving the receive antenna in height along with rotation of the EUT in azimuth ( $0^\circ$  to  $360^\circ$ ). The required range of height investigation is specified below and illustrated in Figure 16 for two typical categories of EUTs.

**Table 3 – Minimum dimension of  $w$  ( $w_{\min}$ )**

| Frequency<br>GHz | $\theta_{3\text{ dB}, \min}$<br>° | $w_{\min}$<br>m |
|------------------|-----------------------------------|-----------------|
| 1,00             | 60                                | 1,15            |
| 2,00             | 35                                | 0,63            |
| 4,00             | 35                                | 0,63            |
| 6,00             | 27                                | 0,48            |
| 8,00             | 25                                | 0,44            |
| 10,00            | 25                                | 0,44            |
| 12,00            | 25                                | 0,44            |
| 14,00            | 25                                | 0,44            |
| 16,00            | 5                                 | 0,09            |
| 18,00            | 5                                 | 0,09            |

NOTE 1 The dimension,  $w$ , is permitted to be larger than the minimum shown, and other antennas and distances may be used to satisfy the minimum required value of  $w = w_{\min}$  shown, provided that Equation (9) is met.

NOTE 2 Because both polarizations are required to be measured for each height of the receive antenna,  $w$  forms a minimum square observation area equal to  $w^2$  ( $\text{m}^2$ ).

NOTE 3 In some cases,  $w$  may encompass multiple physical components of the EUT that are physically separated. For example, multiple separate cabinets of a multi-cabinet system that are tested simultaneously.

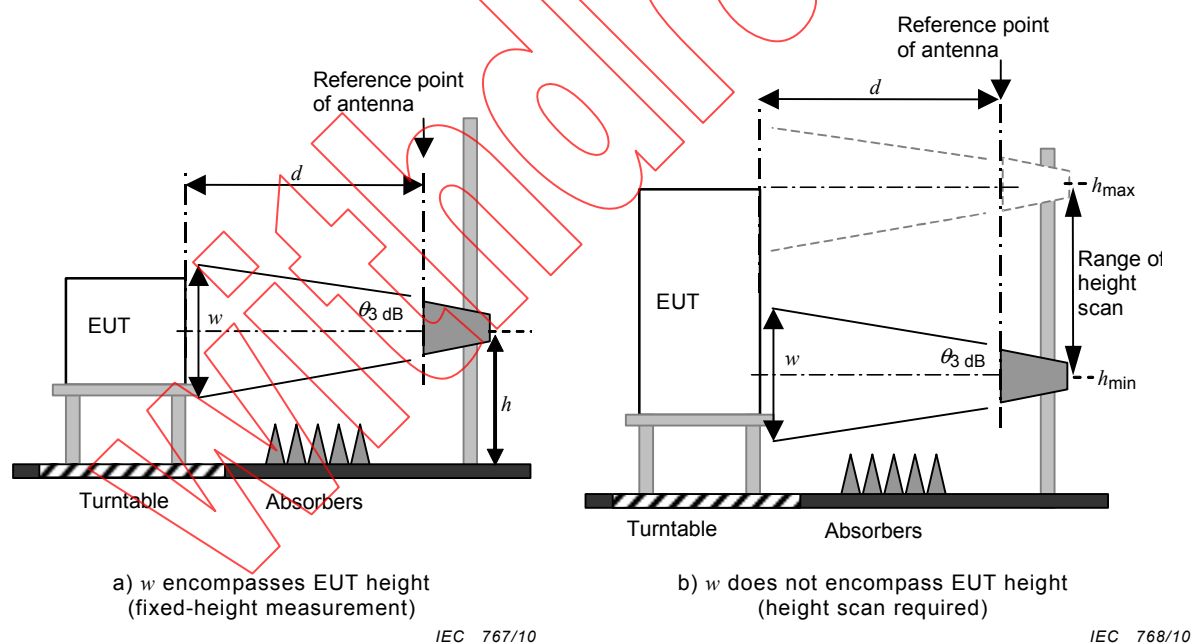
NOTE 4 The height scan requirement depends on  $w$  such that it may be advantageous to maximize  $w$  by selection of a wider beamwidth antenna and a larger measurement distance than the minimum requirements shown.

NOTE 5 The pattern and beamwidth of the antenna used can affect the measurement result. The antenna has at least two influence factors in addition to uncertainty in the antenna factor: 1) ripple or other anomalies in the antenna pattern, and 2) beamwidth differences between antennas, which may give different results depending on how many (constructive) emissions emanating from separate physical locations on the EUT fall within the antenna beamwidth.

**Table 4 – Example values of  $w$  for three antenna types**

| Frequency<br>GHz | DRG Horn                    |                  |                  |                   | LPDA or LPDA-V <sup>a</sup> |                  |                  |                   |
|------------------|-----------------------------|------------------|------------------|-------------------|-----------------------------|------------------|------------------|-------------------|
|                  | $\theta_{3\text{ dB}}$<br>° | $d = 1\text{ m}$ | $d = 3\text{ m}$ | $d = 10\text{ m}$ | $\theta_{3\text{ dB}}$<br>° | $d = 1\text{ m}$ | $d = 3\text{ m}$ | $d = 10\text{ m}$ |
|                  |                             | $w$<br>m         | $w$<br>m         | $w$<br>m          |                             | $w$<br>m         | $w$<br>m         | $w$<br>m          |
| 1,00             | 60                          | 1,15             | 3,46             | 11,55             | 60                          | 1,15             | 3,46             | 11,55             |
| 2,00             | 35                          | 0,63             | 1,89             | 6,31              | 55                          | 1,04             | 3,12             | 10,41             |
| 4,00             | 35                          | 0,63             | 1,89             | 6,31              | 55                          | 1,04             | 3,12             | 10,41             |
| 6,00             | 27                          | 0,48             | 1,44             | 4,80              | 55                          | 1,04             | 3,12             | 10,41             |
| 8,00             | 25                          | 0,44             | 1,33             | 4,43              | 50                          | 0,93             | 2,80             | 9,33              |
| 10,00            | 25                          | 0,44             | 1,33             | 4,43              | 50                          | 0,93             | 2,80             | 9,33              |
| 12,00            | 25                          | 0,44             | 1,33             | 4,43              | 50                          | 0,93             | 2,80             | 9,33              |
| 14,00            | 25                          | 0,44             | 1,33             | 4,43              | 45                          | 0,83             | 2,49             | 8,28              |
| 16,00            | 5                           | 0,09             | 0,26             | 0,87              | 40                          | 0,73             | 2,18             | 7,28              |
| 18,00            | 5                           | 0,09             | 0,26             | 0,87              | 40                          | 0,73             | 2,18             | 7,28              |

<sup>a</sup> LPDA-V: V-type log periodic dipole array. The values shown for  $\theta_{3\text{ dB}}$  and  $w$  are typical of both the LPDA and LPDA-V. However, these antennas typically have different gains.

**Figure 16 – Illustration of height scan requirements for two different categories of EUTs**

For any EUT with maximum dimensions equal to or smaller than  $w$ , the centre of the receive antenna shall be fixed at the height of the centre of the EUT (Figure 16 a)). For any EUT with a maximum vertical dimension larger than  $w$ , the centre of the antenna shall be scanned vertically along the line parallel to  $w$ , as shown in Figure 16 b). The required scanning range for  $h$  is 1 m to 4 m. If EUT height is less than 4 m, scanning the centre of the receive antenna to heights above the top of the EUT is not required. In both cases the fixed height,  $h$ , or the range of heights investigated shall be recorded in the test report.

NOTE When a height scan is required per the above paragraph, a continuous height scan within the required height range is recommended, to obtain the final, maximum emission. If stepped height increments are used, caution is advised to ensure that the height increments are sufficiently small in order to capture the maximum emission.

Regarding the horizontal extent of  $w$ , the EUT is not required to be fully within  $w$ . In cases where the EUT width is larger than  $w$ , the EUT shall be centred horizontally on the measurement axis, and rotation of the EUT provides the necessary horizontal scan for the determination of the maximum field strength. Horizontal-line (sideways, transverse) scanning by moving the receive antenna horizontally off the measurement axis is not required, but may be used if specified in a product standard.

## **7.6.6.2 Measurements using conventional (non-statistical) detectors**

### **7.6.6.2.1 General measurement procedure**

For any EUT, the frequencies of emission should first be detected by a preliminary emission maximization procedure (see 7.6.6.2.2). Then the final emission test is performed (see 7.6.6.2.3). Both of these measurements are to be made preferably at the specific limit distance. If, for any justified reason, the final measurement is performed at a distance different from the limit distance, a measurement at the limit distance should be made first, to help in interpreting the resulting data in case of dispute.

In performing these measurements, the sensitivity of the measurement equipment relative to the limit shall be determined before the test. If the overall measurement sensitivity is inadequate, low-noise amplifiers, closer measurement distances or higher-gain antennas may be used. If closer measurement distances or higher gain antennas are used, the beam width versus size of the EUT shall be accounted for. Also, measurement system overload levels shall be determined to be adequate when preamplifiers are used.

Burn-out and saturation protection for the measuring instrumentation is required when low-level emissions are to be measured in the presence of a high level signal. A combination of band-pass, band-stop, low-pass and high-pass filters may be used. However, the insertion loss of these or any other devices at the frequencies of measurement shall be known and included in any calculations in the report of measurements.

**NOTE** A simple method of determining whether non-linear effects (overload, saturation, etc.) occur, consists of inserting a 10 dB attenuator at the input of the measurement instrument (ahead of any pre-amplifier if one is used) and verifying that the amplitude of all the harmonics of the high-amplitude signal (that may cause non-linear effects) is reduced by 10 dB.

### **7.6.6.2.2 Preliminary measurement procedure**

The procedures of this subclause are for informative purposes – normative measurement requirements are listed in 7.6.6.2.3. The maximum radiated emission for a given mode of operation may be found during a preliminary test. To minimize measurement time, it is suggested to first perform measurements using peak detection, and then compare the test results to the average limit. Subsequent measurements with the average detector and comparison of results to the average limit will only be performed in those frequency ranges where the average limit was exceeded by data collected with peak detection.

Guidelines for a preliminary procedure to identify the radiated emissions are as follows.

- a) Use scan or sweep mode over the complete frequency range of the antenna using peak detection and Max-Hold mode.
- b) The proper sweep or scan time should be determined to ensure adequate signal interception.
- c) If necessary, during preliminary tests, the resolution bandwidth may be reduced in sweep mode to reduce the displayed noise level of the spectrum analyzer or receiver. Note that this may reduce the amplitude of broadband emissions, so additional investigations to determine whether the emissions are broadband or narrowband may be necessary.
- d) Rotate the EUT continuously or in increments of 15° or less, then repeat for the other polarization. The EUT should be rotated 360° in azimuth for both polarizations to determine the maximum emissions at each frequency of interest.

- e) For continuous turntable rotation mode, spectrum-analyzer sweep time should be set such that the selected frequency span can be swept within a time that is equal to or less than the time needed for the turntable to rotate  $15^\circ$ . If the rotational speed of the turntable is such that an angle larger than  $15^\circ$  is covered during a complete sweep or scan of the spectrum analyzer, a smaller frequency range should be used to reduce spectrum analyzer sweep time and to achieve the maximum  $15^\circ$  turntable rotation per sweep.
- f) As needed to identify the frequencies of maximum emissions, the method described above may be applied for all the height levels required by 7.6.6.1 (and Figure 16), and for the various operating modes of the EUT.
- g) To further evaluate the frequencies found in steps a) to d), use a small frequency span (typically 5 MHz or less) and investigate around frequencies near the limit using additional smaller turntable increments and height steps. Typically, all frequencies within approximately 10 dB of the specification limit warrant further investigation with a narrow frequency span and additional finer rotation/height increments.

#### 7.6.6.2.3 Final measurement procedure

The field strength emitted by the EUT at the given measurement distance is measured using the configuration (antenna height, EUT azimuth, etc.) producing the maximum emission, as identified during the preliminary emission maximization (the receiving antenna being aligned with this maximum emission). Final measurements shall be done using the EUT operational mode identified by preliminary measurements to have the highest emissions.

This final measurement shall be the result of a maximum hold on the spectrum analyzer during a given time proportional to the frequency span used. This given time should be defined for each product or product family, taking into account the duration of the operating modes and the time constants associated with each specific product to be tested. Final measurements shall be performed using all required detectors. Alternatively, peak measurement results may be used to demonstrate compliance with all specified limits.

If the configuration of the EUT (antenna height, EUT azimuth, operation mode, etc.) producing the maximum emission was not conclusively determined by a preliminary measurement the following additional measurements shall be done:

- a) For any EUT with maximum dimension equal to or smaller than  $w$ , the centre of the receiving antenna shall be fixed at the height of the centre of the EUT [see Figure 16 a)].
- b) For any EUT with maximum vertical dimension larger than  $w$ , height scanning shall be performed in accordance with the height scan requirements (upper and lower bounds) specified in 7.6.6.1.
- c) In all cases, in order to find the maximum emissions, the EUT shall be rotated in azimuth through all angles in the range of  $0^\circ$  to  $360^\circ$ , and the measurements shall be performed for both horizontal and vertical polarizations.

In summary, the requirements for final measurements above 1 GHz are as follows.

The maximum emissions shall be recorded from the following required investigations, some of which may be performed during the preliminary measurement procedure.

- 1) The EUT shall be rotated in azimuth from  $0^\circ$  to  $360^\circ$  either by a turntable or movement of the receive antenna around the volume.
- 2) The receive antenna shall be height-scanned if the EUT height is larger than  $w$  in the vertical direction.
- 3) Both horizontal and vertical polarizations shall be investigated.

### 7.6.6.3 Measurements using APD (statistical) function

#### 7.6.6.3.1 General

The measurement of the amplitude probability distribution (APD) of a disturbance signal provides a statistical characterization of the disturbance signal in question. Background material on the application of the APD-measuring function is provided in 4.6 of CISPR 16-3 [2]. A product committee may choose the APD measurement as the method to be used for final emission testing. The APD measurement shall be made at those frequencies where the EUT generates high disturbance field strengths. The number and selection method of frequencies shall be established by a product committee.

APD measurement shall be made using one of the following two methods. The first method is for measurement of the disturbance level  $E_{\text{meas}}$  in dB( $\mu\text{V/m}$ ) related to the specified probability of time  $p_{\text{limit}}$ , designated as Method 1 (see 7.6.6.3.2). The second method is the measurement of the probability of time  $p_{\text{meas}}$  during which the disturbance envelope exceeds a specified level  $E_{\text{limit}}$  in dB( $\mu\text{V/m}$ ), designated as Method 2 (see 7.6.6.3.3). Additional information and figures are given in Annex D to show the specifics of the two APD measurement methods.

If a product committee decides to use the APD approach, either Method 1 or Method 2 shall be selected. If the APD measuring instrument does not include an A/D converter, only Method 2 shall be used. If the APD measuring instrument includes an A/D converter, either Method 1 or Method 2 may be used.

The number of pairs of limits ( $E_{\text{limit}}$ ,  $p_{\text{limit}}$ ) and their values shall be specified by the product committee. The product committee shall also decide whether to also use a peak limit together with the APD limits.

#### 7.6.6.3.2 Method 1 – Measurement of the level of disturbance

The measurement shall be performed using the following procedure:

- 1) Set the resolution bandwidth (RBW) and the video bandwidth (VBW) of the spectrum analyzer according to CISPR 16-1-1 (for measurements above 1 GHz).
- 2) Find the frequencies at which high disturbances are observed. This can be accomplished by using the maximum hold function in the frequency span of interest. Peak detection shall be used when applying this procedure.

NOTE In cases where narrowband emissions are hidden by broadband emissions, the maximum hold mode in combination with the peak detector may overlook narrowband emissions. Therefore, an additional measurement may be needed to find the frequencies of the narrowband emissions to be measured. The product committee may require additional sweeps using the average detector or digital video averaging. Furthermore, the number of frequencies for the APD measurement may also be specified by the product committee.

- 3) Determine the frequencies for the APD measurement. The number of the frequencies shall be specified by the product committee.
- 4) Set the centre frequency of spectrum analyzer to the frequency at which the highest level is observed during the application of step 2) of this procedure.
- 5) Set the reference level of the spectrum analyzer to minimum 5 dB above the maximum level of disturbance that is obtained in step 2).
- 6) Set the spectrum analyzer to the zero frequency span mode and measure the APD of disturbance during the measurement time that is specified by the product committee. The measurement time shall be longer than the period of the disturbance.

In case of fluctuating disturbance frequencies, the product committee shall specify the frequency range  $XX$  (in MHz) in which the APDs of the disturbance shall be measured. APDs within the range  $XX$  MHz shall be measured with a 1 MHz frequency step size. However, for frequency ranges with APD measurement values that are greater than -6 dB from the APD limit, additional measurements may be needed with a smaller frequency