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# NORME INTERNATIONALE



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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 – Mesurages des perturbations rayonnées**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION  
INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

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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**

**FOREWORD**

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**CISPR 16-2-3 edition 4.2 contains the fourth edition (2016-09) [documents CISPR/A/1176A/FDIS and CISPR/A/1182/RVD], its amendment 1 (2019-06) [documents CISPR/A/1278/FDIS and CISPR/A/1283/RVD] and its amendment 2 (2023-06) [documents CIS/A/1391/FDIS and CIS/A/1397/RVD].**

**In this Redline version, a vertical line in the margin shows where the technical content is modified by amendments 1 and 2. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.**

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

This fourth edition constitutes a technical revision.

This edition includes the following significant technical change with respect to the previous edition: addition of content on correction of the electric field strength to account for phase centre of log-periodic dipole array antennas.

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*.

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 document and its amendments will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](http://webstore.iec.ch) in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

**IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

## INTRODUCTION to Amendment 1

Amendment of CISPR 16-2-3 regarding EUT volume specifications for radiated disturbance measurements depending on test method and on measurement distance

## 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 [13]<sup>1</sup>, 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 subcommittees 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 documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CISPR 14-1:2016, *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 16-1-2:2014, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Coupling devices for conducted disturbance measurements*

CISPR 16-1-4:~~2010~~2019, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Antennas and test sites for radiated disturbance measurements*

CISPR 16-1-4:2019/AMD1:2020

CISPR 16-1-4:2019/AMD2:2023

CISPR 16-2-1:2014, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements*

CISPR TR 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*

<sup>1</sup> Numbers in square brackets refer to the Bibliography.

CISPR 16-4-2:2011<sup>2</sup>, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Measurement instrumentation uncertainty*

CISPR 16-4-2:2011/AMD1:2014

CISPR 16-4-2:2011/AMD2:2018

CISPR TR 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, *International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility*

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

IEC 61000-4-3:2006/AMD1:2007

IEC 61000-4-3:2006/AMD2:2010

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, definitions and abbreviations

#### 3.1 Terms and definitions

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

##### 3.1.1

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

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

Note 1 to entry: CISPR 16-1-4 uses the analogous term free-space open-area test site (FSOATS).

##### 3.1.2

##### **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

##### 3.1.3

##### **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

##### 3.1.4

##### **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

Note 1 to entry: It may be expressed for the *H* plane or for the *E* plane of the antenna.

Note 2 to entry: Antenna beamwidth is expressed in degrees.

<sup>2</sup> A consolidated version of this publication exists, comprising CISPR 16-4-2:2011, CISPR 16-4-2:2011/AMD1:2014 and CISPR 16-4-2:2011/AMD2:2018.

**3.1.5**  
**associated equipment**  
**AE**

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

Note 1 to entry: This note applies to the French language only.

**3.1.6**  
**auxiliary equipment**  
**AuxEq**

peripheral equipment that is part of the system under test

Note 1 to entry: This note applies to the French language only.

**3.1.7**  
**basic standard**

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

Note 1 to entry: A basic standard may function as a standard for direct application or as a basis for other standards.

[SOURCE: ISO/IEC Guide 2:1991, definition 5.1 [6]]

**3.1.8**  
**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

**3.1.9**  
**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

Note 1 to entry: This note applies to the French language only.

[SOURCE: CISPR 16-1-4:20102019, ~~3.1.4~~ 3.1.7]

**3.1.10**  
**conformity assessment**

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

Note 1 to entry: The subject field of conformity assessment includes activities defined elsewhere in ISO/IEC 17000:2004 [7], such as testing, inspection and certification, as well as the accreditation of conformity assessment bodies.

[SOURCE: ISO/IEC 17000:2004, 2.1, modified – Note 2 has been deleted.]

**3.1.11**  
**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

[SOURCE: IEC 60050-161:1990, 161-02-11, modified – The definition has been changed.]

### 3.1.12

#### **emission**

<electromagnetic> phenomenon by which electromagnetic energy emanates from a source

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

### 3.1.13

#### **emission limit**

<from a disturbing source> specified maximum emission level of a source of electromagnetic disturbance

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

### 3.1.14

#### **equipment under test**

##### **EUT**

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

Note 1 to entry: This note applies to the French language only.

### 3.1.15

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

##### **FAR**

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

Note 1 to entry: This note applies to the French language only.

### 3.1.16

#### **large loop-antenna system**

##### **LLAS**

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

Note 1 to entry: This note applies to the French language only.

### 3.1.17

#### **measurement, scan and sweep times**

##### 3.1.17.1

##### **measurement time**

$T_m$

effective, coherent time for a measurement result at a single frequency

- 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

Note 1 to entry: In some areas "measurement time" is also called dwell time.

##### 3.1.17.2

##### **scan**

continuous or stepped frequency variation over a given frequency span

### 3.1.17.3

#### span

$\Delta f$

difference between stop and start frequencies of a sweep or scan

### 3.1.17.4

#### sweep

continuous frequency variation over a given frequency span

### 3.1.17.5

#### sweep or scan rate

frequency span divided by the sweep or scan time

### 3.1.17.6

#### sweep or scan time

$T_s$

time between start and stop frequencies of a sweep or scan

### 3.1.17.7

#### observation time

$T_o$

sum of measurement times  $T_m$  on a certain frequency in case of multiple sweeps

Note 1 to entry: If  $n$  is the number of sweeps or scans, then  $T_o = n \times T_m$ .

### 3.1.17.8

#### total observation time

$T_{tot}$

effective time for an overview of the spectrum (either single or multiple sweeps)

Note 1 to entry: If  $c$  is the number of channels within a scan or sweep, then  $T_{tot} = c \times n \times T_m$ .

### 3.1.18

#### 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 complies with CISPR 16-1-1

### 3.1.19

#### number of sweeps per time unit

$n_s$

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

Note 1 to entry: Sweeps per second, for example.

### 3.1.20

#### open-area test site

#### OATS

facility for measurements and calibrations in which the ground reflection is made reproducible by a large flat electrically conducting ground plane

Note 1 to entry: An OATS can be used for radiated disturbance measurements, where it is also designated as a COMTS. An OATS can also be used for antenna calibrations, where it is designated as a CALTS.

Note 2 to entry: An OATS is an uncovered outdoor site, and is far enough away from buildings, electric lines, fences, trees, underground cables, pipelines, and other potentially reflective objects, so that the effects due to such objects are negligible. See CISPR 16-1-4 for guidance on the construction of an OATS.

Note 3 to entry: This note applies to the French language only.

### 3.1.21

#### **product standard**

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

Note 1 to entry: 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 to entry: 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.

[SOURCE: ISO/IEC Guide 2:2004, definition 5.4 [6]]

### 3.1.22

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

##### **SAC**

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

Note 1 to entry: This note applies to the French language only.

### 3.1.23

#### **test configuration**

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

### 3.1.24

#### **weighting**

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 to entry: 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 to entry: 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.

Note 3 to entry: Weighting of impulsive disturbance, for example.

#### 3.1.24.1

##### **weighted disturbance measurement**

measurement of disturbance using a weighting detector

#### 3.1.24.2

##### **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

#### 3.1.24.3

##### **weighting detector**

detector that provides an agreed weighting function

#### 3.1.24.4

##### **weighting factor**

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

Note 1 to entry: Weighting factor is expressed in dB.

### 3.1.24.5

#### **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

### 3.1.25

#### **measurement**

process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity

[SOURCE: 2.1 of ISO/IEC Guide 99:2007 [9]<sup>3</sup>, modified – Notes 1 to 3 have been deleted.]

### 3.1.26

#### **test**

technical operation that consists of the determination of one or more characteristics of a given product, process or service according to a specified procedure

Note 1 to entry: A test is carried out to measure or classify a characteristic or a property of an item by applying to the item a set of environmental and operating conditions and/or requirements.

[SOURCE: IEC 60050-151:2001, 151-16-13 [10]]

### 3.1.27

#### **highest internal frequency**

highest frequency generated or used within the EUT or the highest frequency at which the EUT operates or tunes

### 3.1.28

#### **module**

part of an EUT that provides a function and may contain radio-frequency sources

### 3.1.29

#### **compliance test site**

#### **COMTS**

environment that assures valid, reproducible measurement results of the disturbance field strength from equipment under test for comparison to a compliance limit

### 3.1.30

#### **far-field region**

region of the electromagnetic field of a radiating EUT or antenna where the predominant components of the field represent a propagation of energy and where the radiation pattern is essentially independent of the distance from the radiating EUT or antenna

Note 1 to entry: In the far-field region, all the components of the electromagnetic field change with an inverse proportion to the distance from the radiating EUT or antenna.

[SOURCE: IEC 60050-712:1992 [14], 712-02-02, modified – Replacement of "far field region" by "far-field region" in the term itself, replacement of "antenna" by "radiating EUT or antenna", replacement of "angular field distribution" by "radiation pattern" and deletion of Note 2 to entry.]

### 3.1.31

#### **near-field effect**

deviation of the field propagation from far-field propagation

<sup>3</sup> Figures in square brackets refer to the Bibliography.

Note 1 to entry: The near-field effect occurs in the zone close to the EUT where reactive (non-radiating) field-strength components exist. Although not contributing to far-field radiation, they are real measurable field strengths.

Note 2 to entry: A criterion can be set to limit the deviation from far-field propagation, e.g. 1 dB. If  $E_1$  and  $E_2$  are field-strength levels in dB( $\mu$ V/m) at distances  $d_1$  and  $d_2$  from an EUT, then e.g. the following inequality describes the criterion:  $(20\lg(d_2/d_1) - 1 \text{ dB}) \leq (E_1 - E_2) \leq (20\lg(d_2/d_1) + 1 \text{ dB})$ , which can be reduced to  $-1 \text{ dB} \leq [(E_1 - E_2) - 20\lg(d_2/d_1)] \leq 1 \text{ dB}$ , where  $(E_1 - E_2) \geq 6 \text{ dB}$ .

### 3.1.32

#### test volume

validated volume within a test facility in which an EUT may be positioned

Note 1 to entry: Validation procedures in CISPR 16-1-4 are used to determine the test volume.

Note 2 to entry: The test volume as defined in this document is cylindrical in shape. Different test volume shapes have been defined in other documents, e.g. in a cubic form in IEC 61000-4-20 (TEM waveguides).

### 3.1.33

#### EUT volume

cylinder defined by EUT boundary diameter and height that fully encompasses all portions of the actual EUT, including cable racks and 1,6 m of cable length (for 30 MHz to 1 GHz), or 0,3 m of cable length (for 1 GHz and above)

Note 1 to entry: The test volume is one of several criteria limiting the EUT volume.

Note 2 to entry: The EUT volume has a diameter  $D$  (boundary diameter) and a height  $h$ .

### 3.1.34

#### protection distance

distance between the source of a radiated disturbance and the victim receiver at the edge-of-service area used for the derivation of a specific CISPR radiated disturbance limit

Note 1 to entry: The edge-of-service area is defined by the minimum value of the wanted field strength of a radio service or application derived from ITU-R specifications.

Note 2 to entry: This definition can vary in other publications, when conducted disturbances are concerned.

Note 3 to entry: Every limit has an associated protection distance; the protection distance can vary with frequency.

### 3.1.35

#### small EUT

equipment under test, including its cables, either positioned on a tabletop or standing on the floor, that fits in a cylindrical volume of 1,5 m (2,0 m) in diameter and 1,5 m (2,0 m) in height measured from the floor with a measurement distance of 3 m (5 m) at an OATS/SAC

### 3.1.36

#### feed point of a shielded loop antenna

location of the slit in the shielding of a loop antenna

Note 1 to entry: The feed point of a shielded loop antenna is important for a correct set-up. The location of the feed point has an influence on the site insertion loss between two magnetic field antennas [24], [25].

## 3.2 Abbreviated terms

The following abbreviations, not already provided in 3.1 are used in this standard.

|     |                                    |
|-----|------------------------------------|
| AF  | Antenna factor                     |
| AM  | Amplitude modulation               |
| APD | Amplitude probability distribution |
| AV  | Average                            |
| BB  | Broadband                          |

|                |                                   |
|----------------|-----------------------------------|
| CW             | Continuous wave                   |
| FFT            | Fast-Fourier transform            |
| FM             | Frequency modulation              |
| FSOATS         | free-space OATS                   |
| GP             | ground plane                      |
| HPBW           | Half-power beamwidth              |
| IF             | Intermediate frequency            |
| ISM            | Industrial, scientific or medical |
| LPDA           | Log-periodic dipole array         |
| NB             | Narrowband                        |
| NSA            | Normalized site attenuation       |
| PRF            | Pulse repetition frequency        |
| RBW            | Resolution bandwidth              |
| RE             | radiated emission                 |
| RF             | Radio frequency                   |
| <del>RGP</del> | <del>Reference ground plane</del> |
| RI             | radiated immunity                 |
| QP             | Quasi-peak                        |
| TEM            | Transverse electromagnetic        |
| UFA            | Uniform field area                |
| VBW            | Video bandwidth                   |

## 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>4</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:

- 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);
- 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

<sup>4</sup> Psychophysical means psychological relationship between physical stimuli and sensory response.

- 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.

### 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.

## 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. Should the ambient noise level exceed the required level, it shall be recorded in the test report.

### 6.2.2 Compliance (conformity assessment) testing

A **compliance** test site (**COMTS**) 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 the required ambient level may be determined by measuring the ambient noise level with the test unit in place but not operating.

When evaluating compliance with 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. Further guidance on measurement of disturbances in the presence of ambient emissions is provided in Annex A.

## 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 whose level 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 shall 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 EUT arrangement and measurement conditions

The EUT shall be operated under the following conditions.

### 6.4.1 General arrangement of the EUT

#### 6.4.1.1 General

Where not specified in the product standard, the EUT shall be configured as described below.

The EUT shall be installed, arranged and operated in a manner consistent with typical applications. Where the manufacturer has specified or recommended an installation practice, that practice shall be used in the test arrangement, where possible. This arrangement shall be typical of normal installation practice. Interface cables, loads, and devices shall be connected to at least one of each type of interface port of the EUT and, where practical, each cable shall be terminated in a device typical of actual usage.

Where there are multiple interface ports of the same type, additional interconnecting cables, loads and devices may have to be added to the EUT depending upon the results of preliminary tests. Connecting a cable or wire to just one of that type of port may be sufficient. The actual number of additional cables or wires may be limited to the condition where the addition of another cable or wire does not significantly affect the emission level, i.e. varies less than 2 dB, provided that the EUT remains compliant. The rationale for the selection of the configuration and loading of ports shall be included in the test report.

Interconnecting cables should be of the type and length specified in the individual equipment requirements. If the length can be varied, the length shall be selected to produce maximum disturbance.

If shielded or special cables are used during the tests to achieve compliance, then a note shall be included in the instruction manual advising of the need to use such cables.

Excess lengths of cables shall be bundled at the approximate centre of the cable with the bundles 30 cm to 40 cm in length. If it is impractical to do so because of cable bulk or stiffness, the disposition of the excess cable shall be precisely noted in the test report.

The results of an evaluation of EUTs having one of each type of module can be applied to configurations having more than one of each of those modules. This is permissible because it has been found that disturbances from identical modules are generally not additive in practice. However, the 2 dB criteria defined in this clause shall be applied.

Any set of results shall be accompanied by a complete description of the cable and equipment orientation so that results can be reproduced. If specific conditions of use are required to meet the limits, those conditions shall be specified and documented; for example cable length, cable type, shielding and grounding. These conditions shall be included in the instructions to the user.

Equipment that is populated with multiple modules (drawer, plug-in card, board, etc.) shall be tested with a mix and number representative of that used in a typical installation. The number of additional boards or plug-in cards of the same type may be limited to the condition where the addition of another board or plug-in card does not significantly affect the emission level, i.e. varies less than 2 dB, provided that the EUT remains compliant. The rationale used for selecting the number and type of modules shall be stated in the test report.

A system that consists of a number of separate units shall be configured to form a minimum representative configuration. The number and mix of units included in the test configuration shall be representative of that used in a typical installation. The rationale used for selecting units shall be stated in the test report.

At least one module of each type shall be operative in each equipment evaluated in an EUT. For a system EUT, at least one of each type of equipment that can be included in the possible system configuration shall be included in the EUT.

The EUT position relative to the ~~RGP~~ GP shall be equivalent to that occurring in use. Therefore, floor-standing equipment is placed on, but insulated from, a ~~RGP~~ GP, and tabletop equipment is placed on a non-conductive table.

Equipment designed for wall-mounted or ceiling mounted operation shall be tested as tabletop EUT. The orientation of the equipment shall be consistent with normal installation practice.

Combinations of the equipment types identified above shall also be arranged in a manner consistent with normal installation practice. Equipment designed for both tabletop and floor standing operation shall be tested as tabletop equipment unless the usual installation is floor standing, then that arrangement shall be used.

The ends of signal cables attached to the EUT that are not connected to another unit or auxiliary equipment shall be terminated using the correct terminating impedance defined in the product standard.

Cables or other connections to associated equipment located outside the test area shall drape to the floor, and then be routed to the place where they leave the test volume.

Auxiliary equipment shall be installed in accordance with normal installation practice. Where this means that the auxiliary equipment is located on the test site, it shall be arranged using the same conditions applicable for the EUT (e.g distance from ground plane and insulation from the ground plane if floor standing, and layout of cabling).

#### 6.4.1.2 Tabletop arrangement

Equipment intended for tabletop use shall be placed on a non-conductive table. The size of the table will nominally be 1,5 m by 1,0 m, but may ultimately be dependent on the horizontal dimensions of the EUT.

All units forming the system under test (including the EUT, connected peripherals and auxiliary equipment or devices) shall be arranged according to normal use. Where not defined in the normal use, a nominal 0,1 m separation distance between the neighbouring units shall be defined for the test arrangement.

Intra-unit cables shall be draped over the back of the table. If a cable hangs closer than 0,4 m to the horizontal ground plane (or floor), the excess shall be folded at the cable centre into a bundle no longer than 0,4 m, such that the bundle is at least 0,4 m above the horizontal ~~RGP~~ GP.

Cables shall be positioned as for normal usage.

If the mains port input cable is less than 0,8 m long, (including power supplies integrated in the mains plug) an extension cable shall be used such that the external power supply unit is placed on the tabletop. The extension cable shall have characteristics similar to the mains cable (including the number of conductors and the presence of a ground connection). The extension cable shall be treated as part of the mains cable.

In the above arrangements, the cable between the EUT and the power accessory shall be arranged on the tabletop in the same manner as other cables connecting components of the EUT.

#### 6.4.1.3 Floor-standing arrangement

The EUT shall be placed on the horizontal ~~RGP~~ GP, orientated for normal use, but separated from metallic contact with the ~~RGP~~ GP by up to 15 cm of insulation.

The cables shall be insulated (by up to 15 cm) from the horizontal ~~RGP~~ GP. If the equipment requires a dedicated ground connection, then this shall be provided and bonded to the horizontal ground plane.

Intra-unit cables (between units forming the EUT or between the EUT and auxiliary equipment) shall drape to, but remain insulated from, the horizontal ~~RGP~~ GP. Any excess shall either be folded at the cable centre into a bundle no longer than 0,4 m or arranged in a serpentine fashion. If an intra-unit cable length is not long enough to drape to the horizontal ~~RGP~~ GP but drapes closer than 0,4 m, then the excess shall be folded at the cable centre into a bundle no longer than 0,4 m. The bundle shall be positioned such that it is either 0,4 m above the horizontal ~~RGP~~ GP or at the height of the cable entry or connection point if this is within 0,4 m of the horizontal ~~RGP~~ GP.

For equipment with a vertical cable riser, the number of risers shall be typical of installation practice. Where the riser is made of non-conductive material, a minimum spacing of at least 0,2 m shall be maintained between the closest part of the equipment and the nearest vertical cable. Where the riser structure is conductive, the minimum spacing of 0,2 m shall be between the closest parts of the equipment and riser structure.

#### **6.4.1.4 Combinations of tabletop and floor-standing equipment arrangement**

Intra-unit cables between a tabletop unit and a floor standing unit shall have the excess folded into a bundle no longer than 0,4 m. The bundle shall be positioned such that it is either 0,4 m above the horizontal ~~RGP~~ GP or at the height of the cable entry or connection point if this is within 0,4 m of the horizontal ~~RGP~~ GP.

#### **6.4.2 Operation of the EUT**

The operating conditions of the EUT shall be determined by the manufacturer according to the typical use of the EUT with respect to the expected highest level of emission. The determined operational mode and the rationale for the selected operating conditions shall be stated in the test report.

The EUT shall be operated within the rated (nominal) operating voltage range and typical load conditions (mechanical or electrical) for which it is designed. Actual loads should be used whenever possible. If a simulator is used, it shall represent the actual load with respect to its radio frequency and functional characteristics.

The test programmes or other means of exercising the equipment should ensure that various parts of a system are exercised in a manner that permits detection of all system disturbances.

#### **6.4.3 EUT 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 EUT shall be continuously operated throughout the test.

#### **6.4.4 EUT 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 product standards.

#### **6.4.5 EUT 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 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.

#### **6.4.6 EUT mode of operation**

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

#### **6.4.7 Operation of multifunction equipment**

Multifunction equipment which is subjected simultaneously to different clauses of a product standard, and/or different standards, shall be tested with each function operated in isolation, if this can be achieved without modifying the equipment internally. The equipment thus tested

shall be deemed to have complied with the requirements of all clauses and/or standards when each function has satisfied the requirements of the relevant clause and/or standard.

For equipment where it is not practical to test with each function operated in isolation, or where the isolation of a particular function would result in the equipment being unable to fulfil its primary function, or where the simultaneous operation of several functions would result in saving measurement time, the equipment shall be deemed to have complied if it meets the provisions of the relevant clause and/or standard with the necessary functions operated.

#### **6.4.8 Determination of arrangement(s) causing maximum emissions**

Initial testing shall identify the frequency that has the highest disturbance relative to the limit. This identification shall be performed while operating the EUT in typical modes of operation and with cable positions in a test arrangement that is representative of typical installation practice.

The frequency of highest disturbance with respect to the limit shall be found by investigating disturbances at a number of significant frequencies. This provides confidence that the probable frequency of maximum disturbance has been found and that the associated cable, EUT arrangement and mode of operation has been identified.

For initial testing, the EUT should be arranged in accordance with the product standards as appropriate.

#### **6.4.9 Recording of measurements**

Of those disturbances above ( $L - 20$  dB), where  $L$  is the limit level in logarithmic units, the disturbance levels and the frequencies of at least the six highest disturbances shall be recorded.

For radiated disturbances, the antenna polarization and height for each reported disturbance shall be recorded.

### **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 4.4 of CISPR 14-1:2016).
- 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.

### 6.5.3 Measurement of the duration of disturbance

The duration of a disturbance shall be known in order to measure it correctly and to determine if it is discontinuous. The duration of a disturbance may be measured in one of the following ways:

- through the connection of an oscilloscope to a measuring receiver's IF output to allow monitoring of the disturbance in the time-domain;
- through the tuning of either an EMI receiver or a spectrum analyzer to the disturbance frequency without frequency scanning (i.e. 'zero-span' mode) to allow monitoring of the disturbance in the time-domain; or
- through the use of the time-domain output of an FFT-based measuring receiver.

Guidance for the determination of the appropriate measurement time can be found in 8.3.

## 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

The minimum measurement (dwell) times are given in Table 1. From Table 1, the minimum scan times for measurements over a complete CISPR band have been derived in Table 2. These minimum measurement (dwell) times for scanning receivers and FFT-based measuring instruments in Table 1 and the scan times for spectrum analyzers in Table 2 apply to CW signals.

In addition, the test report shall include the value of the measurement instrumentation uncertainty corresponding to the used test set-up, calculated as per the requirements of CISPR 16-4-2.

**Table 1 – Minimum measurement times for the four CISPR bands**

| Frequency band |                     | Minimum measurement time $T_m$ |
|----------------|---------------------|--------------------------------|
| A              | 9 kHz to 150 kHz    | 10,00 ms                       |
| B              | 0,15 MHz to 30 MHz  | 0,50 ms                        |
| C and D        | 30 MHz to 1 000 MHz | 0,06 ms                        |
| E              | 1 GHz to 18 GHz     | 0,01 ms                        |

**Table 2 – Minimum scan times for the three CISPR bands  
with peak and quasi-peak detectors**

| Frequency band |                     | Scan time $T_s$ for<br>peak detection | Scan time $T_s$ for<br>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           |

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 shall 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.

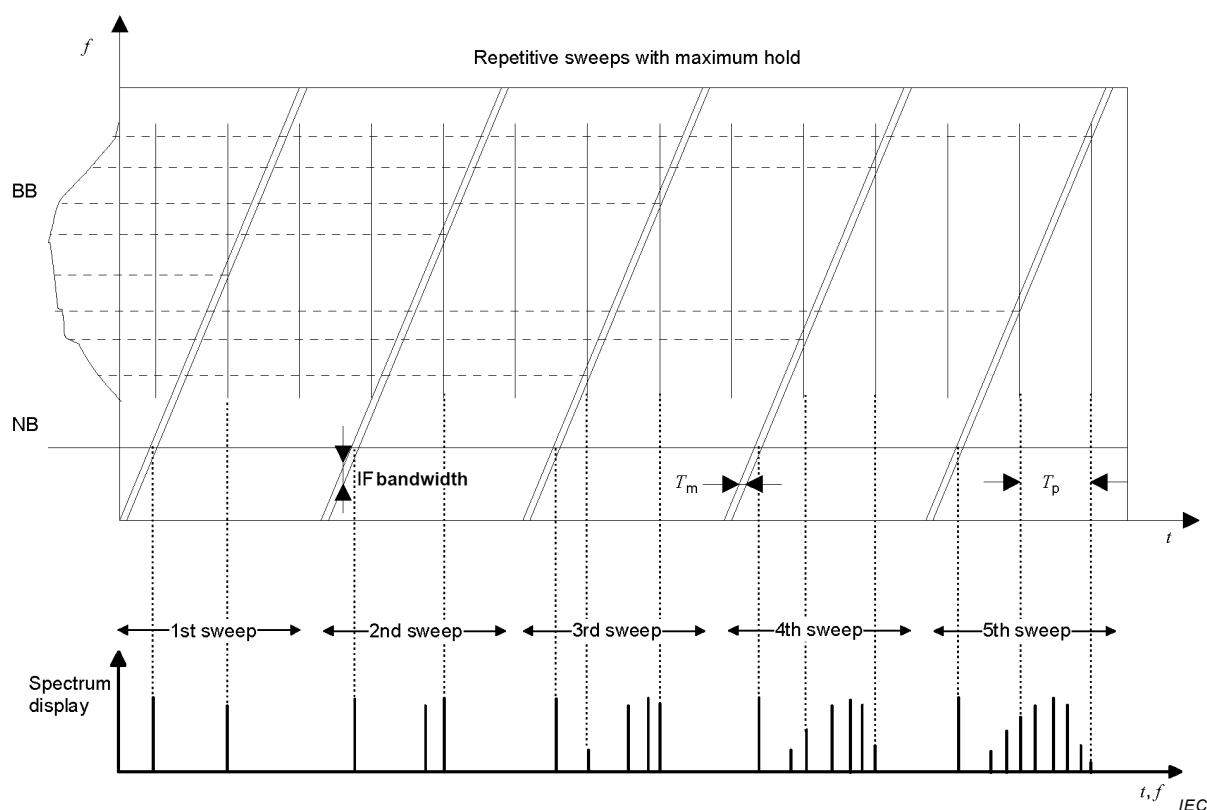
For purely broadband emissions, the frequency step size may be increased. In this case, the objective is to find the maxima of the emission spectrum only.

### 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 shall 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.



**Key:**

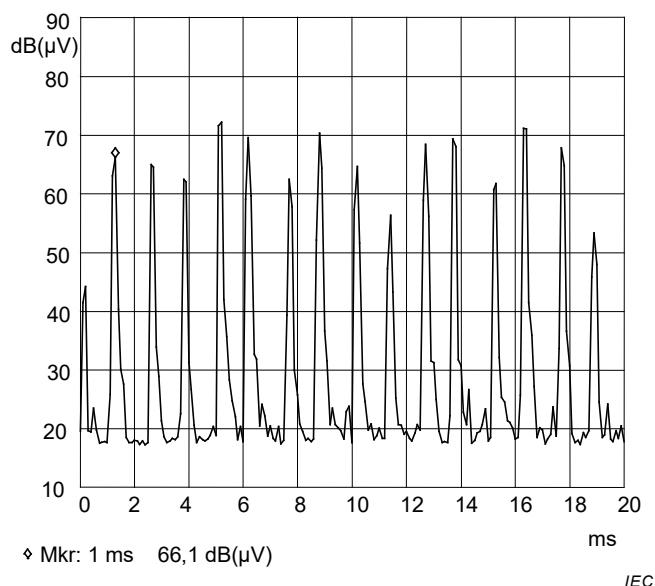
$T_o$  is the pulse-repetition interval of the impulsive signal. A pulse occurs at each vertical line of the spectrum versus time display (upper part of the figure).

**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.

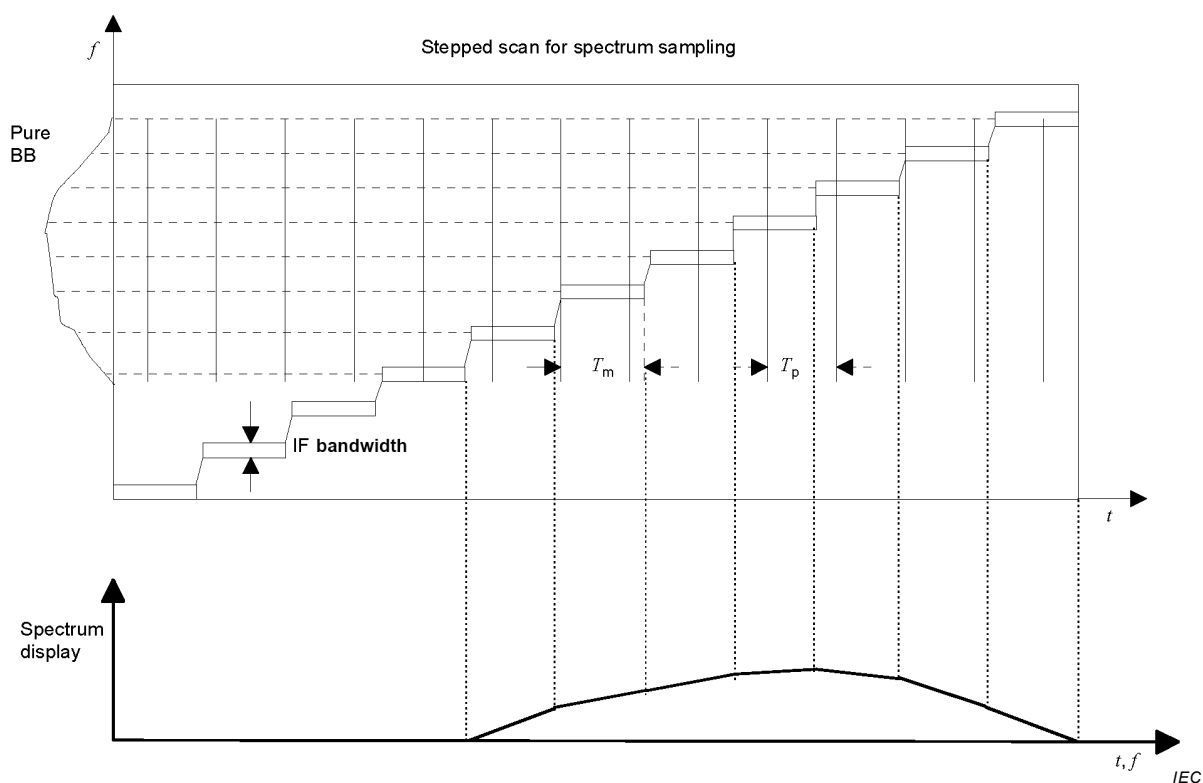


NOTE Disturbance from a d.c. collector motor; due to the number of collector segments, the pulse repetition frequency is high (approximately 800 Hz) and the pulse amplitude varies considerably. Therefore for this example, the recommended measurement (dwell) time with the peak detector is >10 ms.

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

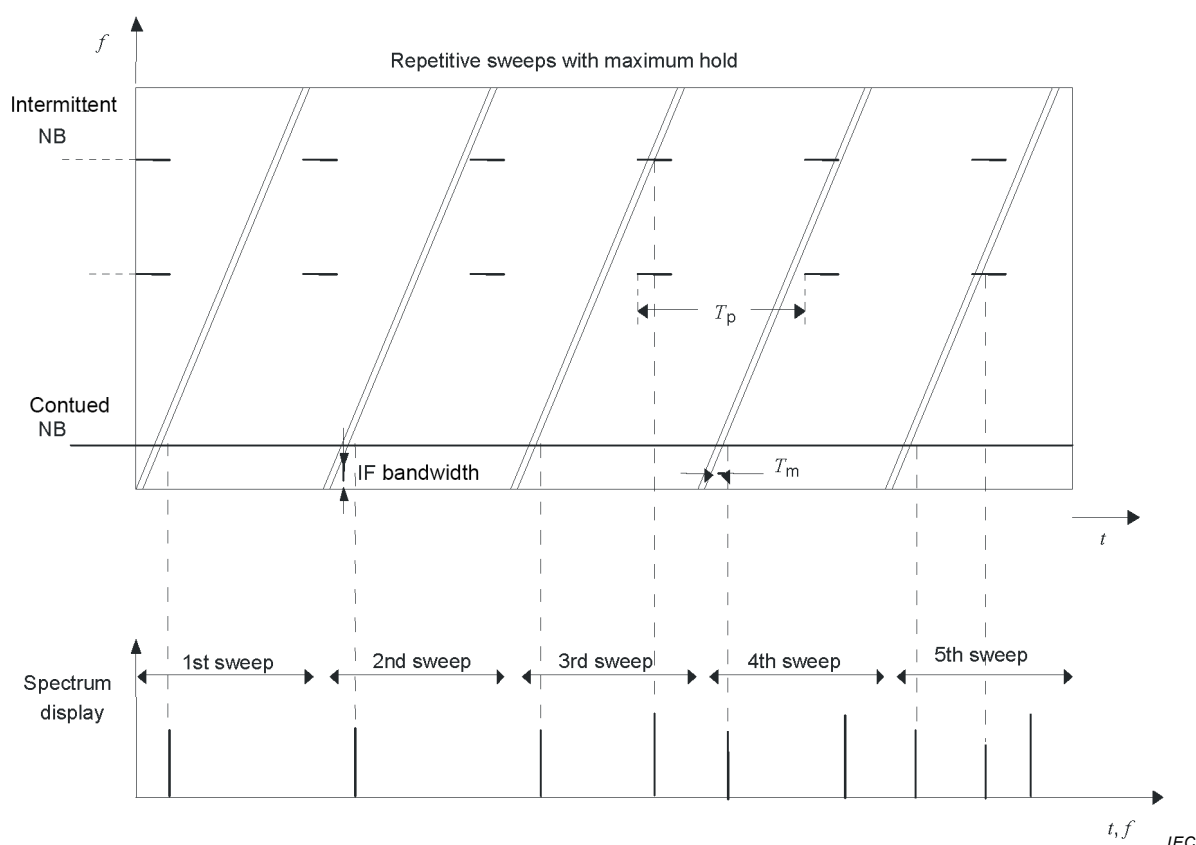
From such a timing analysis, pulse durations and pulse repetition frequencies can be determined and scan rates or dwell times selected, and according to the following:

- 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.



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**

#### 6.6.6 Timing considerations using FFT-based instruments

FFT-based measuring instruments may combine the parallel calculation at  $N$  frequencies and a stepped scan. For this purpose the frequency range of interest is subdivided into a number of segments  $N_{\text{seg}}$  that are scanned sequentially. The procedure is shown in Figure 5 for three segments. The total scan time for the frequency range of interest  $T_{\text{scan}}$  is calculated as:

$$T_{\text{scan}} = T_m N_{\text{seg}} \quad (4)$$

where

$T_m$  is the measurement time for each segment, and

$N_{\text{seg}}$  is the number of segments.

FFT-based measuring instruments may also provide methods to improve the frequency resolution across a given frequency range. In general, an FFT-based measuring instrument will have a fixed frequency step  $f_{\text{step FFT}}$  that is determined by the number of frequencies of the FFT. Increased frequency resolution is achieved by performing repeat calculations over a given

frequency range. For each repeat calculation, the lowest frequency is incremented by a frequency step,  $f_{\text{step final}}$ .

Hence the first calculation over the given frequency range considers the following frequencies:

$$\begin{aligned} &f_{\text{min}}, \\ &f_{\text{min}} + f_{\text{step FFT}}, \\ &f_{\text{min}} + 2f_{\text{step FFT}}, \\ &f_{\text{min}} + 3f_{\text{step FFT}} \dots \end{aligned}$$

The second calculation over the given frequency range considers the following frequencies:

$$\begin{aligned} &f_{\text{min}} + f_{\text{step final}}, \\ &f_{\text{min}} + f_{\text{step final}} + f_{\text{step FFT}}, \\ &f_{\text{min}} + f_{\text{step final}} + 2f_{\text{step FFT}}, \\ &f_{\text{min}} + f_{\text{step final}} + 3f_{\text{step FFT}} \dots \end{aligned}$$

This procedure, applied for a step ratio of 3, is displayed in Figure 6.

The scan time  $T_{\text{scan}}$  is calculated as:

$$T_{\text{scan}} = T_m \frac{f_{\text{step FFT}}}{f_{\text{step final}}} \quad (5)$$

where

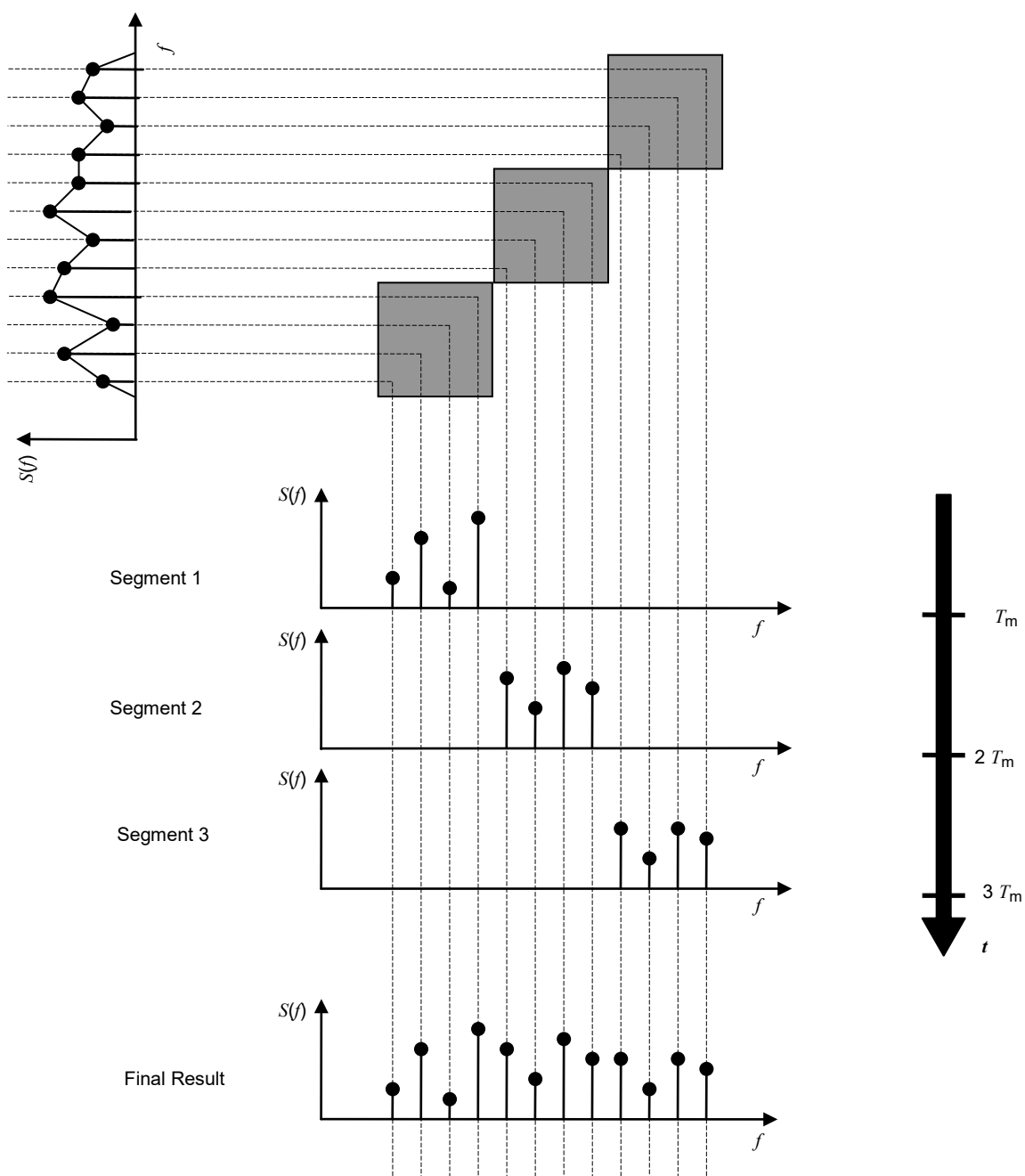
$T_m$  is the measurement time, and  
 $\frac{f_{\text{step FFT}}}{f_{\text{step final}}}$  is the step ratio.

For a system that combines both methods the scan time  $T_{\text{scan}}$  is calculated as:

$$T_{\text{scan}} = T_m N_{\text{seg}} \frac{f_{\text{step FFT}}}{f_{\text{step final}}} \quad (6)$$

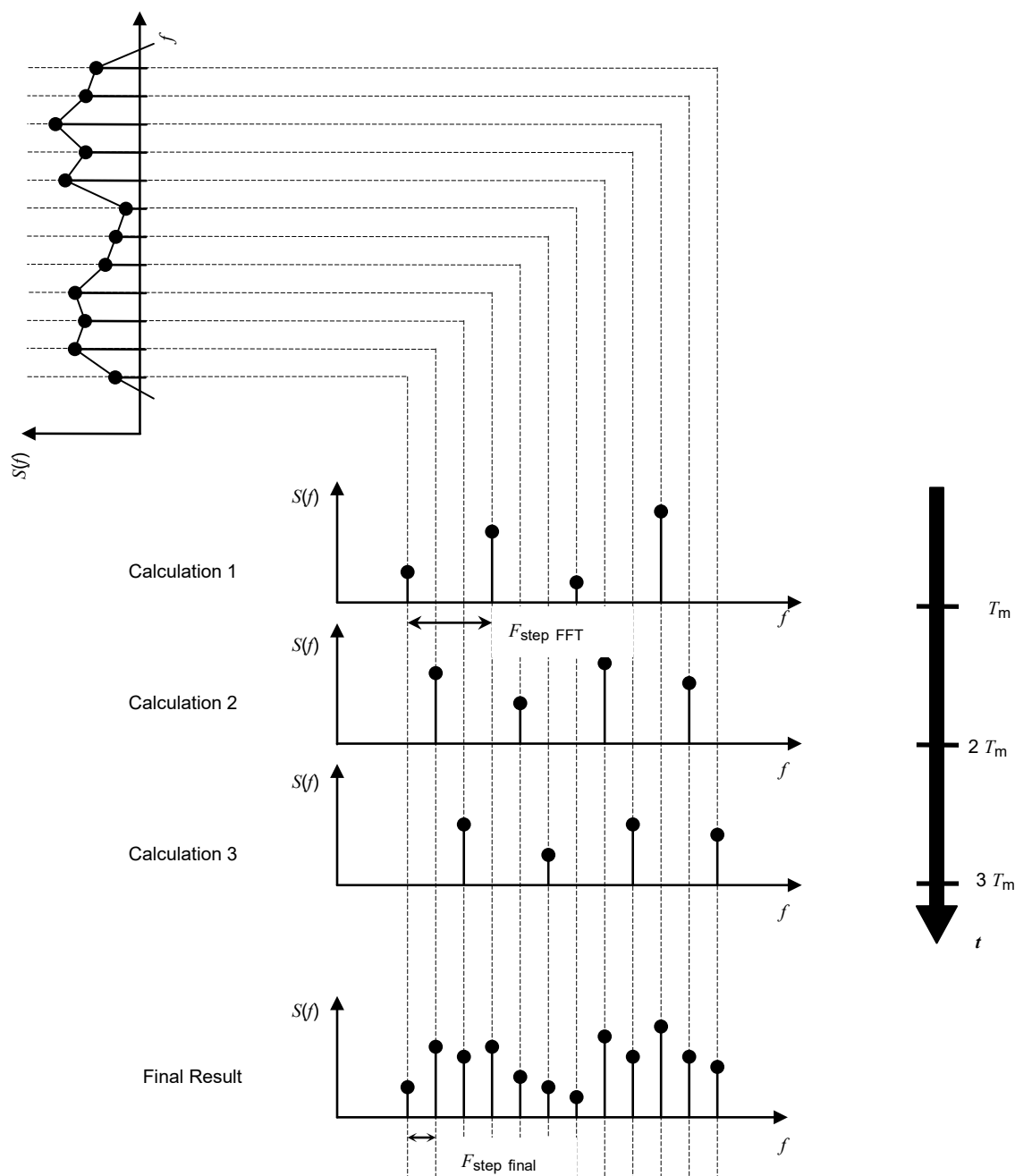
NOTE 1 FFT-based measuring instruments may combine both methods, the stepped scan as well as a method to improve the frequency resolution.

NOTE 2 Additional background information on the definition of the FFT-based receiver can be found in CISPR TR 16-3 [3].



IEC

Figure 5 – FFT scan in segments



IEC

**Figure 6 – Frequency resolution enhanced by FFT-based measuring instrument**

## 7 Measurement of radiated disturbances

### 7.1 ~~Introductory remarks~~ General

~~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 3 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 3 — 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 |                 |                          |                 |

### 7.1.1 General remarks and overview of test methods

Clause 7 sets forth the general procedures for the measurement of the field strength of radio disturbance produced by devices and systems. Most experience with radiated disturbance measurements exists for OATS/SAC with 10 m distance in the frequency range 30 MHz to 1 000 MHz. In this frequency range this is therefore called the established test method to which other test methods are compared regarding the level of radio protection (see also CISPR TR 16-4-5). The effects of leads and cables associated with the EUT in terms of length, layout, and termination shall be taken into account (see Garbe and Battermann [21], Garbe [22]). Table 8 provides a summary list of CISPR radiated disturbance test sites and measurement methods, and the related cross-references to subclauses within this document or to other documents. Tables 9, 10, 11 and 12 provide information on maximum EUT volumes associated with the various measurement methods. Background on the criteria for EUT volumes is given in Annex F.

For some products, it can be required to measure the electric field strength, the magnetic field strength, 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 relative to the installation plane.

or ground plane. The results of measurements of either the electric field-strength component or magnetic field-strength component may be expressed in peak, quasi-peak, average, or rms-average values.

The magnetic field strength component of a disturbance is typically measured at frequencies up to 30 MHz. Generally, in magnetic field strength measurements, the horizontal and vertical components of the field at the position of the receiving antenna are measured when using the distant single antenna procedure. If an LLAS is used, the three orthogonal magnetic dipole moments of the EUT are measured.

NOTE 1 In the magnetic field-strength measurement method using a distant single antenna (e.g. 60 cm loop antenna), the horizontal components of the field at the position of the antenna are determined by the horizontal and vertical dipole moments of the EUT.

**Table 8 – Applicable frequency ranges and document references  
for CISPR radiated disturbance test sites and measurement 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             |
| LLAS                                                                   | 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 starts 80 MHz) | n/a             |
| Absorber-lined<br>OATS/SAC                                             | n/a             | n/a                       | 7.6             |
| <i>In situ</i>                                                         | 7.7.2           | 7.7.3, 7.7.4.2            | 7.7.3, 7.7.4.3  |
| Substitution method                                                    | n/a             | 7.8                       | 7.8             |
| Reverberation chamber                                                  | n/a             | 7.9<br>(Starts 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 |                 |                           |                 |

## 7.1.2 Overview of maximum EUT volumes depending on measurement method, frequency range, and measurement distance

### 7.1.2.1 Frequency range 9 kHz to 30 MHz

- a) Maximum EUT dimensions for large-loop antenna system (LLAS) measurements are listed in Table 9.

It is recommended to use a 3 m LLAS for  $1,6 \text{ m} < \text{EUT dimensions} \leq 2,4 \text{ m}$ , and to use a 4 m LLAS for  $2,4 \text{ m} < \text{EUT dimensions} \leq 3,2 \text{ m}$ .

**Table 9 – Maximum EUT dimensions for different LLAS diameters, 9 kHz to 30 MHz**

| LLAS diameter                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2 m   | 3 m   | 4 m   |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|-------|
| EUT dimension <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1,6 m | 2,4 m | 3,2 m |
| <sup>a</sup> The specified EUT dimension applies for the diameter of a sphere that fully encompasses the EUT; e.g. for an EUT in the form of a cube, the maximum cube side length for a 2 m LLAS will be $(1,6 \text{ m})/\sqrt{3} = 0,92 \text{ m}$ ; for a 3 m LLAS: $(2,4 \text{ m})/\sqrt{3} = 1,39 \text{ m}$ ; and for a 4 m LLAS: $(3,2 \text{ m})/\sqrt{3} = 1,85 \text{ m}$ . These maximum EUT dimensions are the same as specified in CISPR 16-1-4. |       |       |       |

- b) Recommended maximum EUT dimensions for an OATS/SAC or an outdoor site are listed in Table 10.

**Table 10 – Recommended maximum EUT-volume diameter  $D$  (in m) and height  $h$  (in m), OATS/SAC and outdoor site, 9 kHz to 30 MHz**

| Measurement distance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 3 m                     | 5 m                     | 10 m       | 30 m                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------------------|------------|------------------------|
| $D$ by $h$ at OATS/SAC <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1,5 by 1,5 <sup>b</sup> | 2,0 by 2,0 <sup>b</sup> | 5,0 by 4,0 | 15 by 4,0 <sup>d</sup> |
| $D$ by $h$ at outdoor site <sup>c</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1,5 by 1,5 <sup>b</sup> | 2,0 by 2,0 <sup>b</sup> | 5,0 by 4,0 | 15 by 4,0 <sup>d</sup> |
| <sup>a</sup> Test site specifications and validation methods for OATS/SAC are under development.<br><sup>b</sup> EUT volumes less than or equal to those for $d = 3 \text{ m}$ ( $5 \text{ m}$ ) are small EUTs, as defined in 3.1.35. Disturbance limits for larger EUTs can be defined for these distances taking the EUT volume diameter into account (see e.g. [18]). Work is in progress to define conditions for medium-sized EUT volumes.<br><sup>c</sup> An outdoor site is a non-validated test site without a conducting ground plane.<br><sup>d</sup> The EUT diameter for 30 m is proportional to the diameters for 3 m and 10 m. The distance of 30 m is regarded as a protection distance, where any EUT volume that is encompassed by the receive antenna beamwidth is acceptable. This table includes the 30 m distance because it is specified in CISPR 11, regardless that an associated validation method is not available or in preparation for the frequency range 9 kHz to 30 MHz. EUT height is limited to 4 m, because heights greater than 4 m are not practically needed. |                         |                         |            |                        |

- c) Maximum EUT dimensions in a TEM waveguide are as follows.

The usable test volume is  $0,6W$  by  $0,6L$  by  $0,33H$ , where  $W$  = the (average) septum width,  $H$  = the (average) septum height, and  $L = z_{\max} - z_{\min}$ , i.e. the region where the TEM mode requirements are fulfilled (see IEC 61000-4-20). The EUT volume is limited by the test volume.

### 7.1.2.2 Frequency range 30 MHz to 1 000 MHz

- a) Maximum EUT dimensions for an OATS/SAC and a FAR are listed in Table 11.

**Table 11 – Maximum EUT-volume diameter  $D$  (in m) and height  $h$  (in m),  
OATS/SAC and FAR, 30 MHz to 1 000 MHz**

| Measurement distance   | 3 m        | 5 m                     | 10 m                    | 30 m                   |
|------------------------|------------|-------------------------|-------------------------|------------------------|
| $D$ by $h$ at OATS/SAC | 1,5 by 1,5 | 2,0 by 2,0              | 5,0 by 4,0 <sup>a</sup> | 15 by 4,0 <sup>a</sup> |
| $D$ by $h$ in FAR      | 1,5 by 1,5 | 2,0 by 2,0 <sup>b</sup> | 3,0 by 3,0 <sup>b</sup> | -                      |

NOTE EUT volumes less than or equal to those for  $d = 3$  m (5 m) are small EUTs as defined in 3.1.35. Work is in progress to define conditions for medium-sized EUT volumes.

<sup>a</sup> For an OATS/SAC, the EUT volume at 10 m and 30 m distances is a recommendation only because these distances may be regarded as protection distances, where any EUT volume that is encompassed by the receive antenna beamwidth is accepted, provided that the test volume fulfils the validation criteria.

<sup>b</sup> Table 14 of CISPR 16-1-4 specifies maximum diameters and heights of the EUT volume for radiated disturbance measurements in a FAR as 1,5 m, 2,5 m, and 5 m for measurement distances  $d = 3$  m, 5 m, and 10 m, respectively. The reason why the maximum EUT dimensions are less than 2,5 m and 5 m at  $d = 5$  m and 10 m, respectively, is mainly due to the near-field effect and the fact that a FAR is an alternative test site.

b) Maximum EUT dimensions in a TEM waveguide are as follows.

The usable test volume is  $0,6w$  by  $0,6L$  by  $0,33h$ . For definitions of  $w$ ,  $L$ , and  $h$ , see 7.1.2.1 c).

c) Maximum EUT dimensions in a reverberation chamber (RC) are as follows.

At the lowest usable frequency of an RC, the EUT shall be at least  $\lambda/4$  away from the chamber walls. Additional space is required for the tuner/stirrer and for the transmit antenna and receive antenna; see IEC 61000-4-21 for details.

### 7.1.2.3 Frequency range 1 GHz to 18 GHz

a) Recommended maximum EUT dimensions for an absorber-lined OATS/SAC and FAR are listed in Table 12.

**Table 12 – Recommended maximum EUT-volume diameter  $D$  (in m) and height  $h$  (in m) –  
for reduced near-field uncertainty; absorber-lined OATS/SAC and FAR,  
1 GHz to 18 GHz**

| Measurement distance                        | 3 m        | 5 m        | 10 m       |
|---------------------------------------------|------------|------------|------------|
| $D$ by $h$ in 1 GHz to 6 GHz <sup>a,b</sup> | 1,5 by 1,5 | 2,0 by 2,0 | 5,0 by 3,0 |
| $D$ by $h$ in 6 GHz to 18 GHz <sup>a</sup>  | 1,5 by 1,5 | 2,0 by 2,0 | 5,0 by 3,0 |

<sup>a</sup> The minimum antenna beamwidths required for the EUT volumes in this table are  $28^\circ$  (for  $d = 3$  m),  $22,6^\circ$  (for  $d = 5$  m) and  $22,6^\circ$  (for  $d = 10$  m), as determined using Equation (13); see also Table 5.

<sup>b</sup> At present CISPR 32 does not specify disturbance limits for frequencies above 6 GHz. If CISPR disturbance limits for frequencies above 6 GHz are adopted, the EUT dimension recommendations might have to be amended.

b) Maximum EUT dimensions in a TEM waveguide are as follows.

The usable test volume is  $0,6w$  by  $0,6L$  by  $0,33h$ . For definitions of  $w$ ,  $L$ , and  $h$ , see 7.1.2.1 c).

c) Maximum EUT dimensions in a reverberation chamber (RC) – see 7.1.2.2 c).

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

### 7.2.1 General

The ~~loop-antenna system (LAS)~~ LLAS 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 LLAS by the magnetic disturbance field of the EUT. The LLAS shall be validated regularly using the method described in CISPR 16-1-4. CISPR 16-1-4 also gives a complete description of the LLAS and a relation between the measuring results obtained with the LLAS and those obtained as described in this subclause.

### 7.2.2 General measurement method

Figure 7 shows the general concept of measurements made with the LLAS. The EUT is placed in the centre of the LLAS. The current induced by the magnetic field strength from the EUT into each of the three large loop antennas of the LLAS 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 strength components, are measured in sequence. Each current level measured shall comply with the emission limit, expressed in dB( $\mu$ A), as specified in the product standard. The emission limit shall apply for an LLAS having large loop antennas with the standardized diameter of 2 m.

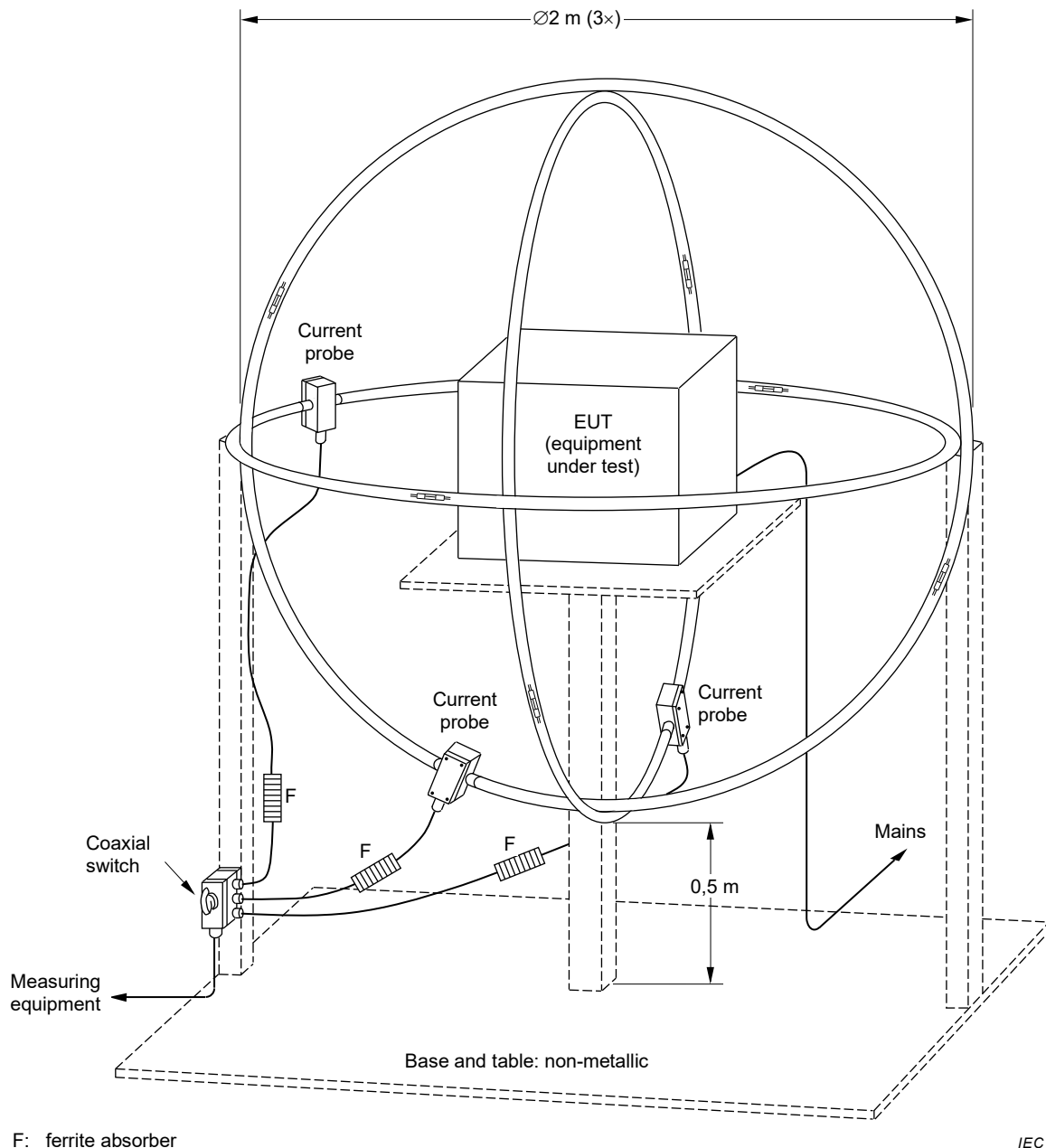


**Figure 7 – Concept of magnetic field induced current measurements made with the loop antenna system**

### 7.2.3 Test environment

The distance between the outer perimeter of the LLAS and nearby objects, such as floor and walls, shall be at least 0,5 m. The currents induced in the LLAS 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 LLAS, 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 LLAS.

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 LLAS may be increased up to 4 m. In that case:

- a) the current values measured shall be corrected in accordance with Clause B.6 of CISPR 16-1-2:2014; 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 LLAS

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  $F_a$ :

$$E = V_r + A_c + F_a \quad (7)$$

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.

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

In an EMC disturbance measurement the electric field strength is required at a given distance from the boundary of the EUT. The test distance is measured from the reference point of the antenna to the boundary of the EUT (see Figure 8). 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.

NOTE 1 See also 7.5.2.2 and A.6.2 of CISPR 16-1-6:2014 [2] about corrections of field strength results for antenna phase centre variations.

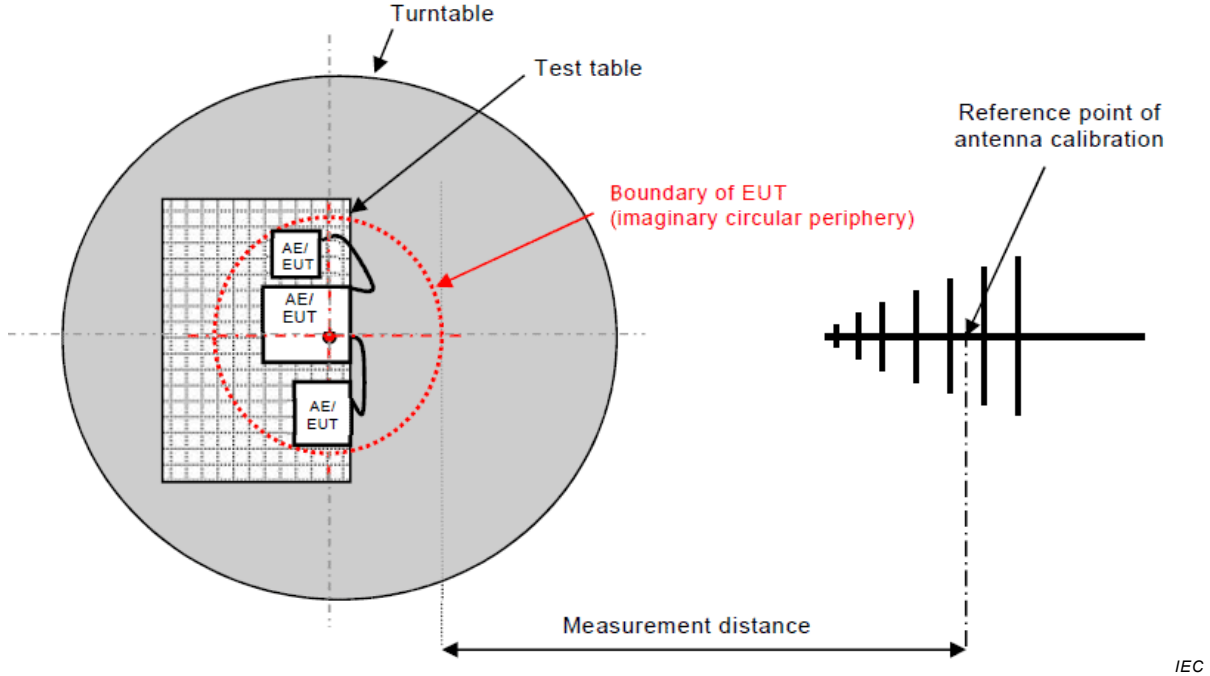


**Figure 8 – Measurement distance**

As an example, consider a typical log-periodic dipole array (LPDA) antenna that has a separation of approximately 0,6 m between the dipole that is responsive to the field at 200 MHz and the dipole that is responsive at 1 000 MHz. For the measurement of the emission at a distance  $d = 3$  m from the EUT, at a frequency of 200 MHz, the electric field strength will be measured at a distance of approximately 3,3 m from P2 in Figure 9, according to the value of  $d_{\text{phase}}$  from Equation (11), where P2 is the boundary of the EUT.

For a given frequency, the following correction,  $\Delta E$  in dB, shall be added to the measured electric field strength:

$$\Delta E = 20 \lg \left( \frac{d_{\text{phase}}}{d} \right) \quad (8)$$

Referring to Figure 9 the distance from P2 to the resonant element at a given frequency is  $d_{\text{phase}}$  given by Equation (9). Point P1 is the manufacturer's mark or the centre of the antenna,  $d_{1P}$  is the distance from the tip of the antenna to P1 and  $d_{1f}$  is the distance from the tip of the antenna to the phase centre position at frequency  $f$ .

$$d_{\text{phase}} = d + (d_{1f} - d_{1P}) \quad (9)$$

where

$$d_{1f} = \frac{(l_f - l_{\min})(d_{\max} - d_{\min})}{l_{\max} - l_{\min}} + d_{\min} \quad (10)$$

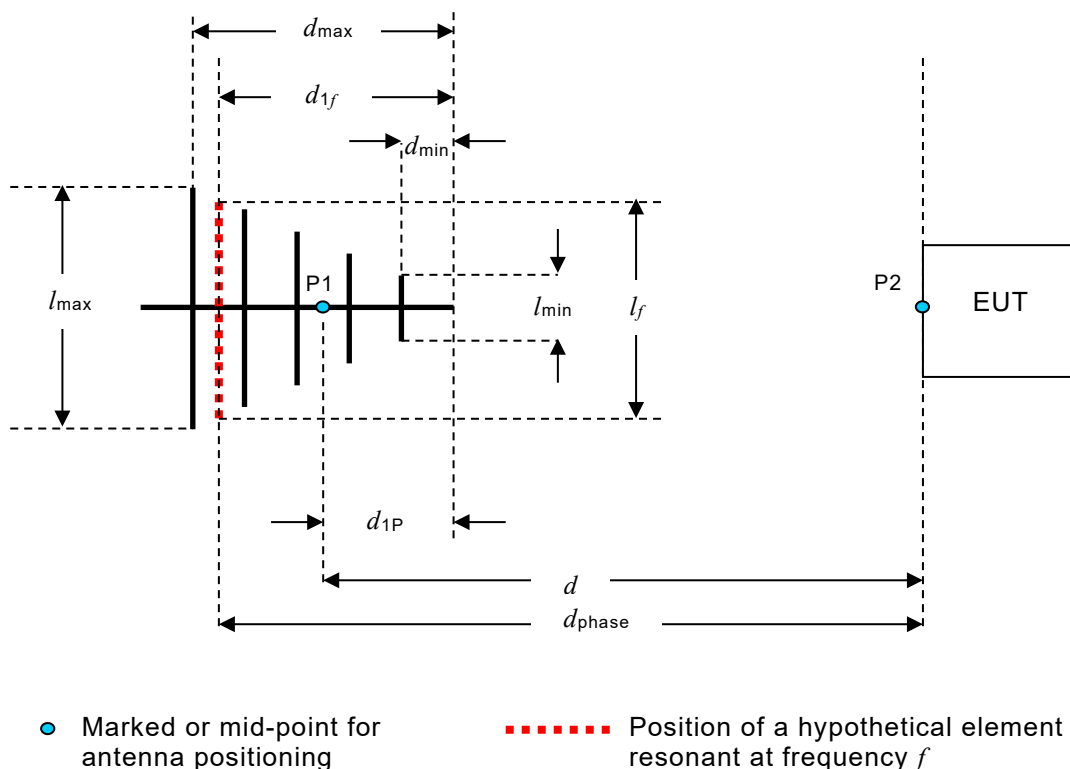
- $l_f$  is the length of the dipole element that is nominally resonant at frequency  $f$  in MHz and is equal to  $0,9 \times 150/f$  in m, where 0,9 is a generic shortening factor due to the finite radius of the dipole [11];
- $l_{\min}$  and  $l_{\max}$  are lengths of the dipoles having minimum and maximum lengths (i.e. the dipoles are resonant at approximately the upper and lower operating frequencies, respectively);
- $d_{\min}$  and  $d_{\max}$  are the distances from the minimum and maximum length dipoles to the antenna tip, respectively.

For hybrid antennas the phase center position  $d_{\text{phase}}$  is determined using information supplied by the antenna manufacturer. In case of tabular form the antenna manufacturer shall provide  $d_{1f}$  for the frequency range 100 MHz to 300 MHz with a maximum frequency step of 20 MHz.

It is assumed in Equation (8) that the field point is in the far-field of the antenna. In a near-field situation, usually for less than half a wavelength, the measurement for  $A_{\text{APR}}$  (see Equation (35-13) of CISPR 16-1-4:2010/AMD1:2012/2019) takes near-field effects into account. For more detail, including corrections for tapered LPDA sections of hybrid antennas, see 7.5.2.2 of CISPR 16-1-6:2014 [2]. Linear interpolation is used to estimate the phase centre position for frequencies between the resonant frequencies of the elements at the ends of the operating frequency range.

If a phase centre correction is not applied it shall be considered in the measurement instrumentation uncertainty budget in accordance with CISPR 16-4-2.

NOTE 2 The antenna calibration laboratory may provide the electric field strength correction for specific measurement distances (e.g. 3 m and 10 m) by equivalent corrections of the antenna factor for these distances.



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**Figure 9 – Separation distance relative to the phase centre of an LPDA antenna**

### 7.3.2 Test site requirements

The **compliance** test site (**COMTS**) 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 10 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.