มาตรฐานผลิตภัณฑ์อุตสาหกรรม

THAI INDUSTRIAL STANDARD

มอก. 2092 เล่ม 3 – 2552

CISPR 16 – 2 – 3(2003)

(Amendment 1(2005))

ข้อกำหนดสำหรับอุปกรณ์และวิธีวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน

เล่ม 2-3 วิธีการวัดสัญญาณรบกวนและภูมิคุ้มกัน - การวัดสัญญาณรบกวนที่แผ่ออก

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS-

PART 2-3 METHODS OF MEASUREMENT OF DISTURBANCES AND IMMUNITY-RADIATED DISTURBANCE MEASUREMENTS

สำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม

กระทรวงอุตสาหกรรม

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มาตรฐานผลิตภัณฑ์อุตสาหกรรม

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สำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม

กระทรวงอุตสาหกรรม ถนนพระรามที่ 6 กรุงเทพฯ 10400

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ประกาศในราชกิจจานุเบกษา ฉบับประกาศและงานทั่วไป เล่ม 127 ตอนพิเศษ 144ง

วันที่ 16 ธันวาคม พุทธศักราช 2553

มาตรฐานผลิตภัณฑ์อุตสาหกรรม ข้อกำหนดสำหรับอุปกรณ์และวิธีวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน เล่ม 2-3 วิธีการวัดสัญญาณรบกวนและภูมิคุ้มกัน-การวัดสัญญาณรบกวนที่แผ่ออก ได้ประกาศใช้ครั้งแรกโดยรับ CISPR 16-2-3 (2003-11) Specification for radio disturbance and immunity measuring apparatus and methods - Part2-3: methods of measurement of disturbances and immunity - Radiated disturbance measurements มาใช้ในระดับเหมือนกัน ทุกประการ (Identical) โดยใช้ CISPR ฉบับภาษาอังกฤษเป็นหลัก โดยประกาศในราชกิจจานุเบกษา ฉบับประกาศทั่วไป เล่มที่ 123 ตอนที่ 84ง วันที่ 24 สิงหาคม พุทธศักราช 2549

เนื่องจาก CISPR ได้แก้ไขปรับปรุงมาตรฐาน CISPR 16-2-3 (2003-11) เป็น CISPR 16-2-3 (2003) (Amendment 1(2005)) จึงได้ยกเลิกมาตรฐานเดิมและกำหนดมาตรฐานใหม่โดยรับ CISPR 16-2-3 (2003) (Amendment 1(2005)) Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3 methods of measurement of disturbances and immunity-Radiated disturbance measurements มาใช้ในทุกระดับเหมือนกันทุกประการโดยใช้มาตรฐาน CISPR ฉบับภาษาอังกฤษเป็นหลัก

คณะกรรมการมาตรฐานผลิตภัณฑ์อุตสาหกรรมได้พิจารณามาตรฐานนี้แล้ว เห็นสมควรเสนอรัฐมนตรีประกาศตามมาตรา 15 แห่งพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม พ.ศ. 2511

ประกาศกระทรวงอุตสาหกรรม

ฉบับที่ 4245 (พ.ศ. 2553)

ออกตามความในพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม

พ.ศ. 2511

เรื่อง ยกเลิกและกำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม

ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน

เล่ม 2-3 วิธีการวัดของสัญญาณรบกวนและภูมิคุ้มกัน - การวัดสัญญาณรบกวนที่แผ่ออก

โดยที่เป็นการสมควรปรับปรุงมาตรฐานผลิตภัณฑ์อุตสาหกรรม ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน เล่ม 2-3 วิธีการวัดของสัญญาณรบกวนและภูมิคุ้มกัน - การวัดสัญญาณรบกวนที่แผ่ออก มาตรฐานเลขที่ มอก.2092 เล่ม 3-2549

อาศัยอำนาจตามความในมาตรา 15 แห่งพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม พ.ศ. 2511 รัฐมนตรีว่าการกระทรวงอุตสาหกรรมออกประกาศยกเลิกประกาศกระทรวงอุตสาหกรรม ฉบับที่ 3498 (พ.ศ.2549) ออกตามความในพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม พ.ศ.2511 เรื่อง กำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน เล่ม 2-3 วิธีการวัดของสัญญาณรบกวนและภูมิคุ้มกัน - การวัดสัญญาณรบกวนที่แผ่ออก ลงวันที่ 14 พฤษภาคม พ.ศ.2549 และออกประกาศกำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน เล่ม 2-3 วิธีการวัดของสัญญาณรบกวนและภูมิคุ้มกัน - การวัดสัญญาณรบกวนที่แผ่ออก มาตรฐานเลขที่ มอก.2092 เล่ม 3-2552 ขึ้นใหม่ ดังมีรายละเอียดต่อท้ายประกาศนี้

ทั้งนี้ให้มีผลตั้งแต่วันถัดจากวันที่ประกาศในราชกิจจานุเบกษา เป็นต้นไป

ประกาศ ณ วันที่ 31 สิงหาคม พ.ศ. 2553

ชัยวุฒิ บรรณวัฒน์

รัฐมนตรีว่าการกระทรวงอุตสาหกรรม

มาตรฐานผลิตภัณฑ์อุตสาหกรรม
ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน
เล่ม 2-3 วิธีการวัดของสัญญาณรบกวนและภูมิคุ้มกัน – การวัดสัญญาณรบกวนที่แผ่ออก

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้กำหนดขึ้นโดยรับ CISPR 16-2-3 (2003) (Amendment 1(2005)) Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3 methods of measurement of disturbances and immunity-Radiated disturbance measurements มาใช้ในระดับเหมือนกันทุกประการ (identical) โดยใช้ CISPR ฉบับภาษาอังกฤษเป็นหลัก

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้ได้รับการระบุให้เป็นมาตรฐานพื้นฐาน ซึ่งกำหนดวิธีการวัดของปรากฏการณ์สัญญาณรบกวนที่แผ่ออก ในพิสัย 9 กิโลเฮิรตซ์-18 จิกะเฮิรตซ์

รายละเอียดให้เป็นไปตาม CISPR 16-2-3 (2003) (Amendment 1(2005))

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FOREWORD

This amendment has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods.

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

FDIS	Report on voting
CISPR/A/573/FDIS	CISPR/A/585/RVD

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

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

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

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7.3.2 Measurement distance

Add, after the first paragraph, the following new paragraph:

The measurement distance, d, is the horizontal distance between the periphery of the EUT and the receive antenna reference point (see Figure 13). The EUT encompasses all portions of the EUT, including cable racks and support equipment and a minimum cable length of 30 cm.

Delete the third sentence (above the note):

In case of dispute, measurements performed at 3 m shall take precedence.

Add, below the note, the following new paragraph :

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

7.3.3 Set-up of the equipment under test (EUT)

Replace the existing title and text with the following:

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

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

The test setup should also consider that absorbers are typically required on the floor between the antenna and EUT for measurements above 1 GHz. Whenever practical, for emission measurements above 1 GHz the EUT should be raised above the height of the absorbers. If it is not possible to raise the entire EUT above the absorbers (i.e. rack-mounted or floor-standing equipment), an attempt should be made to configure the EUT (in a rack or chassis, for example) such that the radiating elements are located above the absorbers. The EUT shall be located in the validated test volume as described in 5.8.2.2 of CISPR 16-1-4. If it is not practical and safe to raise the EUT or its radiating elements above the absorber height, the maximum portion of the EUT that may be located below the highest point of the absorbers is 30 cm (see 7.3.6.1 and Figure 12 below).

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

Insert, after 7.3.3, the two following new subclauses 7.3.4 and 7.3.5 as follows.

7.3.4 Measurement site

The measurement site shall comply with the requirements described in 8.2 of CISPR 16-1-4.

7.3.5 Measurement instrumentation

The measurement instrumentation shall comply with the requirements described in 8.2 of CISPR 16-1-1 and 4.6 of CISPR 16-1-4.

Measurements to verify compliance with a peak limit shall be conducted with the peak measuring spectrum analyzer or receiver using a measurement bandwidth of 1 MHz (impulse bandwidth) as defined in CISPR 16-1-1 (subclause 8.2).

Measurements to verify compliance with an average limit shall be conducted with a peak measuring spectrum analyzer using a measurement bandwidth of 1 MHz (impulse bandwidth) and a reduced video bandwidth, set as defined in CISPR 16-1-1, (subclause 8.2, c)). The value of video bandwidth required for an average measurement shall be less than the lowest spectral component of the input signals to be measured.

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

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

7.3.4 Measurement procedure

Renumber existing subclause 7.3.4, which now becomes 7.3.6 due to insertion of the above new subclauses 7.3.4 and 7.3.5.

7.3.4.1 Encompassing of the EUT by the measuring antenna

Replace the existing title and text of subclause 7.3.4.1, now renumbered 7.3.6.1, by the following:

7.3.6.1 General description of the radiated field measurement method above 1 GHz

The radiated field measurement method above 1 GHz is based on measurement of the maximum electric field emitted from the EUT as shown in Figure 12.

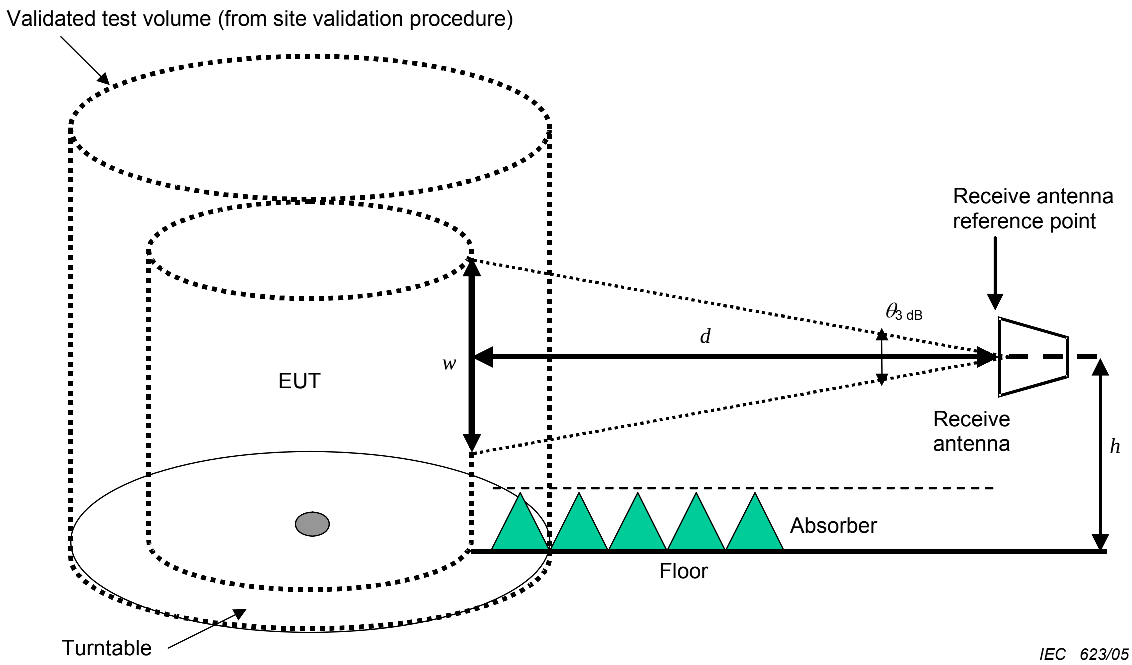


Figure 12 – Measurement method above 1 GHz, receive antenna in vertical polarization

Definitions referring to Figure 12

Validated test volume: The volume validated during the site validation procedure (see 5.8.2.2 of CISPR 16-1-4). Typically, this is the largest diameter EUT that can be used in the test facility.

EUT: The smallest diameter cylinder that will fully encompass all portions of the actual EUT, including cable racks and a minimum length of 30 cm of cables. The EUT that is located within this cylinder must be capable of rotating about its centre (typically by a remotely controlled turntable). The EUT must be located within the validated test volume. A maximum of 30 cm of w (see definition of w below) may be below the height of absorbers on the floor only when the EUT is floor standing and cannot be raised above the height of the absorbers (see 7.3.3).

$\theta_{3\ \mathrm{dB}}$: The minimum 3 dB beamwidth of the receive antenna at each frequency of interest. $\theta_{3\ \mathrm{dB}}$ is the minimum of both the E-plane and H-plane values at each frequency. $\theta_{3\mathrm{dB}}$ may be obtained from manufacturer provided data for the receive antenna.

d: The measurement distance (in meters). This is measured as the horizontal distance between the periphery of the EUT and the reference point of the receive antenna.

w: The dimension of the line tangent to the EUT formed by $\theta_{3\ \mathrm{dB}}$ at the measurement distance d. Equation (10) shall be used to calculate w for each actual antenna and measurement distance used. The values of w shall be included in the test report. This calculation may be based on the manufacturer-provided receive-antenna beamwidth specifications :

$$w = 2 \times d \times \tan\ (0{,}5 \times \theta_{3\ \mathrm{dB}}) \qquad (10)$$

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

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

Table 3 specifies the minimum acceptable dimension of w (w_{min}). The minimum requirements shown in Table 3 are calculated from equation (10) based on testing at the minimum permissible 1 m measurement distance specified in paragraph 7.3.2 and the values of $\theta_{3\ \mathrm{dB(min)}}$ shown. The selection of measurement distance, d, and antenna type shall be made such that w is equal to, or greater than, the values shown in Table 3 at any frequency where the field is measured. At frequencies not shown in Table 3, the limit of w_{min} shall be linearly interpolated between the nearest two frequencies listed:

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

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

NOTE 1 The dimension, w, is permitted to be larger than the minimum specified in Table 3, and other antennas and distances may be used to satisfy the minimum required value of $w = w_{min}$ shown in Table 3 provided equation (10) is met.

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

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

NOTE 4 The height scan requirement depends on w such that it may be advantageous to maximize w by selection of a wider beamwidth antenna and a larger measurement distance than the minimum requirements of Table 3.

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

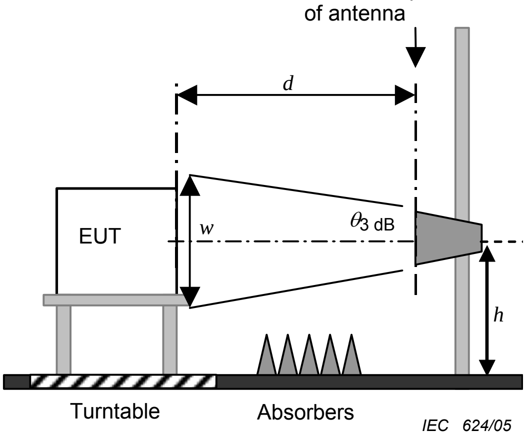
Table 4 lists example values of w calculated using equation (10) for three antenna types at a 1 m, 3 m, and 10 m measurement distance.

Table 4 – Example values of w for three antenna types

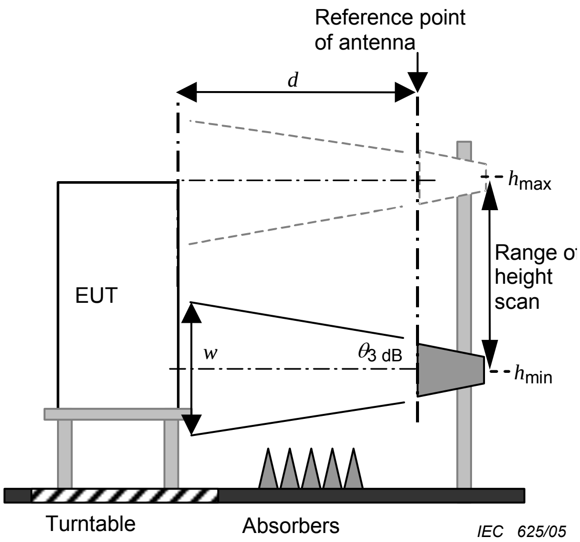
Frequency GHz	**DRG Horn**				**LPDA or LPDA-V** [a]			
	$\theta_{3\ dB}$	d = 1m	d = 3m	d = 10m	$\theta_{3\ dB}$	d = 1m	d = 3m	d = 10m
	(°)	W m	W m	W m	(°)	W m	W m	W m
1,00	60	1,15	3,46	11,55	60	1,15	3,46	11,55
2,00	35	0,63	1,89	6,31	55	1,04	3,12	10,41
4,00	35	0,63	1,89	6,31	55	1,04	3,12	10,41
6,00	27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

[a] LPDA-V : V-Type Log Periodic Dipole Array. The values shown for $\theta_{3\ dB}$ and w are typical of both the LPDA and LPDA-V. However, these antennas typically have different gain.

The maximum emission is measured by moving the receive antenna in height along with rotation of the EUT in azimuth (0 to 360 degrees). The required range of height investigation is specified below and illustrated in Figure 13 for two typical categories of EUTs.



a) w encompasses EUT height
(fixed-height measurement)



b) w does not encompass EUT height
(height scan required)

Figure 13 – Illustration of height scan requirements for two different categories of EUTs

For any EUT with maximum dimensions equal to or smaller than w, the centre of the receive antenna shall be fixed at the height of the centre of the EUT (Figure 13 a)).

For any EUT with a maximum vertical dimension larger than w, the centre of the antenna shall be scanned vertically along the line parallel to w, as shown in Figure 13 b). The required scanning range for h is 1 m to 4 m. If EUT height is less than 4 m, scanning the centre of the receive antenna to heights above the top of the EUT is not required. In both cases the fixed height, h, or the range of heights investigated shall be recorded in the test report.

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

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

Renumber subclause 7.3.4.2 as 7.3.6.2; the existing text of the subclause remains unchanged.

Renumber subclause 7.3.4.3 as 7.3.6.3, and replace the existing title and text of the subclause as follows :

7.3.6.3 Preliminary measurement procedure

The maximum radiated emission for a given mode of operation may be found during a preliminary test.

The procedures of this section are informative. The normative measurement requirements are listed in subclause 7.3.6.4 below.

In order to reduce the measurement time, it is suggested to first perform a measurement using peak detection and compare the test results to the average limit. Subsequent measurements with the average detector and comparison of results to the average limit will only be performed in those frequency ranges where the average limit was exceeded by data collected with peak detection.

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

a) Use scan or sweep mode over the complete frequency range of the antenna using peak detection and Max Hold mode.
b) The proper sweep or scan time should be determined to ensure adequate signal interception.
c) If necessary, during preliminary tests, the resolution bandwidth may be reduced in sweep mode to reduce the displayed noise level of the spectrum analyzer or receiver. Note that this may reduce the amplitude of broadband emissions, so additional investigations to determine whether the emissions are broadband or narrowband may be necessary.
d) Rotate the EUT continuously or in increments of 15° or less, then repeat for the other polarization. The EUT should be rotated 360° in azimuth for both polarizations to determine the maximum emissions at each frequency of interest.
e) For continuous turntable rotation mode, spectrum analyzer sweep time should be set such that the selected frequency span can be swept within a time that is equal to or less than the time needed for the turntable to rotate 15°. If the rotational speed of the turntable is such that an angle larger than 15° is covered during a complete sweep or scan of the spectrum analyzer, a smaller frequency range should be used to reduce spectrum analyzer sweep time and to achieve the maximum 15° turntable rotation per sweep.
f) As needed to identify the frequencies of maximum emissions, the method described above may be applied for all the height levels required by 7.3.6.1 (and Figure 13), and for the various operating modes of the EUT.
g) To further evaluate the frequencies found in steps a) to d), use a small frequency span (typically 5 MHz or less) and investigate around frequencies near the limit using additional smaller turntable increments and height steps. Typically, all frequencies within approximately 10 dB of the specification limit warrant further investigation with a narrow frequency span and additional finer rotation/height increments.

7.3.4.4 Final emission test

Renumber subclause 7.3.4.4 as 7.3.6.4, and modify its title as follows:

7.3.6.4 Final measurement procedure

Add, at the end of the subclause, the following new paragraphs:

Final measurements shall be done using the EUT operational mode identified by preliminary measurements to have the highest emissions.

Final measurements shall be performed using all required detectors. Alternatively, peak measurement results may be used to demonstrate compliance with all specified limits.

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

a) For any EUT with maximum dimension equal to or smaller than w, the centre of the receiving antenna shall be fixed at the height of the centre of the EUT (see Figure 13a)).
b) For any EUT with maximum vertical dimension larger than w, height scanning shall be performed in accordance with the height scan requirements (upper and lower bounds) specified in 7.3.6.1.
c) In all cases, in order to find the maximum emissions, the EUT shall be rotated in azimuth through all angles in the range of 0° to 360°, and the measurements shall be performed for both horizontal and vertical polarizations.

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

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

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

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION
INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

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

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

This second edition of CISPR 16-2-3 cancels and replaces the first edition published in 2003, amendment 1 (2005) and amendment 2 (2005).

The document CISPR/A/657/FDIS, circulated to the National Committees as amendment 3, led to the publication of the new edition.

The text of this standard is based on the first edition, its amendment 1, amendment 2 and the following documents:

FDIS	Report on voting
CISPR/A/657/FDIS	CISPR/A/672/RVD

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

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

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

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

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 is designated a basic standard, which specifies the methods of measurement of radiated disturbance phenomena in the frequency range 9 kHz to 18 GHz.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CISPR 13:2001, *Sound and television broadcast receivers and associated equipment – Radio disturbance characteristics – Limits and methods of measurement*

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

CISPR 16-1-1:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

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

CISPR 16-1-4:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Ancillary equipment - Radiated disturbances*

CISPR 16-1-5:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-5: Radio disturbance and immunity measuring apparatus – Antenna calibration and site validation*

CISPR 16-2-1:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements*

CISPR 16-2-2:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-2: Methods of measurement of disturbances and immunity – Measurement of disturbance power*

CISPR 16-2-4:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-4: Methods of measurement of disturbances and immunity – Immunity measurements*

CISPR 16-3:2003, *Specification for radio disturbance and Immunity measuring apparatus and methods – Part 3: CISPR technical reports*
Amendment 1 (2005)

CISPR 16-4-1:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-1: Uncertainties, statistics and limit modelling – Uncertainties in standardized EMC tests*

CISPR 16-4-2:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Uncertainty in EMC measurements*

CISPR 16-4-3:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-3: Uncertainties, statistics and limit modelling – Statistical considerations in the determination of EMC compliance of mass-produced products*

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

3 Terms and definitions

For the purpose of this part of CISPR 16, the definitions of IEC 60050(161) apply, as well as the following:

3.1
associated equipment

1) transducers (e.g. probes, networks and antennas) connected to a measuring receiver or test generator
2) transducers (e.g. probes, networks, antennas) which are used in the signal or disturbance transfer between an EUT and measuring equipment or a (test-) signal generator

3.2
EUT
the equipment (devices, appliances and systems) subjected to EMC (emission) compliance tests

3.3
product publication
publication specifying EMC requirements for a product or product family, taking into account specific aspects of such a product or product family

3.4
emission limit (from a disturbing source)
the specified maximum emission level of a source of electromagnetic disturbance

[IEV 161-03-12]

3.5
ground reference
a connection that constitutes a defined parasitic capacitance to the surrounding of an EUT and serves as reference potential

NOTE See also IEV 161-04-36.

3.6
(electromagnetic) emission
the phenomenon by which electromagnetic energy emanates from a source

[IEV 161-01-08]

3.7
coaxial cable
a cable containing one or more coaxial lines, typically used for a matched connection of associated equipment to the measuring equipment or (test-)signal generator providing a specified characteristic impedance and a specified maximum allowable cable transfer impedance

3.8
measuring receiver
a receiver for the measurement of disturbances with different detectors

NOTE The receiver is specified according to CISPR 16-1-1.

3.9
test configuration
gives the specified measurement arrangement of the EUT in which an emission level is measured

NOTE The emission level is measured as required by IEV 161-03-11, IEV 161-03-12, IEV 161-03-14 and IEV 161-03-15, definitions of emission level.

3.10
weighting (quasi-peak detection)
the repetition-rate dependent conversion of the peak-detected pulse voltages to an indication corresponding to the psychophysical annoyance of pulsive disturbances (acoustically or visually) according to the weighting characteristics, or alternatively gives the specified manner in which an emission level or an immunity level is evaluated

NOTE 1 The weighting characteristics are specified in CISPR 16-1-1.

NOTE 2 The emission level or immunity level is evaluated as required by IEC 60050(161) definitions of level (see IEV 161-03-01, IEV 161-03-11 and IEV 161-03-14).

3.11
continuous disturbance
RF disturbance with a duration of more than 200 ms at the IF-output of a measuring receiver, which causes a deflection on the meter of a measuring receiver in quasi-peak detection mode which does not decrease immediately

[IEV 161-02-11, modified]

NOTE The measuring receiver is specified in CISPR 16-1-1.

3.12
discontinuous disturbance
for counted clicks, disturbance with a duration of less than 200 ms at the IF-output of a measuring receiver, which causes a transient deflection on the meter of a measuring receiver in quasi-peak detection mode

NOTE 1 For impulsive disturbance, see IEV 161-02-08.

NOTE 2 The measuring receiver is specified in CISPR 16-1-1.

3.13
measurement time
T_m
the effective, coherent time for a measurement result at a single frequency (in some areas also called dwell time)

– for the peak detector, the effective time to detect the maximum of the signal envelope,
– for the quasi-peak detector, the effective time to measure the maximum of the weighted envelope
– for the average detector, the effective time to average the signal envelope
– for the r.m.s. detector, the effective time to determine the r.m.s. of the signal envelope

3.14
sweep
a continuous frequency variation over a given frequency span

3.15
scan
a continuous or stepped frequency variation over a given frequency span

3.16
sweep or scan time
T_s
the time between start and stop frequencies of a sweep or scan

3.17
span
Δf
difference between stop and start frequencies of a sweep or scan

3.18
sweep or scan rate
the frequency span divided by the sweep or scan time

3.19
number of sweeps per time unit (e.g. per second)
n_s
1/(sweep time + retrace time)

3.20
observation time
T_o
the sum of measurement times T_m on a certain frequency in case of multiple sweeps. If n is the number of sweeps or scans, then $T_o = n \times T_m$

3.21
total observation time
T_{tot}
the effective time for an overview of the spectrum (either single or multiple sweeps). If c is the number of channels within a scan or sweep, then $T_{tot} = c \times n \times T_m$

4 Types of disturbance to be measured

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

4.1 Types of disturbance

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

a) *narrowband continuous disturbance*, i.e. disturbance on discrete frequencies as, for example, the fundamentals and harmonics generated with the intentional application of RF energy with ISM equipment, constituting a frequency spectrum consisting only of individual spectral lines whose separation is greater than the bandwidth of the measuring receiver so that during the measurement only one line falls into the bandwidth in contrast to b);

b) *broadband continuous disturbance,* which normally is unintentionally produced by the repeated impulses of, for example, commutator motors, and which have a repetition frequency which is lower than the bandwidth of the measuring receiver so that during the measurement more than one spectral line falls into the bandwidth; and

c) *broadband discontinuous disturbance* is also generated unintentionally by mechanical or electronic switching procedures, for example by thermostats or programme controls with a repetition rate lower than 1 Hz (click-rate less than 30/min).

The frequency spectra of 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 which is wider than the bandwidth of the measuring receiver specified in CISPR 16-1-1.

4.2 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) a peak detector which 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

This subclause describes the connection of measuring equipment, measuring receivers and associated equipment such as artificial networks, voltage and current probes, absorbing clamps and antennas.

5.1 Connection of associated equipment

The connecting cable between the measuring receiver and the associated equipment shall be shielded and its characteristic impedance shall be matched to the input impedance of the measuring receiver.

The output of the associated equipment shall be terminated with the prescribed impedance.

5.2 Connections to RF reference ground

The artificial mains network (AMN) shall be connected to the reference ground by a low RF impedance, e.g. by direct bonding of the case of the AMN to the reference ground or reference wall of a shielded room, or with a low impedance conductor as short and as wide as practical (maximum length to width ratio is 3:1).

Terminal voltage measurements shall be referenced only to the reference ground. Ground loops (common impedance coupling) shall be avoided. This should also be observed for measuring apparatus (e.g. measuring receivers and connected associated equipment, such as oscilloscopes, analyzers, recorders, etc.) fitted with a protective earth conductor (PE) of Protection Class I equipment. If the PE connection of the measuring apparatus and the PE connection of the power mains to the reference ground do not have RF isolation from the reference ground, the necessary RF isolation shall be provided by means such as RF chokes and isolation transformers, or if applicable, by powering the measuring apparatus from batteries, so that the RF connection of the measuring apparatus to the reference ground is made via only one route.

For the treatment of PE connection of the EUT to the reference ground, see Clause A.4 of CISPR 16-2-1:2003.

Stationary test configurations do not require a connection with the protective earth conductor if the reference ground is connected directly and meets the safety requirements for protective earth conductors (PE connections).

5.3 Connection between the EUT and the artificial mains network

General guidelines for the selection of grounded and non-grounded connections of the EUT to the AMN are discussed in Annex A of CISPR 16-2-1.

6 General measurement requirements and conditions

Radio disturbance measurements shall be:

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

   These requirements may be met by observing the following conditions:
c) existence of a sufficient signal-to-noise ratio at the desired measurement level, e.g. the level of the relevant disturbance limit;
d) having a defined measuring set-up, termination and operating conditions of the EUT;
e) having a sufficiently high impedance of the probe at the measuring point, in the case of voltage probe measurements;
f) when using a spectrum analyzer or scanning receiver due considerations shall be given to its particular operating and calibration requirements.

6.1 Disturbance not produced by the equipment under test

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

6.1.1 Compliance testing

A test site shall permit emissions from the EUT to be distinguished from ambient noise. The ambient noise level should preferably be 20 dB, but at least be 6 dB below the desired measurement level. For the 6 dB condition, the apparent disturbance level from the EUT is increased by up to 3,5 dB. The suitability of the site for required ambient level may be determined by measuring the ambient noise level with the test unit in place but not operating.

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

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

6.2 Measurement of continuous disturbance

6.2.1 Narrowband continuous disturbance

The measuring set shall be kept tuned to the discrete frequency under investigation and returned if the frequency fluctuates.

6.2.2 Broadband continuous disturbance

For the assessment of broadband continuous disturbance the level of which is not steady, the maximum reproducible measurement value shall be found. See 6.4.1 for further details.

6.2.3 Use of spectrum analyzers and scanning receivers

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

6.3 Operating conditions of the EUT

The EUT shall be operated under the following conditions:

6.3.1 Normal load conditions

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

6.3.2 The time of operation

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

6.3.3 Running-in time

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

6.3.4 Supply

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

6.3.5 Mode of operation

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

6.4 Interpretation of measuring results

6.4.1 Continuous disturbance

a) If the level of disturbance is not steady, the reading on the measuring receiver is observed for at least 15 s for each measurement; the highest readings shall be recorded, with the exception of any isolated clicks, which shall be ignored (see 4.2 of CISPR 14-1:2005).

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 which 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 which 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.

6.4.2 Discontinuous disturbance

Measurement of discontinuous disturbance may be performed at a restricted number of frequencies. For further details, see CISPR 14-1.

6.4.3 Measurement of the duration of disturbances

The EUT is connected to the relevant artificial mains network. If a measuring set is available, it is connected to the network and a cathode-ray oscilloscope is connected to the IF output of the measuring set. If a receiver is not available, the oscilloscope is connected directly to the network. The time base of the oscilloscope can be started by the disturbances to be tested; the time base is set to a value of 1 ms/div –10 ms/div for EUT with instantaneous switching and 10 ms/div – 200 ms/div for other EUT. The duration of the disturbance can either be recorded directly by a storage oscilloscope or digital oscilloscope or by photograph or hard copy recording of the screen.

6.5 Measurement times and scan rates for continuous disturbance

Both for manual measurements and automated or semiautomated 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 prescans, the measurement times and scan rates have to take the timing of the emission under test into account. More detailed guidance on the execution of automated measurements can be found in Clause 8.

6.5.1 Minimum measurement times

Clause B.7 of the present standard provides a table of the minimum sweep times or the fastest – practically achievable – scan rates. From this table the following minimum scan times for measurements over a complete CISPR band have been derived:

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

Frequency band		Scan time T_s for peak detection	Scan time T_s for quasi-peak detection
A	9 kHz – 150 kHz	14,1 s	2820 s = 47 min
B	0,15 MHz – 30 MHz	2,985 s	5 970 s = 99,5 min = 1 h 39 min
C/D	30 MHz – 1 000 MHz	0,97 s	19 400 s = 323,3 min = 5 h 23 min

The scan times in Table 1 apply to the measurement of CW signals. Depending on the type of disturbance, the scan time may have to be increased – even for quasi-peak measurements. In extreme cases, the measurement time T_m at a certain frequency may have to be increased to 15 s, if the level of the observed emission is not steady (see 6.4.1). However isolated clicks are excluded.

Scan rates and measurement times for use with the average detector will be found in Annex D.

Most product standards call out quasi-peak detection for compliance measurements which is very time consuming, if no time-saving procedures are applied (see Clause 8). Before time-saving procedures can be applied, the emission has to be detected in a prescan. In order to ensure that e.g. intermittent signals are not missed during an automatic scan, the considerations in 6.5.2 to 6.5.4 need to be taken into account.

6.5.2 Scan rates for scanning receivers and spectrum analyzers

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

1) for a single sweep: the measurement time at each frequency must be larger than the intervals between pulses for intermittent signals;
2) 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 instrument's resolution bandwidth 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 display changes, there may still be intermittent signals to discover. The observation time has to 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:

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

where

$T_{\mathrm{s\ min}}$ = Minimum sweep time

Δf = Frequency span

B_{res} = Resolution bandwidth

k = 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:

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

where B_{video} = 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 $T_{\mathrm{s\ min}}$ and the retrace time (time needed to retune the local oscillator and to store the measurement results, etc.).

6.5.3 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 stepwidth. Under these assumptions the scan time $T_{\mathrm{s\ min}}$ for a stepping receiver can be calculated using the following equation:

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

where $T_{\mathrm{m\ min}}$ = 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.

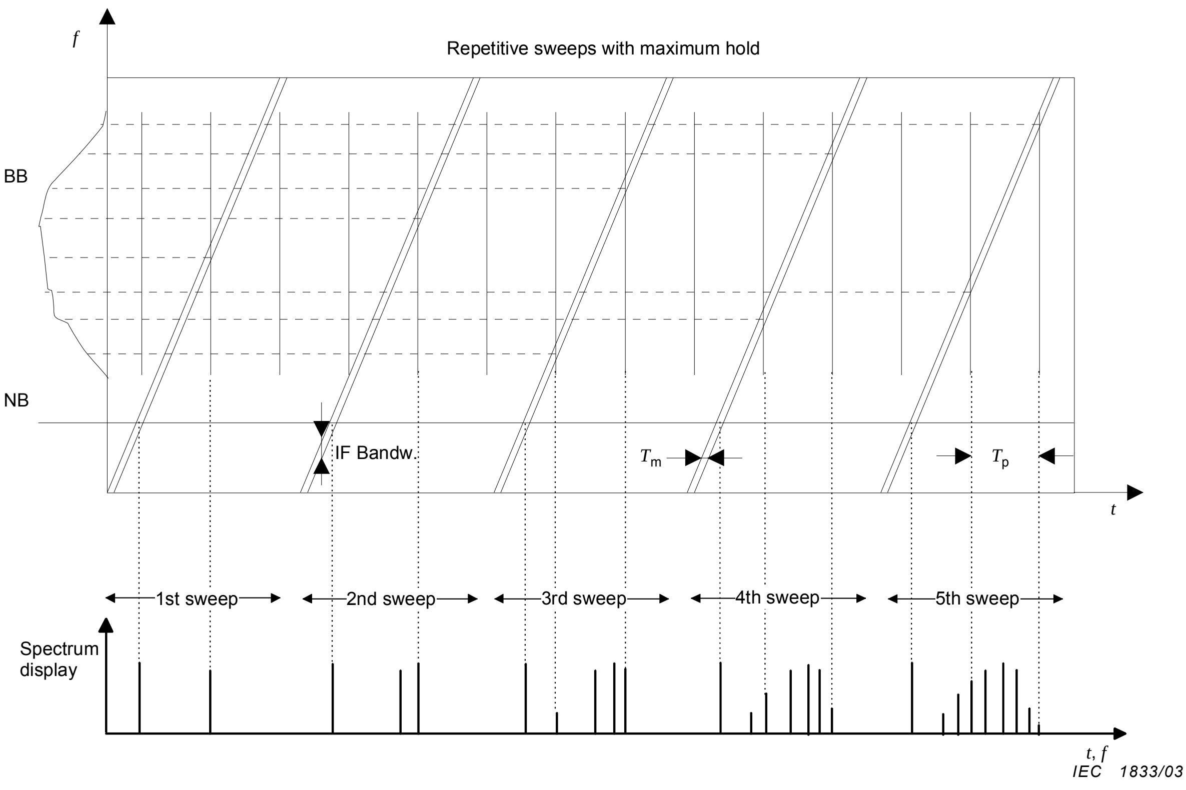
For purely broadband emissions, the frequency step size may be increased. In this case the objective is to find the maxima of the emission spectrum only.

6.5.4 Strategies for obtaining a spectrum overview using the peak detector

For each prescan 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, which may contain narrowband and broadband components, two general approaches are proposed:

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

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

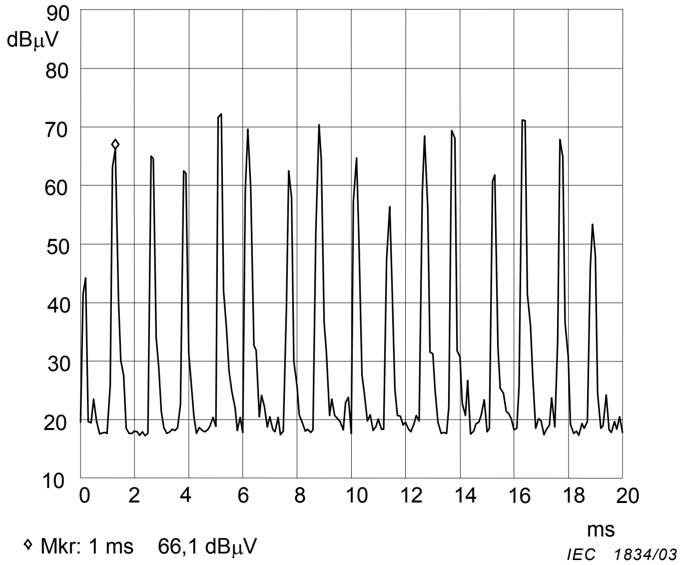


T_p is the pulse-repetition interval of the impulsive signal. A pulse occurs at each vertical line of the spectrum-vs.-time display (upper part of the figure).

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

If the type of emission is unknown, multiple sweeps with the shortest possible sweep time and peak detection allow to determine 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 which provides a graphical signal display, used in zero-span mode or using an oscilloscope connected to the receiver’s IF or video output as e.g. shown in Figure 2.



Disturbance from a DC collector motor: due to the number of collector segments the pulse repetition frequency is high (approx. 800 Hz) and the pulse amplitude varies strongly. Therefore for this example, the recommended measurement (dwell) time with the peak detector is > 10 ms.

Figure 2 – Example of a timing analysis

This way pulse durations and pulse repetition frequencies can be determined and scan rates or dwell times selected accordingly:

– 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 curve as the spectrum envelope (see Figure 3). The step size has to 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.

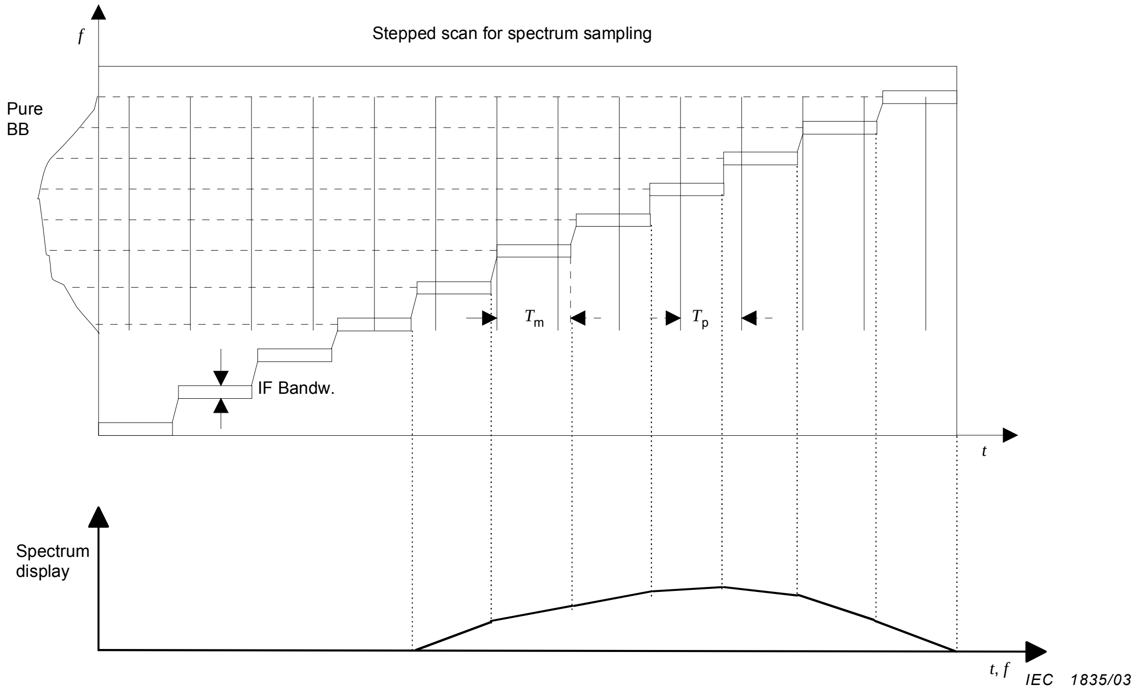
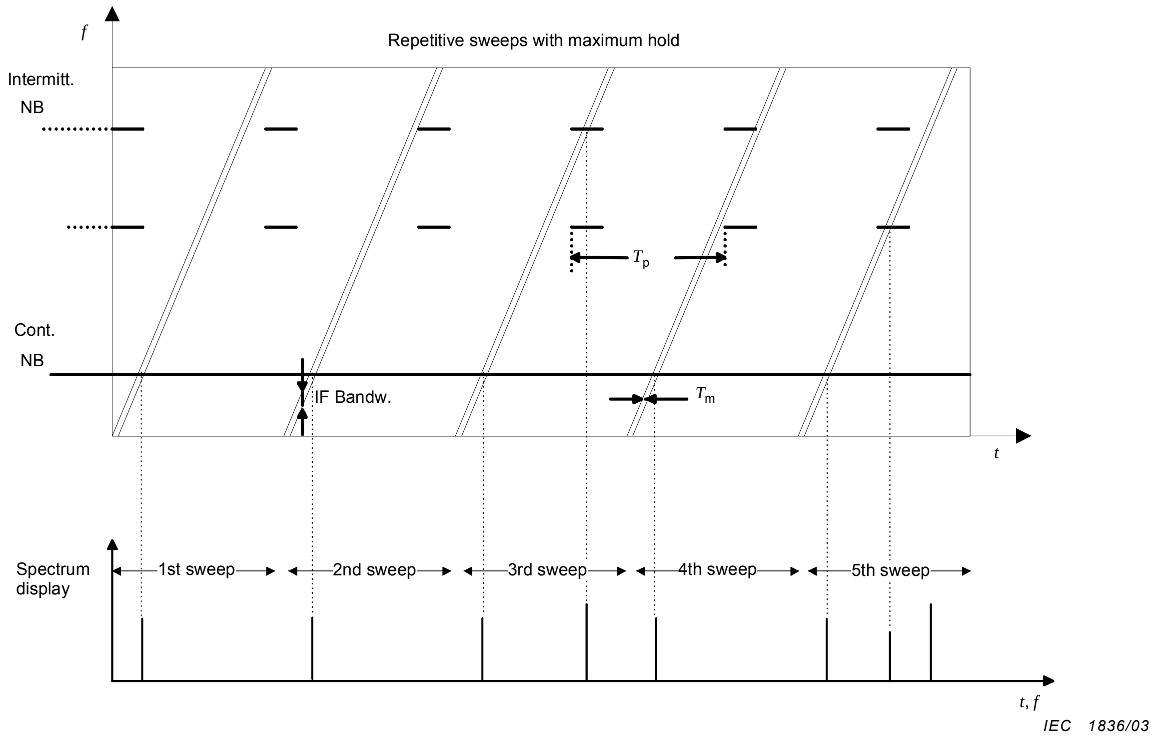


Figure 3 – A broadband spectrum measured with a stepped receiver

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



NOTE In the example above, 5 sweeps are required until all spectral components are intercepted. The number of sweeps required or the sweeptime may have to be increased, depending on pulse duration and pulse repetition interval.

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

Intermittent broadband disturbances have to be measured with discontinuous disturbance analysis procedures, as described in CISPR 16-1-1.

7 Measurement of radiated disturbances

7.1 Introduction

This section 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.

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 r.m.s. 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 large loop antenna (LLA) system 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.)

7.2 Field-strength measurements in the frequency range 9 kHz to 1 GHz

Field-strength measurements may be made on an open area test site, in an absorber-lined shielded enclosure, in a reverberating chamber or using a LLA system. For practical reasons other test sites may have to be specified.

7.2.1 Open area test site measurements

The open area test site shall conform with the relevant specifications of CISPR 16-1-4 and CISPR 16-1-5 for its physical and electrical properties and for its validation.

7.2.2 General measurement method

Figure 5 shows the concept of measurements made on an open area test site with the direct and ground reflected rays arriving at the receiving antenna.

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

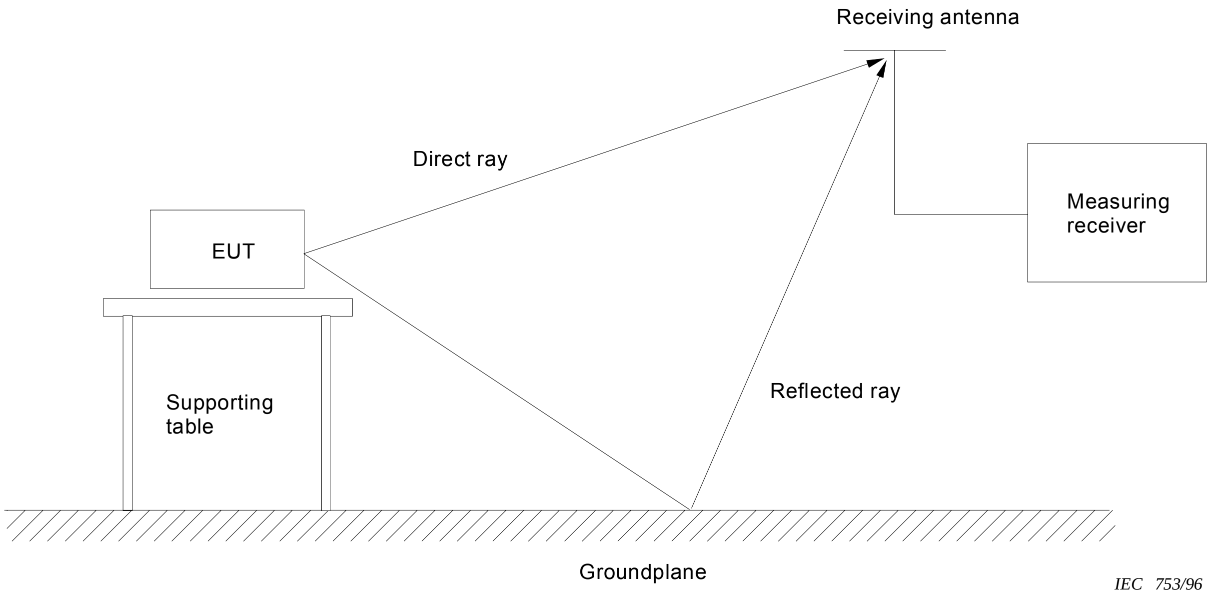


Figure 5 – Concept of electric field strength measurements made on an open area test site (OATS) with the direct and reflective rays arriving at the receiving antenna

7.2.3 Measurement distance

An EUT subject to a radiated disturbance limit at a specified distance should be measured at that distance unless to do so would be impractical because of equipment size, etc. The measurement distance is the length of the projection of the EUTs closest point to the antenna and the midpoint of the antenna onto the ground plane. In some test set-ups the distance is measured from the antenna to the radiation centre of the EUT. For a measurement distance of 10 m either method may be used. A distance of 10 m is preferred at most outdoor sites since at this distance the expected level of the disturbance being measured is sufficiently above the general ambient noise level to permit useful testing. Distances of less than 3 m or greater than 30 m are not generally used. If a measurement distance other than the specified distance is necessary, the results should be extrapolated using the procedures specified in the product standards.. If no guidance is given, suitable justification for extrapolation shall be provided. In general, extrapolation does not follow a simple inverse distance law.

Where possible, measurement should be made in the far field. The far field region may be defined by the following conditions.

Measurement distance d is selected so that:

a) $d \geq \lambda/6$. At this distance $E/H = Z_O = 120\ \pi = 377\ \Omega$, that is electrical and magnetic field strength components are perpendicular to each other and the measurement error is in the order of 3 dB if the EUT is regarded as being a tuned dipole antenna; or

b) $d \geq \lambda$, condition for a plane wave, where the error is in the order of 0,5 dB if the EUT is regarded as a tuned dipole antenna; or

c) $d \geq 2D^2/\lambda$, where D is the largest dimension of either the EUT or the antenna determining the minimum aperture for the illumination of the EUT, which applies to cases, where $D >> \lambda$.

7.2.4 Antenna height variation

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

7.2.5 Product specification details

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

7.2.5.1 Test environment

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

The electromagnetic environment needs special consideration to ensure accurate disturbance measurements. The ambient radio noise and signal levels measured at the test site with the EUT de-energized should be at least 6 dB below the limit. It is recognized that this is not always realizable at all frequencies. However, in the event that the measured levels of the ambient plus EUT radio noise emissions are not above the limit, the EUT shall be considered to be in compliance with the limit. For further guidance on ambient levels and resulting measurements error, see 6.1.1 and Annex A.

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

a) perform measurements at a closer distance and extrapolate results to the distance at which the limit is specified. The extrapolation formula shall be as recommended by the product standard or shall be verified by measurements at no less than three different distances;

b) perform measurements in critical frequency bands during hours when broadcast stations are off the air and the ambients from industrial equipment are lower;

c) compare the amplitude of the EUT disturbance at the frequency under investigation with the amplitude of disturbance on adjacent frequencies in a shielded room or anechoically treated shielded room. The amplitude of the EUT disturbance at the frequency under investigation can be estimated by measuring the amplitude of the adjacent frequency disturbance and making a comparison;

   NOTE The shielded or anechoic room should not be used for compliance determination at the other EUT frequencies unless the anechoic room data is correlatable to the open area test site data.

d) in orienting the axis of an open field area test site, it is desirable to consider the directions of strong ambient signals, so that the orientation of the receiving antenna on the site discriminates against such signals as far as possible;

e) for narrowband disturbances from the EUT occurring near an RF ambient, when both are within the standard bandwidth, a narrower instrument bandwidth may be useful.

7.2.5.2 Configuration of equipment under test

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

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

a) the system is configured for use in a typical manner.

b) the system is configured in a manner that will maximize disturbances.

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

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

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

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

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

Interface cables shall be of the type and length specified by the equipment manufacturer.

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

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

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

The EUT shall be grounded in accordance with the manufacturer's requirements and conditions of intended use. If the EUT is operated without a ground connection, it shall be tested ungrounded. When the EUT is furnished with a grounding terminal or internally grounded lead which is to be connected in actual installation conditions, the ground lead or connection shall be connected to a ground plane (or facility for earth ground), simulating actual installation conditions. Any internally grounded lead included in the plug end of the a.c. mains cord of the EUT shall be connected to ground through the mains power service.

7.2.6 Measurement instrumentation

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

7.2.7 Field-strength measurements on other out-door sites

Out-door test sites similar to an open area test site but without any metal ground plane may have to be prescribed for practical reasons for some products, e.g. ISM equipment and motor vehicles. The provisions given in 7.2.3 to 7.2.6 are valid.

7.2.8 Measurements in reverberating chambers

(Under consideration)

7.2.9 Measurement in absorber-lined shielded enclosures

7.2.9.1 Measurement in absorber-lined shielded enclosures with groundplane (semi-anechoic chambers = SAC or semi-anechoic Room = SAR)

(Under consideration.)

7.2.9.2 Measurement in fully absorber-lined shielded enclosures (fully anechoic chamber = FAC or fully anechoic room = FAR)

7.2.9.2.1 Test set-up

The same type of antenna shall be used for EUT emission testing as the receive antenna used for the FAR validation testing. The antenna height is fixed at the geometrical middle height of the test volume. Measurement will be done in horizontal and vertical polarisation of the receive antenna. Emission should be measured while the turntable rotates with the EUT in each of at least three successive azimuth positions (0°, 45°, 90°), when continuous rotation is not required.

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

NOTE The correction factor, C_{Rd} dB, equation (4a), may be added to the field strength in order to reduce its uncertainty. In the calibration procedure of the antenna a phase correction factor C_{Rd} will be measured for each frequency. (The procedure will be defined with antenna calibration or calculated from the mechanical spacing of the log.-periodic elements) together with the Antenna Factor (AF). The two factors (C_{Rd}, and AF) will be added in dB to the voltage at the output of the antenna to get the field strength equation (4b). If a phase centre correction is not included, an additional term must be included in the uncertainty budget.

$$C_{\text{Rd}} = 20 \lg [(R + P_{\text{f}} - d)/R] \quad (4a)$$

E-field strength is given by equation (4b):

$$E_{\text{f}} = V_{\text{f}} + AF_{\text{FS(f)}} + C_{\text{Rd}} \quad (4b)$$

where

f = frequency, (MHz)

R = the required separation point from the source to the reference point on the antenna (m).

P_{f} = phase centre position as a function of frequency, (m from tip of antenna)

d = distance of the reference point on the antenna from the antenna tip (m).

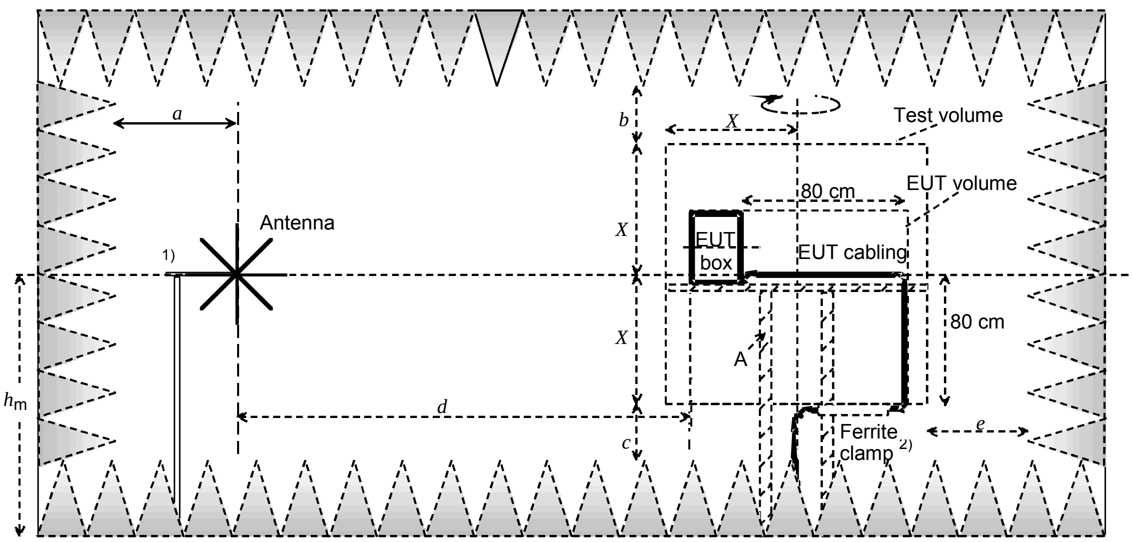
E_{f} = E-field at distance d from source; expressed in dB (µV/m).

V_{f} = voltage at output of antenna at frequency f ; expressed in dB (µV).

C_{Rd} = phase centre correction factor; expressed in dB

$AF_{\text{FS(f)}}$ = antenna factor (free space) for E-field at the phase centre; expressed in dB (m^{-1}).

Figure 6 illustrates typical test set-up.



IEC 1854/03

A = turntable and EUT-support

$2X$ = 1,5 m; 2,5 m;5 m, i.e. corresponds to test distance used (3 m, 5 m, or 10 m respectively)

h_{m} = middle level of the test volume

a, b, c and e ≥ 0,5 m recommended (≥ 1 is more convenient), the actual value is consistent with the FAR calibration procedure of CISPR 16-2-3.

d = 3 m; 5 m or 10 m

1) The antenna and cable lay-out shall be validated together and used in the same configuration during EUT-test.

2) Ferrite clamps are to be used in accordance with the applicable product standard. Their possible use (if required) must be documented in the test report.

Figure 6 – Typical test set-up in FAR, where a, b, c and e depend on the room performance

The EUT shall be placed on a turntable. Figures 6, 7 and 8 explain the different dimensions within the FAR. The turntable, antenna mast and supporting floor shall be in place during the validation procedure, and consist largely of material transparent to electromagnetic waves. The distances a, b, c and e may be limited by the size of the test volume. The level of the bottom plane (absorber height plus c) will be the level for floor standing equipment (transport pallet height will be outside the test volume).

7.2.9.2.2 EUT position

The EUT shall be configured, installed, arranged and operated in a manner consistent with typical applications. Interface cables shall be connected to each type of interface port of the EUT.

If the EUT consists of separate devices, the space between the devices shall be in normal configuration but with 10 cm separation if possible. Interconnecting cables shall be bundled. The bundle shall be around 30 cm to 40 cm long and longitudinal to the cable.

Ancillary equipment, which is required to exercise the EUT but does not form part of the EUT, shall be located outside the screened room.

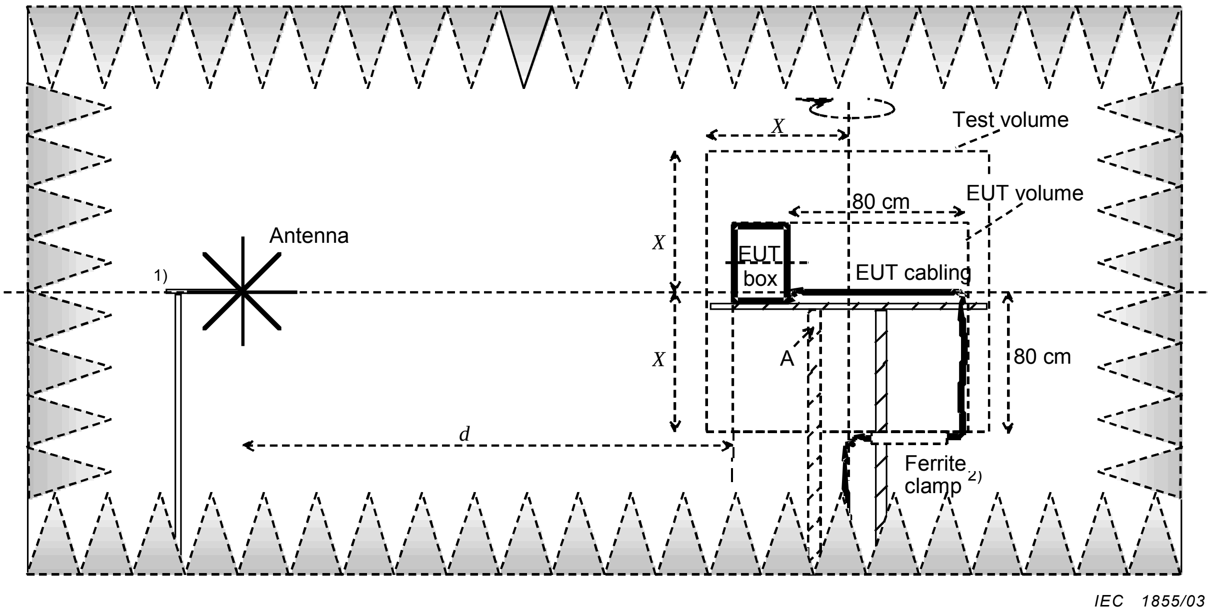
The entire EUT shall fit in the test volume.

To improve the measurement repeatability, the following guidelines shall be taken into account:

The EUT (including the cables laid out according to 7.2.9.2.3) shall be placed so that its centre is at the same height as the centre of the test volume. A non-conductive support of a suitable height may be used to achieve this.

Where it is not physically possible to elevate a large EUT to the centre of the test volume (Figures 6 and 7), the EUT may remain on a non-conductive transport pallet during the test (Figure 8). The height of the pallet shall be recorded in the test report.

Figures 7 and 8 illustrate the set-up of several types of EUT in the FAR.



A = turntable and EUT-support

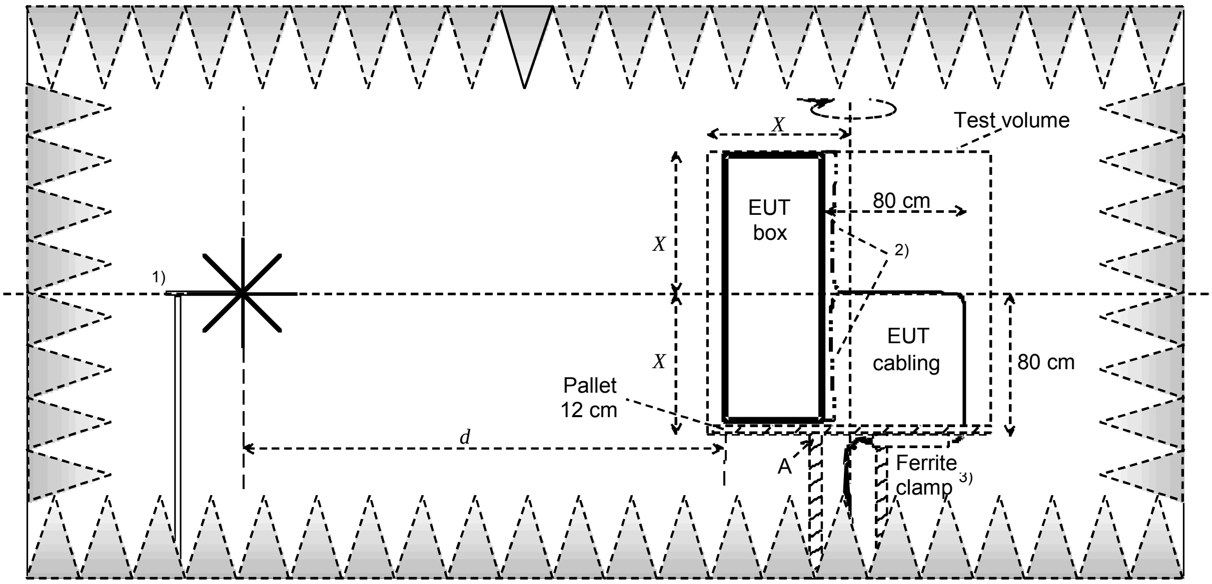
2X = 1,5 m; 2,5 m, 5 m

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

1) The antenna cable layout shall be the same as in the validation procedure (see Figure 6).

2) Ferrite clamps are to be used in accordance with the applicable product standard. Their possible use (if required) must be documented in the test report.

Figure 7 – Typical test set-up for table-top equipment within the test volume of a FAR



A = turntable and EUT-support 2X = 1,5 m; 2,5 m, 5 m

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

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

1) The antenna cable layout shall be the same as in the validation procedure (see Figure 6).

2) The cable layout depends on the location of the cable outlets and shall be close to the surface of the housing

3) Ferrite clamps are to be used in accordance with the applicable product standard. Their possible use (if required) must be documented in the test report.

Figure 8 – Typical test set-up for floor standing equipment within the test volume of a FAR

The installation specifications for some floor standing equipment require the unit to be installed and bonded directly to a conductive floor. The reader is advised of the following notes for testing of floor standing equipment in a FAR:

For results obtained showing non-compliance to a FAR limit of floor standing equipment that is intended to be installed and bonded directly to a conductive floor may be lower if tested on a ground plane that better simulates the final installation environment. This is particularly true if the emissions are at a frequency below 200 MHz, horizontal polarisation, and the source of emissions is from a height on the equipment that would correspond to a height above ground of 0,4 m or less in a typical installation. The reader is advised that prior to a determination of non-compliance based on FAR measurements, additional investigation in a ground plane test environment (i.e. an Open Area Test Site or Semi-Anechoic chamber) is recommended to better simulate the equipment's intended installation condition.

7.2.9.2.3 Cable layout and termination

In EMC testing the reproducibility of measurement results is often poor due to differences in cable layout and termination, when one single EUT is measured at various test-sites.

The following listed items are general conditions of the test set up in order to provide good reproducibility (see Figures 7 and 8). Ideally all radiation to be measured should only be emitted from the test volume. The cables used during the test shall be in accordance with manufacturer‘s specifications. If such cables are not available, the specifications of the cables used during testing shall be clearly described in the test report.

The cables that are connected to the EUT and ancillary equipment or power supply shall include a length of 0,8 m run horizontally and 0,8 m run vertically (without any bundling) inside the test volume (see Figure 7 and 8). Any cable length in excess of 1,6 m with a relative tolerance of ±5 % shall be routed outside the test volume.

If the manufacturer specifies a shorter length than 1,6 m, then where possible, it shall be oriented such that half of its length is horizontal and half is vertical in the test volume.

Cables that are not exercised through ancillary equipment during the test must be appropriately terminated:

– coaxial (shielded) cables with coaxial terminator with correct impedance (50 Ω or 75 Ω);
– shielded cables with more than one inner wire must have common mode (line to reference earth/ground) and differential-mode (line to line) termination in accordance with the manufacturer′s specifications;
– unshielded cables must have differential mode termination as well as common-mode termination in accordance with the manufacturer′s specifications.

If the EUT needs ancillary equipment in order to be operated properly, special care has to be taken that no emission of that equipment can influence the radiation measurement. Ancillary equipment shall be located outside the screened room wherever possible. Measures against RF-leakage into the FAR through the interconnection cables must be taken.

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

Owing to the different nature of the many possible EUTs, product standards may deviate considerably from this subclause, (e.g. 10.5 of CISPR 22:2005).

7.2.9.3 Radiated emissions (30 MHz to 1 GHz) and immunity (80 MHz to 1 GHz) test method with common test set-up in semi-anechoic chamber

7.2.9.3.1 Applicability

As an alternative to different test set-ups for radiated emissions and radiated immunity testing, at the discretion of product committees, testing to both requirements may be performed using a common EUT arrangement in accordance with the provisions of this clause.

The test arrangement described in this clause is applicable when radiated emissions and immunity testing of the EUT using the same configuration and test set-up is technically justified. This test arrangement is considered to be most applicable to EUTs of simple configuration, e.g. single enclosure, combination of small enclosures, less than 5 cables connected to the EUT.

The radiated immunity test may be performed with absorbing material on sections of the ground plane between the EUT and the transmitting antenna, if necessary to achieve field uniformity, as described in IEC 61000-4-3.

The normalized site attenuation characteristics of the semi-anechoic chamber (SAC) shall satisfy the requirements of CISPR 16-1-4:2003.

NOTE This alternative test arrangement is allowed for EUTs whose product emissions standards permit radiated emission tests at 3 m separation distance.

7.2.9.3.2 EUT perimeter definition and antenna-to-EUT separation distance

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

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

The EUT perimeter is defined by the smallest imaginary rectangle encompassing the EUT. All intersystem cables shall be included within this perimeter (see Figure 13). Each edge of this perimeter shall lie in one of the four face planes of the EUT, co-planar with (and possibly residing within) the uniform field areas (UFAs) calibrated for immunity tests, depending upon the horizontal test distance.

7.2.9.3.3 Uniform test volume

The uniform test volume is defined by the following conditions.

- The EUT and its associated peripherals and cables shall fit into a test volume where the NSA requirements of CISPR 16-1-4 are fulfilled. Refer to the NSA procedure for alternative test sites for use in emission measurements of CISPR 16-1-4:2003;

- The EUT and its associated peripherals and cables shall fit into a test volume which allows each of the faces of the EUT and its associated peripherals and cables to be aligned with the uniform field area according to the requirements of IEC 61000-4-3:2002 and as described in this clause.

Evaluation of EUTs having unequal or non-symmetric boundaries at two antenna separation distances requires uniform field area calibrations according to the requirements in IEC 61000-4-3. In the example shown in Figure 13, this is at the plane with length "b" along the front face of the EUT (0° azimuth) and the plane with length "a" along the side face of the EUT (90° azimuth).

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

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

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

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

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

For EUT perimeter dimensions that differ by 20 % or less of the 3 m separation distance (that is 0,6 m or less), only a single uniform field area ca libration is required at the separation distance corresponding to Plane 1 in Figure 13 (the widest face of the EUT).

NOTE When using the method described in the paragraph immediately above this note, two faces of the EUT will be tested at a higher immunity level due to their closer distance to the transmitting antenna.

7.2.9.3.4 Specifications for common emissions/immunity EUT test set-up

The tests shall be performed with the equipment configured as closely as possible to its typical, practical operation. Unless stated otherwise, cables and wiring shall be as specified by the manufacturer and the equipment shall be in its housing (or cabinet) with all covers and access panels in place. Any deviation from normal EUT operating conditions shall be included in the test report.

The definitions of 7.2.5.2 apply.

The EUT (on a non-conductive support structure, where applicable) shall be placed on a remotely operated turntable, as specified in 7.2.5.2, to allow the EUT to be rotated.

The height of the EUT above the ground plane shall be according to the following requirements.

- Table-top equipment is placed on a non-conductive set-up table with height 0,8 m ± 0,01 m, see 7.2.5.2. CISPR 16-1-4 specifies the method to determine the impact of the non-conductive set-up table on test results.
- Floor-standing equipment is placed on a non-conductive support, as specified in the applicable product standard. If there are no EUT height placement requirements in the product standard, the EUT shall be placed on a non-conductive support at a height of 5 cm to 15 cm above the ground plane.

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

Interface cables, loads, and devices should be connected to at least one of each type of the interface ports of the EUT and, where practical, each cable shall be terminated in a device typical for its actual use. Where there are multiple interface ports of the same type, a typical number of these devices shall be connected to devices or loads. It is sufficient to connect only one of the loads, provided that it can be shown, for example by preliminary testing, that the connection of further ports would not significantly increase the level of disturbance (that is, more than 2 dB) or significantly degrade the immunity level. The rationale for the configuration and loading of ports shall be documented in the test report.

The number of additional cables should be limited to the condition where the addition of another cable does not decrease the margin by a significant amount (for example, 2 dB) with respect to the limit.

NOTE 1 In some cases the optimum arrangement of features, loads, interface types, and cables for emissions and immunity tests are different, which may result in the need for some reconfiguration of the EUT within the confines of the uniform EUT arrangement.

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

- The cables shall be oriented so that vertically- and horizontally-polarised radiation fields are not excluded.
- The cable layout rules and cable lengths defined in the applicable product emission and immunity standards shall be applied. However, in case of conflicting requirements, the layout and maximum cable lengths defined in the product emission standard must take precedence. Fulfilling the rules can be accomplished by applying the cable placement rules of the emissions standard and exposing a minimum length of 1 m of cable, with a mix of horizontal or vertical parts, to the electromagnetic field during immunity testing (unless the manufacturer's specifications require shorter cables). Excess cable lengths should be bundled in the approximate centre of the length of the cable to form a bundle 30 cm to 40 cm in length. If no information is provided about cable layout in the product emission standard, the following arrangement is applied:

– For a table-top EUT (Figures 9 and 10), the cables leaving the uniform test volume (that is, those that connect the EUT to the outside world) shall be exposed to the electromagnetic field according to Figures 9 and 10 for a total length of 1 m (± 0,1 m), and then extended vertically down towards the floor (with a minimum length of 0,8 m imposed by the EUT table height). Interconnecting cables that hang from the table shall be at a minimum distance of 0,4 m (± 0,04 m) from the ground plane. If cables, which hang closer than 40 cm to the ground plane cannot be shortened to the appropriate length, the excess cable shall be folded back and forth, forming a bundle 30 cm to 40 cm long. If the maximum length declared by the manufacturer for certain cables does not allow a one meter horizontal cable layout, including a length to get to the ground plane for table-top products (placed on the 0,8 m height table), the horizontal layout shall depend on the length of cable in excess of 0,8 m. Bundling is not required.

– For a floor-standing EUT (Figures 11 and 12), cables leaving the uniform test volume shall be arranged with a length of at least 0,3 m run horizontally within the test volume and with a vertical run according to typical, normal use (depending on the height of the I/O port above floor). Horizontal cables shall be insulated from the ground planes by a minimum height of 10 cm for the entire length of the cable that is intended to be laid out along the floor.

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

- The manufacturer's specified cabling types and connectors shall be used.
- If the manufacturer's specification requires a cable length of less than or equal to 3 m, then the specified length shall be used. The cables shall be exposed for a length of 1 m (± 0,1 m) and the excess shall be folded back and forth, forming a bundle 30 cm to 40 cm long, for table-top equipment (see Figures 9 and 10) and approximately 1 m for floor-standing equipment (see Figures 11 and 12).
- If the specified length is greater than 3 m or is not specified, then the illuminated length shall be 1 m. The excess cables shall be extended outside the test volume.

  EUT combinations of table-top equipment and floor-standing equipment shall be arranged according to the set-up of each individual equipment configuration and the interconnecting cables between table-top equipment and floor-standing equipment shall be according to these rules.

- For the cables not terminated to auxiliary equipment, differential and common mode terminations should be simulated to represent the auxiliary equipment that would be connected to the cables and represent the required functional impedance.
- Cables not connected to another device may be terminated as follows (see also 7.2.5.2).
  - Coaxial shielded cables shall be terminated with a coaxial termination (usually 50 Ω or 75 Ω)
  - Shielded cables with more than one inner wire should have common and differential mode termination according to the EUT manufacturer's specifications. This common mode termination is to be connected appropriately between the inner wires or their differential mode termination and cable shield. If no information is available about the common mode terminations, 150 Ω common mode terminations should be used.
  - Unshielded cables must have differential mode termination according to the manufacturer's specifications.

NOTE 2 All cables which have been shortened in respect to its maximum length declared by the manufacturer and provided with artificial terminations for testing convenience, according to this paragraph, should also be provided with additional 150 Ω common mode terminations to the test chamber wall or floor.

The following items should be considered with 7.2.5.2.

- If the EUT needs auxiliary equipment (AE, see Note 3) to operate properly, special care must be taken to ensure that AE does not affect the radiated emissions measurements or the radiated immunity tests. AE may be located outside the anechoic chamber during testing if proper connecting interfaces are available on the chamber shielding. Measures to prevent RF-leakage into or out of the anechoic chamber through the interconnection cable may be necessary.

  NOTE 3 Auxiliary equipment (AE) is apparatus needed to help exercise the EUT (for example, devices that simulate telecommunications networks). The AE may be physically located outside the test environment.

- Other methods or equipment used to suppress unwanted emissions from AE shall be located outside the test chamber or beneath the raised floor.
- The test set-up, including cable layout, specifications of attached cables and terminations, and other measures taken to suppress emissions from AE outside the test volume, shall be clearly described in the test report.

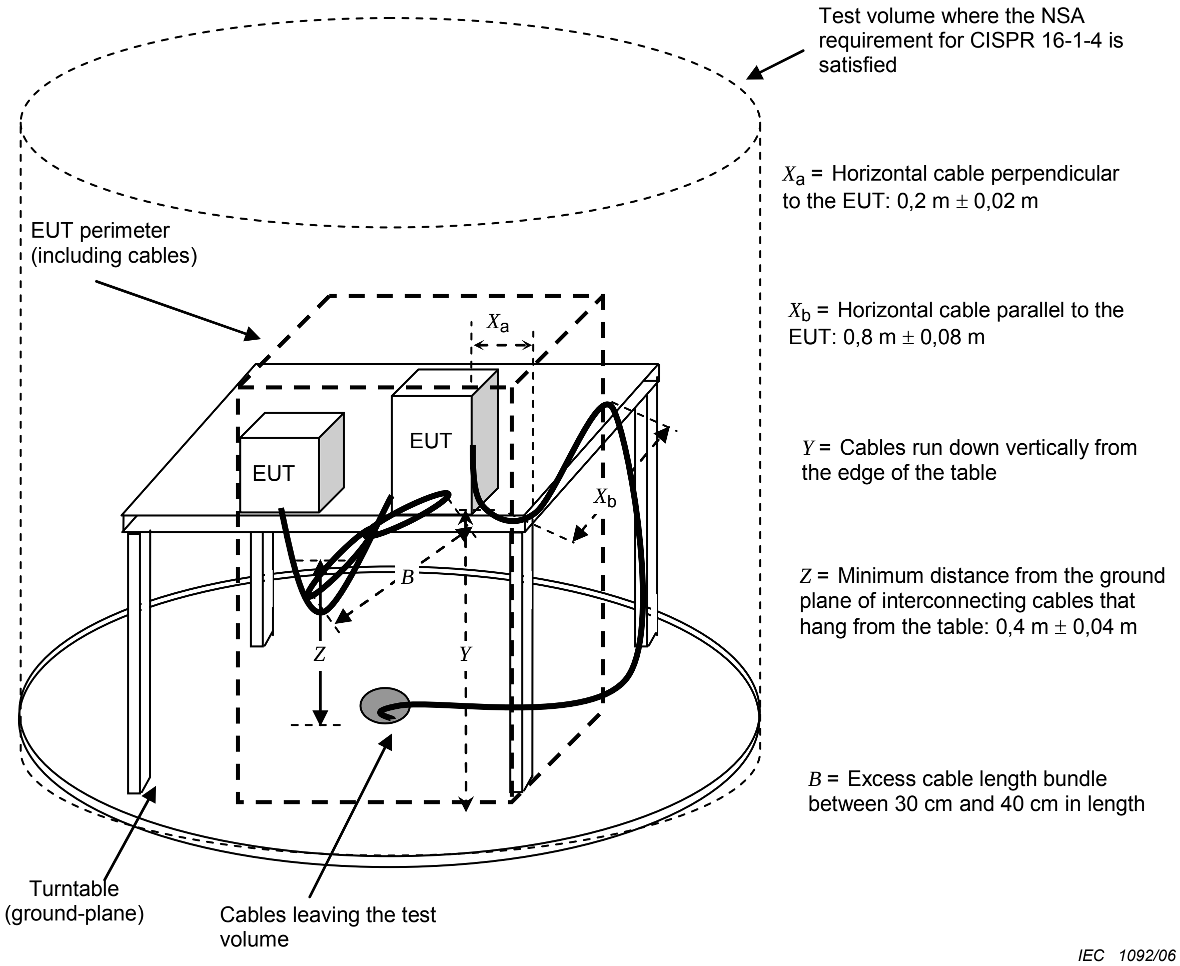


Figure 9 – Test set-up for tabletop equipment

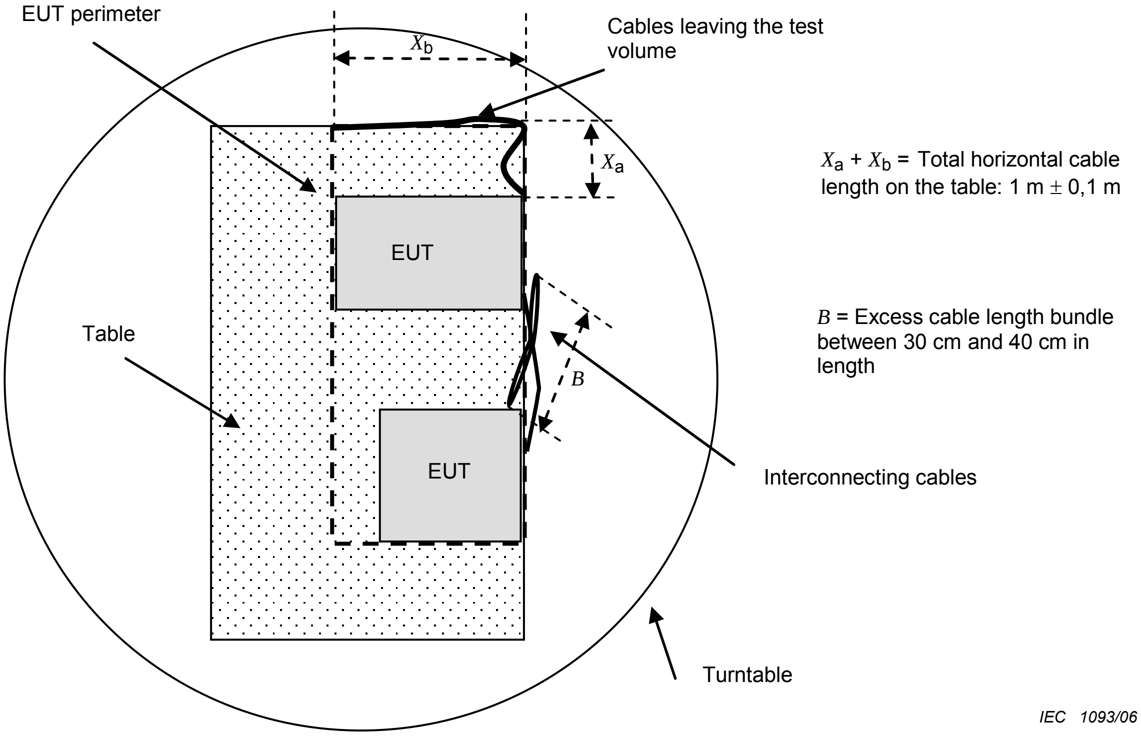


Figure 10 – Test set-up for tabletop equipment – Top view

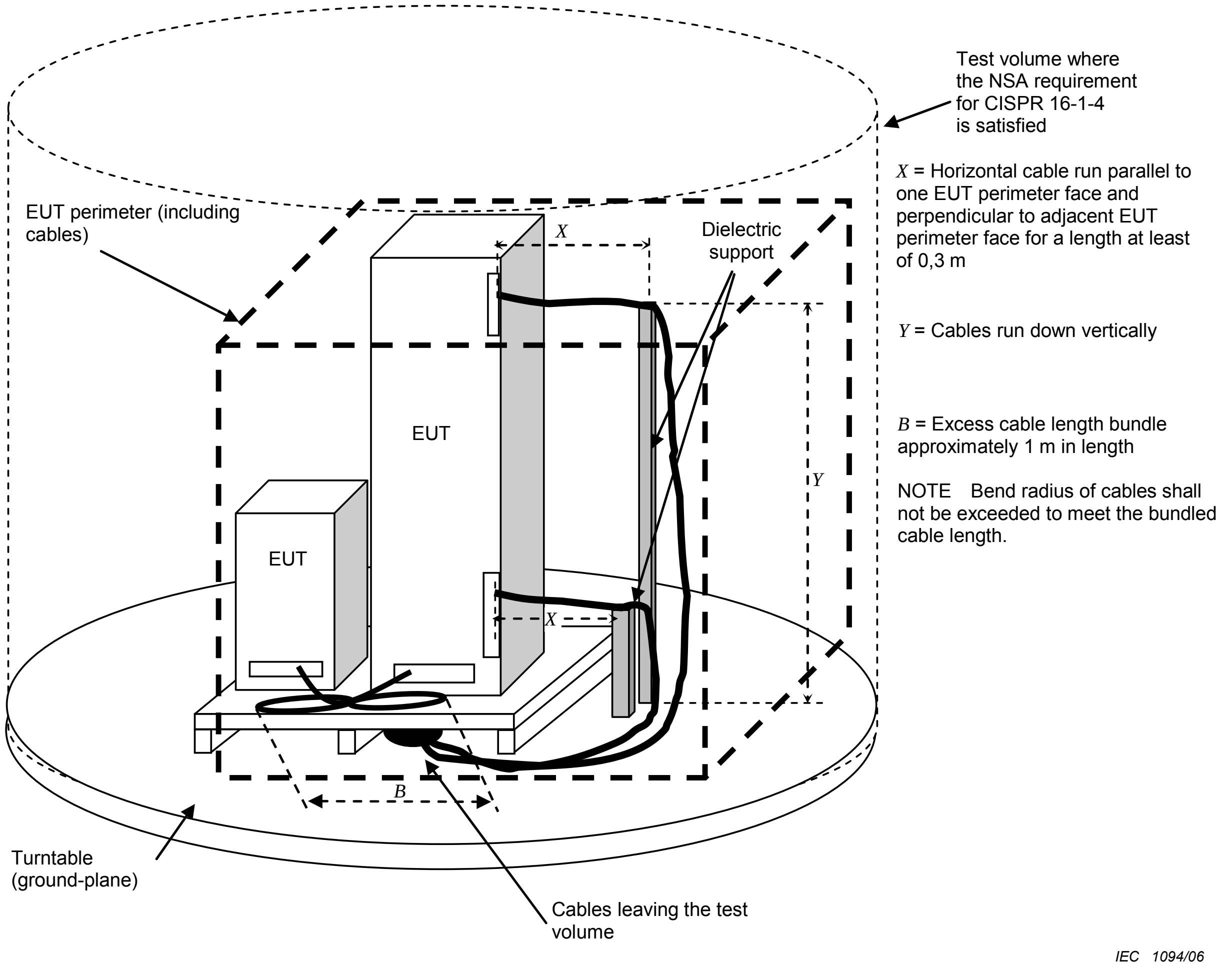


Figure 11 – Test set-up for floor-standing equipment

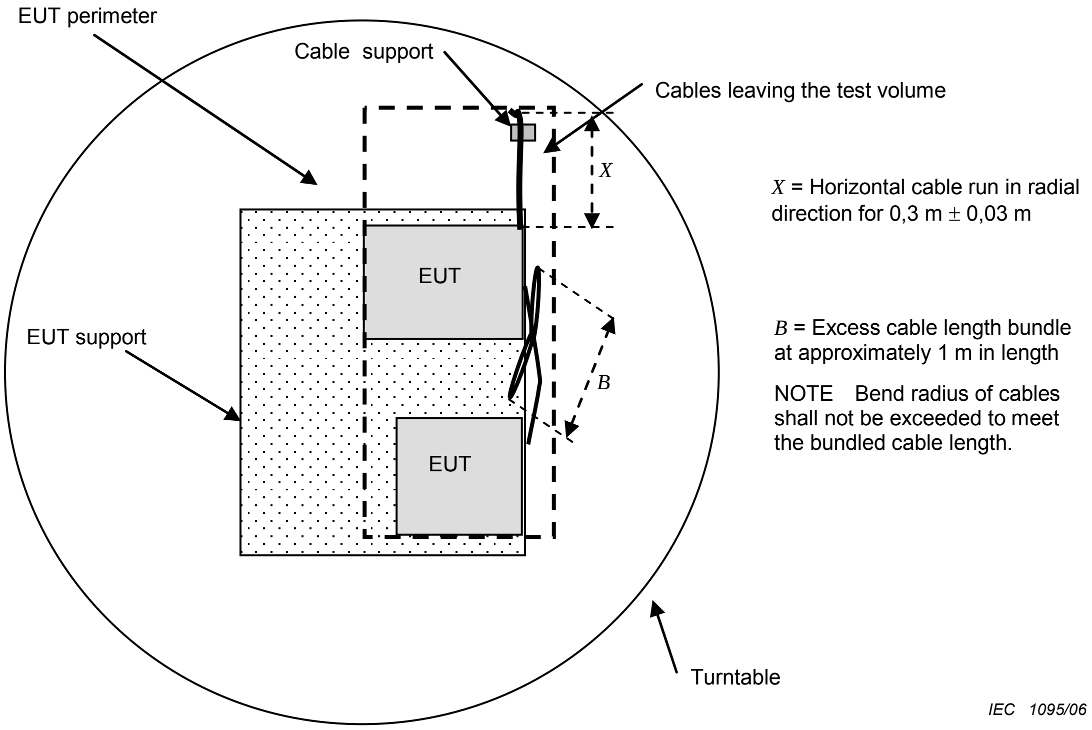


Figure 12 – Test set-up for floor-standing equipment, Top view

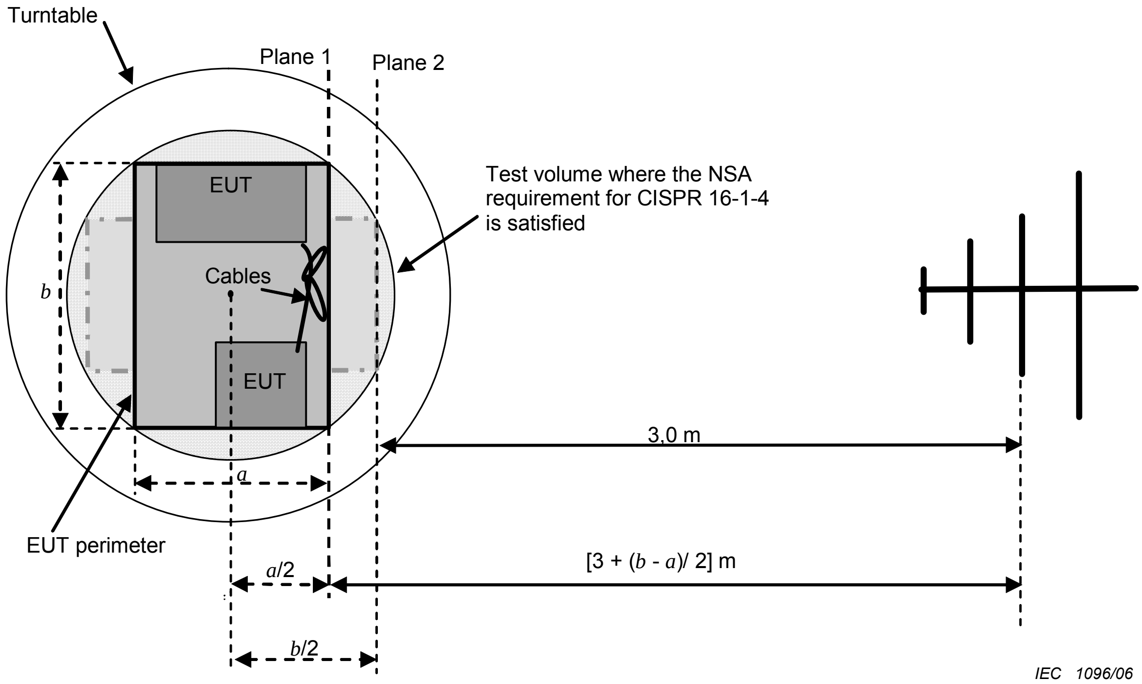


Figure 13 – Position of planes for uniform field calibration (top-view)

The EUT perimeter, including the connecting cables, shall fit within the test volume where the NSA requirement is satisfied.

For uniform common emission/immunity set-up, the facility must be calibrated at two vertical planes corresponding to the minimum and maximum dimensions of the EUT perimeter at 0°, 90°, 180° and 270° to the EUT faces. The types of equipment to be tested in the facility may be considered for selection of the two plane locations.

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

7.2.10 Measurements in TEM cells

(Under consideration)

7.3 Field-strength measurements in the frequency range 1 GHz to 18 GHz

7.3.1 Quantity to measure

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

NOTE In some standards, emission limits for equipment are expressed in terms of ERP (effective radiated power) in dB(pW) above 1 GHz. Under free space far field conditions, the formula to convert ERP into field strength at a 3 m distance is:

$$E_{(3\mathrm{m})}/\mathrm{dB}(\mu\mathrm{V/m}) = \mathrm{ERP}/\mathrm{dB(pW)} + 7{,}4$$

For distances d other than 3 m:

$$E_d/\mathrm{dB}(\mu\mathrm{V/m}) = \mathrm{ERP}/\mathrm{dB(pW)} + 7{,}4 + 20 \log [3/(d/\mathrm{m})]$$

7.3.2 Measurement distance

The field strength emitted by the EUT is measured at a preferred distance of 3 m.

The measurement distance, d, is the horizontal distance between the periphery of the EUT and the receive antenna reference point (see Figure 15). The EUT encompasses all portions of the EUT, including cable racks and support equipment and a minimum cable length of 30 cm.

Other distances may be used in practical situations:

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

NOTE Since dominant disturbances of the EUT may be assumed to be incoherent and radiated from a point source, the minimum distance mentioned above ($D^2/2\lambda$) is to be applied to the measuring antenna and not to the EUT.

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

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

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

The test setup should also consider that absorbers are typically required on the floor between the antenna and EUT for measurements above 1 GHz. Whenever practical, for emission measurements above 1 GHz the EUT should be raised above the height of the absorbers. If it is not possible to raise the entire EUT above the absorbers (i.e. rack-mounted or floor-standing equipment), an attempt should be made to configure the EUT (in a rack or chassis, for example) such that the radiating elements are located above the absorbers. The EUT shall be located in the validated test volume as described in 5.8.2.2 of CISPR 16-1-4:2003. If it is not practical and safe to raise the EUT or its radiating elements above the absorber height, the maximum portion of the EUT that may be located below the highest point of the absorbers is 30 cm (see 7.3.6.1 and Figure 14 below).

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

7.3.4 Measurement site

The measurement site shall comply with the requirements described in 8.2 of CISPR 16-1-4:2003.

7.3.5 Measurement instrumentation

The measurement instrumentation shall comply with the requirements described in 8.2 of CISPR 16-1-1:2003 and 4.6 of CISPR 16-1-4:2003.

Measurements to verify compliance with a peak limit shall be conducted with the peak measuring spectrum analyzer or receiver using a measurement bandwidth of 1 MHz (impulse bandwidth) as defined in 8.2 of CISPR 16-1-1:2003.

Measurements to verify compliance with an average limit shall be conducted with a peak measuring spectrum analyzer using a measurement bandwidth of 1 MHz (impulse bandwidth) and a reduced video bandwidth, set as defined in item c) of 8.2 of CISPR 16-1-1:2003. The value of video bandwidth required for an average measurement shall be less than the lowest spectral component of the input signals to be measured.

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

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

7.3.6 Measurement procedure

7.3.6.1 General description of the radiated field measurement method above 1 GHz

The radiated field measurement method above 1 GHz is based on measurement of the maximum electric field emitted from the EUT as shown in Figure 14.

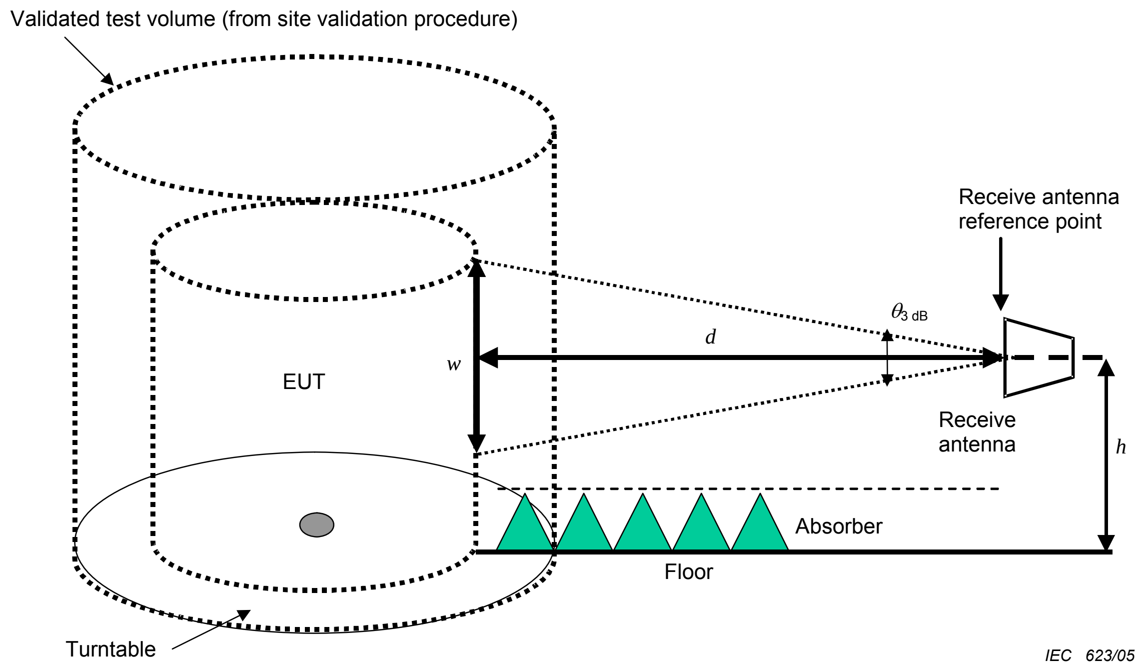


Figure 14 – Measurement method above 1 GHz, receive antenna in vertical polarization

- **Definitions referring to Figure 14**

Validated test volume: The volume validated during the site validation procedure (see 5.8.2.2 of CISPR 16-1-4:2003). Typically, this is the largest diameter EUT that can be used in the test facility.

EUT: The smallest diameter cylinder that will fully encompass all portions of the actual EUT, including cable racks and a minimum length of 30 cm of cables. The EUT that is located within this cylinder must be capable of rotating about its centre (typically by a remotely controlled turntable). The EUT must be located within the validated test volume. A maximum of 30 cm of w (see definition of w below) may be below the height of absorbers on the floor only when the EUT is floor standing and cannot be raised above the height of the absorbers (see 7.3.3).

$\theta_{3\ dB}$: The minimum 3 dB beamwidth of the receive antenna at each frequency of interest. $\theta_{3\ dB}$ is the minimum of both the E-plane and H-plane values at each frequency. θ_{3dB} may be obtained from manufacturer provided data for the receive antenna.

d: The measurement distance (in meters). This is measured as the horizontal distance between the periphery of the EUT and the reference point of the receive antenna.

w: The dimension of the line tangent to the EUT formed by $\theta_{3\ dB}$ at the measurement distance d. Equation (10) shall be used to calculate w for each actual antenna and measurement distance used. The values of w shall be included in the test report. This calculation may be based on the manufacturer-provided receive-antenna beamwidth specifications :

$$w = 2 \times d \times \tan(0{,}5 \times \theta_{3\ dB}) \qquad (10)$$

w shall be of the minimum dimension as specified in Table 2.

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

Table 2 specifies the minimum acceptable dimension of w (w_{min}). The minimum requirements shown in Table 2 are calculated from equation (10) based on testing at the minimum permissible 1 m measurement distance specified in paragraph 7.3.2 and the values of $\theta_{3\ dB(min)}$ shown. The selection of measurement distance, d, and antenna type shall be made such that w is equal to, or greater than, the values shown in Table 2 at any frequency where the field is measured. At frequencies not shown in Table 2, the limit of w_{min} shall be linearly interpolated between the nearest two frequencies listed:

Table 2 – Minimum dimension of w (w_{min})

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

NOTE 1 The dimension, w, is permitted to be larger than the minimum specified in Table 2, and other antennas and distances may be used to satisfy the minimum required value of $w = w_{min}$ shown in Table 2 provided equation (10) is met.

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

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

NOTE 4 The height scan requirement depends on w such that it may be advantageous to maximize w by selection of a wider beamwidth antenna and a larger measurement distance than the minimum requirements of Table 2.

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

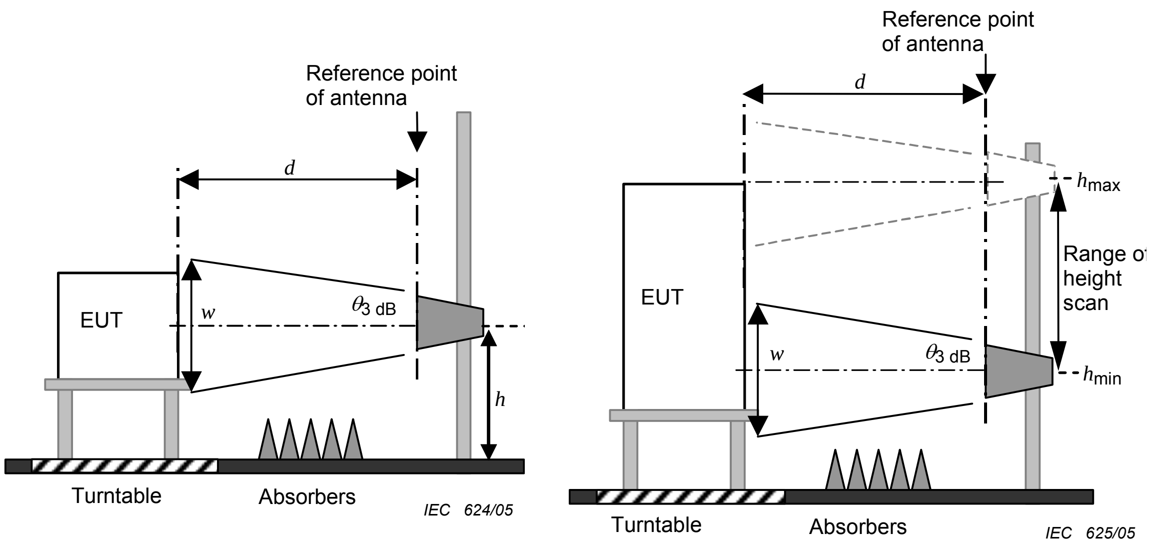
Table 3 lists example values of w calculated using equation (10) for three antenna types at a 1 m, 3 m, and 10 m measurement distance.

Table 3 – Example values of *w* for three antenna types

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

[a] LPDA-V : V-Type Log Periodic Dipole Array. The values shown for $\theta_{3\ dB}$ and w are typical of both the LPDA and LPDA-V. However, these antennas typically have different gain.

The maximum emission is measured by moving the receive antenna in height along with rotation of the EUT in azimuth (0° to 360°). The required range of height investigation is specified below and illustrated in Figure 15 for two typical categories of EUTs.



a) w encompasses EUT height (fixed-height measurement)

b) w does not encompass EUT height (height scan required)

Figure 15 – Illustration of height scan requirements for two different categories of EUTs

For any EUT with maximum dimensions equal to or smaller than w, the centre of the receive antenna shall be fixed at the height of the centre of the EUT (Figure 15 a)).

For any EUT with a maximum vertical dimension larger than w, the centre of the antenna shall be scanned vertically along the line parallel to w, as shown in Figure 15 b). The required scanning range for h is 1 m to 4 m. If EUT height is less than 4 m, scanning the centre of the receive antenna to heights above the top of the EUT is not required. In both cases the fixed height, h, or the range of heights investigated shall be recorded in the test report.

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

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

7.3.6.2 General measurement procedure

For any EUT, the frequencies of emission should first be detected by a preliminary emission maximization (see 7.3.6.3). Then the final emission test takes place (see 7.3.6.4). Both of these measurements are to be made preferably at the limit distance. If, for any justified reason, the final measurement is performed at a different distance than the limit distance, a measurement at the limit distance should be made first, to help in interpreting the resulting data in case of dispute.

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

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

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

7.3.6.3 Preliminary measurement procedure

The maximum radiated emission for a given mode of operation may be found during a preliminary test.

Final measurements shall be done using the EUT operational mode identified by preliminary measurements to have the highest emissions.

Final measurements shall be performed using all required detectors. Alternatively, peak measurement results may be used to demonstrate compliance with all specified limits.

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

a) For any EUT with maximum dimension equal to or smaller than w, the centre of the receiving antenna shall be fixed at the height of the centre of the EUT (see Figure 15a)).
b) For any EUT with maximum vertical dimension larger than w, height scanning shall be performed in accordance with the height scan requirements (upper and lower bounds) specified in 7.3.6.1.
c) In all cases, in order to find the maximum emissions, the EUT shall be rotated in azimuth through all angles in the range of 0° to 360°, and the measurements shall be performed for both horizontal and vertical polarizations.

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

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

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

7.3.6.5 Procedure for APD measurement

The measurement of the amplitude probability distribution (APD) of a disturbance signal provides a statistical characterization of the disturbance signal in question. Background material on the application of the APD-measuring function is provided in 4.7 of CISPR 16-3:2003 (Amendment 1).

A product committee may choose the APD measurement as the method for final emission testing. The APD measurement shall be made at those frequencies where the EUT generates a high disturbance field strength. The number of frequencies and their selection method shall be determined by the product committee.

The measurement shall be made using one of the following two methods. One method is the measurement of the disturbance level E_{meas} in dB(μV/m) related to the specified probability of time p_{limit} (method 1, see 7.3.6.5.1). The second method is the measurement of the probability of time p_{meas} during which the disturbance envelope exceeds a specified level E_{limit} in dB(μV/m) (method 2, see 7.3.6.5.2). Figures are included in Annex E to show the specifics of the two APD measurement methods.

Final measurements shall be done using the EUT operational mode identified by preliminary measurements to have the highest emissions.

Final measurements shall be performed using all required detectors. Alternatively, peak measurement results may be used to demonstrate compliance with all specified limits.

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

a) For any EUT with maximum dimension equal to or smaller than w, the centre of the receiving antenna shall be fixed at the height of the centre of the EUT (see Figure 15a)).
b) For any EUT with maximum vertical dimension larger than w, height scanning shall be performed in accordance with the height scan requirements (upper and lower bounds) specified in 7.3.6.1.
c) In all cases, in order to find the maximum emissions, the EUT shall be rotated in azimuth through all angles in the range of 0° to 360°, and the measurements shall be performed for both horizontal and vertical polarizations.

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

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

1) The EUT shall be rotated in azimuth from 0° to 360° either by a turntable or movement of the receive antenna around the volume.
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3) Both horizontal and vertical polarizations shall be investigated.

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A product committee may choose the APD measurement as the method for final emission testing. The APD measurement shall be made at those frequencies where the EUT generates a high disturbance field strength. The number of frequencies and their selection method shall be determined by the product committee.

The measurement shall be made using one of the following two methods. One method is the measurement of the disturbance level E_{meas} in dB(μV/m) related to the specified probability of time p_{limit} (method 1, see 7.3.6.5.1). The second method is the measurement of the probability of time p_{meas} during which the disturbance envelope exceeds a specified level E_{limit} in dB(μV/m) (method 2, see 7.3.6.5.2). Figures are included in Annex E to show the specifics of the two APD measurement methods.

If a product committee decides to use the APD approach, either method 1 or method 2 shall be selected. In case the APD measuring instrument does not include an A/D converter it can only be used in conjunction with method 2. In case the APD measuring instrument includes an A/D converter it can be used for both methods.

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

7.3.6.5.1 Method 1 – Measurement of the level of disturbance

The measurement shall be carried out using the following procedure:

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

   NOTE In cases where narrowband emissions are hidden by broadband emissions, the maximum hold mode in combination with the peak detector may overlook narrowband emissions. Therefore, an additional measurement may be needed to find the frequencies of the narrowband emissions to be measured. The product committee may require additional sweeps using the average detector or digital video averaging. Furthermore, the number of frequencies for the APD measurement may also be specified by the product committee.
3) Determine the frequencies for the APD measurement. The number of the frequencies shall be specified by the product committee.
4) Set the center frequency of spectrum analyzer to the frequency at which the highest level is observed during the application of step 2) of this procedure.
5) Set the reference level of the spectrum analyzer to minimum 5 dB above the maximum level of disturbance that is obtained in step 2).
6) Set the spectrum analyzer to the zero frequency span mode and measure the APD of disturbance during the measurement time that is specified by the product committee. The measurement time shall be longer than the period of the disturbance.

   In case of fluctuating disturbance frequencies, the product committee shall specify the frequency range XX (in MHz) in which the APDs of the disturbance shall be measured. APDs within the range XX MHz shall be measured with a 1 MHz frequency step size. However, at frequencies with APD measurement values which are approximately 6 dB lower than the APD limit, additional measurements may be needed with a smaller frequency step size (e.g. 0,5 MHz). The product committee shall define the smaller frequency step size.
7) Change the center frequency of spectrum analyzer to the next frequency determined in step 2), then repeat the procedures of steps 4) - 6) until the APD measurements for all frequencies are carried out.
8) Read the disturbance level E_{meas} in dB(μV/m) related to the specified probability p_{limit} from the results of step 6).
9) Compare E_{meas} dB(μV/m) against the limit E_{limit} dB(μV/m). The EUT complies if E_{meas} is less than or equal to E_{limit} at all frequencies.

7.3.6.5.2 Method 2 - Measurement of the probability of time

The measurement shall be carried out using the following procedure:

Steps 1), 2), 3), 4), 5) and 7) of method 2 are the same as the corresponding steps of method 1 (7.3.6.5.1).

Step 6) in method 2 is changed as follows:

6) Set the spectrum analyzer to the zero frequency span mode and measure the APD (or measure the probability p_{meas} related to the specified levels directly) of the disturbance during the measurement time which is to be specified by the product committee.

8) Read the probabilities p_{meas} during which the disturbance envelope exceeds a specified level E_{limit} in dB(μV/m) from the results of step 6).

9) Compare p_{meas} against the limits p_{limit}. The EUT complies if p_{meas} is less than or equal to p_{limit} at all frequencies.

7.4 Substitution method of measurement in the frequency range of 30 MHz to 18 GHz

The method is intended for measuring radio disturbance radiated from the cabinet, including wiring and circuitry inside the cabinet, of an equipment under test. The EUT may be either a self-contained unit with no port for any connection or have one or several ports for power and other external connections.

The substitution method is currently being used to measure emissions from microwave ovens in the frequency range 1 GHz –18 GHz.

For future product standards, product committees are invited to use the field-strength measurement method described in 7.3.

7.4.1 Test site

The test site shall be a level area. Indoor sites may be used, but may need special arrangements, especially in the upper part of the frequency range, in order to meet the requirements of stable and non-critical reflections from the surroundings – for example, a corner reflector added to the measuring antenna and an absorbing wall behind the EUT. The suitability of the site shall be determined as follows:

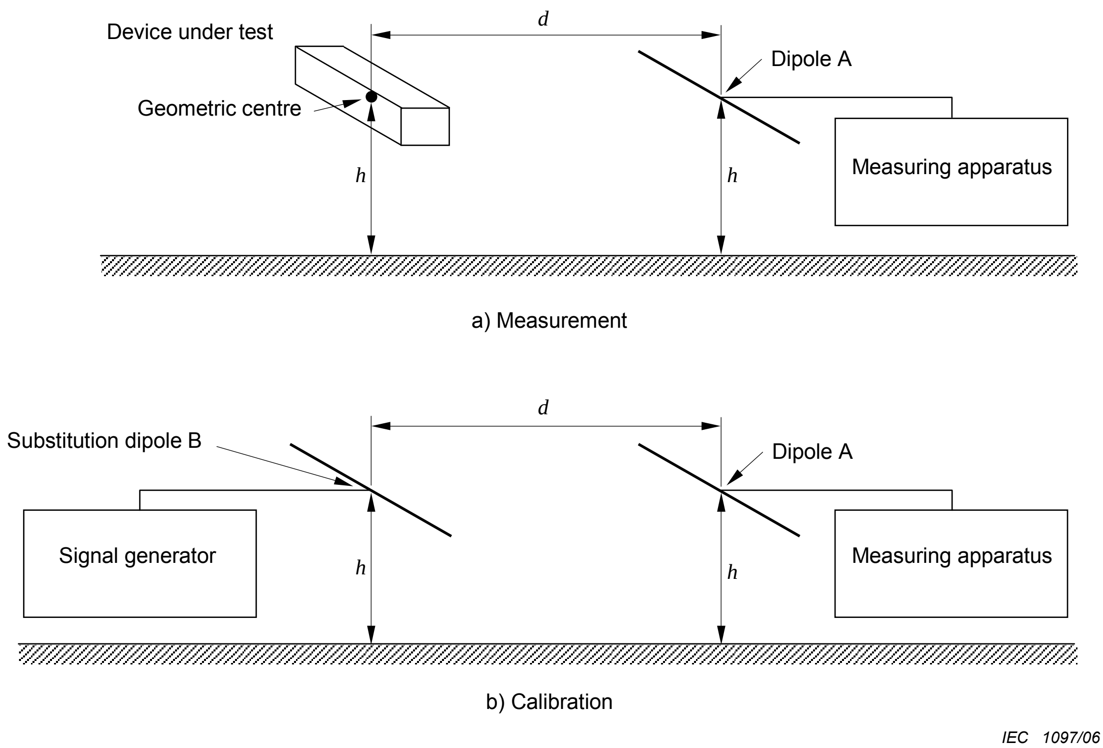


Figure 16 – Method of measurement – Substitution method
(see 7.4.1 and 7.4.3)

Two horizontal half-wavelength dipoles (see also 7.4.2) shall be placed parallel to each other, at the same height *h*, being not less than 1 m above the floor and spaced at the measurement distance *d*. Dipole B shall be connected to a signal generator and dipole A to the input of the measuring receiver. The signal generator shall be tuned to give maximum indication on the measuring receiver and its output adjusted to a convenient level. The site shall be considered suitable for the purpose of measurement at the test frequency if the indication on the measuring receiver does not vary more than ±1,5 dB when dipole B is moved 100 mm in any direction. The test shall be repeated throughout the frequency range at frequency intervals small enough to ensure that the site is satisfactory for all measurements intended.

If an EUT requires that measurements be made also with vertical polarization (see 7.4.3), the suitability test of the site shall be repeated with the two dipoles positioned for vertical polarization.

7.4.2 Test antennas

The test antennas A and B of Figure 16 have been described above as half-wave dipoles. For the frequency range below 1 GHz, this requirement applies primarily to the transmitting antenna B for which the radiated power in the direction of maximum radiation must be relatable to the power at the terminals of antenna B. The measuring antenna A should also be a half-wave dipole. Its actual sensitivity will be included in the substitution calibration of the test configuration.

In the frequency range of 1 GHz to 18 GHz linearly polarized horn antennas are recommended.

7.4.3 EUT configuration

The EUT shall be placed on a non-conducting table with provision to rotate in the horizontal plane. The EUT shall be set up so that the geometric centre of the EUT coincides with the point earlier used as centre point for dipole B (Figure 16). If the EUT is comprised of more than one unit, each unit shall be measured separately. Detachable leads to the EUT should be removed if operation is not affected adversely. Required leads shall be provided with absorbing ferrite rings and be so positioned that they will not influence the measurements. For shielded EUTs, all connectors not used shall be terminated by shielded terminations.

7.4.4 Test procedure

With the EUT arranged as described in 7.4.3, the horizontally polarized measuring dipole A shall be placed in the same position as when checking the test site. The dipole shall be normal to a vertical plane through its centre and that of the EUT. The EUT is first measured in its normal table-standing position and secondly when tilted 90° to stand on a normally vertical side. In each position it shall be rotated 360° in the horizontal plane. The highest reading Y shall be the characteristic value for the EUT.

The measuring system is calibrated by replacing the EUT with a half-wave dipole B. The centre of this calibrating dipole B shall be placed in the same spot as the geometric centre of the previously measured EUT and parallel with the measurement antenna A, and be connected to a signal generator. The radiated power from the cabinet of the EUT is defined as the power at the terminals of the half-wave dipole B when the signal generator is adjusted to give the same reading on the measuring receiver as the maximum reading recorded earlier (Y), at each frequency of measurement.

When measurements are made with both horizontally and vertically polarized measuring dipoles, separate calibrations must be made for the two modes.

7.5 Measurements of equipment *in situ*

7.5.1 Applicability of and preparation for *in situ* measurements

In situ measurements may be necessary for the investigation of an interference problem at a particular location, i.e. where electrical equipment is suspected of causing interference to radio reception in its vicinity.

Where allowed by the relevant product standard, *in situ* measurements may be made for the evaluation of compliance, if it is not possible for technical reasons to make radiated emission measurements on a standard test site. Technical reasons for *in situ* measurements are excessive size and/or weight of the EUT or situations where the interconnection to the infrastructure for the EUT is too expensive for the measurement on standard test sites. *In situ* measurement results of an EUT type will normally deviate from site to site or from results obtained on a standard test site and can therefore not be used for type testing.

NOTE 1 In general, however, due to imperfections such as mutual coupling between the conductive structures present in the *in situ* environment, which may also be more or less polluted by ambient electromagnetic fields, and the measuring antenna/equipment under test, *in situ* measurements cannot fully replace measurements on a suitable test site (open-area test site or alternative test sites, for example, (semi-)anechoic chambers) as specified in CISPR 16-1.

The EUT usually consists of one or more devices and/or systems, is part of an installation, or is interconnected with an installation.

A perimeter connecting the outer parts of the EUT is usually taken as the reference point to determine the measurement distance. In some product standards, the exterior walls or boundaries of business parks or industrial areas are taken as the reference points.

Preliminary measurements shall be made to identify the frequency and amplitude of the disturbance field strengths amongst the ambient signals taking into account the potential sources of interference (for example, oscillators) in the EUT. For these measurements the use of a spectrum analyser is recommended in place of a receiver because a large frequency spectrum can be analysed. For the identification of the frequency and amplitude of the disturbance signals the use of a current probe on the connected cables, or near-field probes or the measurement antennas placed closer to the EUT is recommended.

Measurements shall also be made on selected frequencies to determine, where possible, the modes of operation in which the EUT generates the highest disturbance field strengths. The subsequent measurements shall be made with the EUT in these modes of operation.

NOTE 2 Where the EUT is a piece of equipment, the operating mode of which cannot be switched independently of the operation of other equipment, the selection of conditions producing the highest disturbances may be impossible. For some of them, these conditions may be dependent on time, particularly if they are on cyclic operation. In such cases, the period of observation should be chosen to approach the conditions of highest disturbance production.

Measurements shall be made around the EUT at approximately the same measurement distance on each of the selected frequencies to determine the direction of the highest disturbance field strength. The EUT should be tested in at least three different directions. The final disturbance field-strength measurements on each frequency shall be made in the directions of the highest disturbance field strengths (which may vary from frequency to frequency) taking into account the local conditions.

The highest disturbance field strengths shall be measured with the antenna in vertical and horizontal polarization.

If the ratio of the measured disturbance field strength to any ambient emission is lower than 6 dB, the measurement methods described in Annex A can be used.

7.5.2 Field-strength measurements in the frequency range 9 kHz to 30 MHz

7.5.2.1 Measurement method

The magnetic disturbance field strength shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength.

The horizontally polarized disturbance field strength shall be measured at the standard measurement distance d_{limit} using a loop antenna as described in 4.2.1 of CISPR 16-1-4:2003 at a height of 1 m (between the ground and lowest part of the antenna). The maximum disturbance field strength shall be determined by rotating the antenna.

NOTE For the measurement of the maximum disturbance field strength from lines arranged in any direction, the antenna should be oriented in three orthogonal directions, and the measured field strength is calculated by

$$E_{\text{sum}} = \sqrt{E_x^2 + E_y^2 + E_z^2}$$

In cases where limits are given for the E field equivalent but the measured field strengths are the magnetic components, the H field strength can be converted to the corresponding E field strength using the free space impedance of 377 Ω by multiplying the H field reading by 377. The H field in this case is given by

$$H_{\text{sum}} = \sqrt{H_x^2 + H_y^2 + H_z^2}$$

This H field value can be used directly in cases where limits are directly given for the magnetic field strength.

If the antenna cannot be moved in three orthogonal directions, it can be turned by hand in the direction of maximum reading for the measurement of the maximum disturbance field strength.

7.5.2.2 Measurement distances other than the standard distance

If it is not possible to adhere to the standard distance d_{limit}, as specified in the product or generic standard, the measurements should be made at distances either less or greater than the standard measuring distance in the direction of the maximum radiation.

At least three measurements at different measuring distances less or greater than the standard measuring distance shall be used if it is not possible to use the standard distance.

The measurement results (in decibels) shall be plotted as a function of the measurement distance on a logarithmic scale. One line shall be drawn to join up the measurement results. This line represents the decrease in the field strength and can be used to determine the disturbance field strength at distances other than the measurement distance, for example, at the standard distance.

7.5.3 Field-strength measurements in the frequency range above 30 MHz

7.5.3.1 Measurement method

The electric disturbance field strength shall be measured in the direction of maximum radiation at the standard distance with the EUT in the mode of operation generating the highest disturbance field strength. The maximum horizontally and vertically polarized disturbance field strengths shall be measured using broadband antennas with, as far as practicable, a variable height of 1 m to 4 m. The highest value shall be taken as the measured value.

It is recommended that biconical antennas be used for measurements in the frequency range up to 200 MHz and log-periodic antennas for measurements in the frequency range above 200 MHz. The distance between the measuring antenna and any nearby metallic elements (including cables) should be greater than 2 m.

7.5.3.2 Measurement distances other than the standard distance

The standard measurement distance d_{std} is specified in the product or generic standard. If it is not possible to adhere to the standard measurement distance, the disturbance field strength shall be measured in different measuring distances as described in 7.5.2.2. A height scan of the antenna shall be used for each measurement The disturbance field strength at the standard distance d_{std} shall be determined according to 7.5.2.2 by plotting the measured field strength as a function of the measurement distance on a logarithmic scale.

If it is not possible to measure at different measuring distances and the measurement distance refers to the outer wall of a building or the border of the premises, the measurement results shall be converted to the standard distance using equation (5).

$$E_{\text{std}} = E_{\text{mea}} + n \times 20 \times \log \frac{d_{\text{mea}}}{d_{\text{std}}} \tag{5}$$

where

E_{std} is the field strength at the standard distance in dB(µV/m) for comparison with the emission limit;

E_{mea} is the field strength at the measurement distance in dB(µV/m);

d_{mea} is the measurement distance in metres;

d_{std} is the standard distance in metres.

n depends on the distance d_{mea} as follows:

if 30 m ≤ $d_{mea,}$ n = 1;

if 10 m < d_{mea} < 30 m n = 0,8;

if 3 m < d_{mea} < 10 m n = 0,6.

NOTE n < 1 accommodates the difference between the measuring distance and the distance to the EUT.

Measurement distances closer than 3 m shall not be used.

If it is not possible to measure at different measuring distances, and equation (5) is not used because the measurement distance does not refer to the outer wall of a building or boundary of premises, the field strength should be determined by measurement of the radiated disturbance power (see 7.5.4).

7.5.4 *In situ* measurement of the effective radiated disturbance power using the substitution method

7.5.4.1 General measurement condition

The substitution method can be used without additional conditions if, and only if, the EUT can be switched off and if the EUT can be removed for the substitution.

If the EUT cannot be removed, and if its front face is a large plane surface, the effect of this face on the substitution shall be taken into account (see equation (7b)). If the front surface of the EUT does not fit into a two-dimensional plane in the measurement direction, the additional measurement uncertainty is not considered.

If the EUT cannot be switched off, it is still possible to use the substitution method to measure the radiated power of a disturbance from the EUT at a particular frequency, by using a nearby frequency at which the field strength of the disturbance from the EUT is at least 20 dB below that at the frequency of interest (“nearby” means within one or two receiver IF-bandwidths). The frequency selected should, where possible, be chosen with regard to possible interference to radio services.

7.5.4.2 Frequency range 30 MHz to 1 000 MHz

7.5.4.2.1 Measurement distance

The measurement distance chosen shall be such that the measurement is made in the far field. This requirement is generally met, if

a) d is greater than $\frac{\lambda}{2\pi}$ and

b) $$d \geq \frac{2 \times D^2}{\lambda} \tag{6}$$

where

d is the measurement distance in meters;

D is the maximum dimension of the EUT with cabling in meters;

λ is the wavelength in meters;

or

the measurement distance d is equal to, or greater than, 30 m.

In the far field the exponent n in equation (5) may be assumed to be 1. If a shorter measurement distance is chosen, this assumption can be validated by using the procedure of 7.5.3.2 to verify that the field strength falls off inversely with distance.

If the local conditions require that a shorter measurement distance be chosen, this shall be indicated.

7.5.4.2.2 Measurement method

The effective radiated disturbance power shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength. The measurement distance shall be chosen according to 7.5.4.2.1 and the highest disturbance field strength on the selected frequency determined by varying the antenna height at least in the range of 1 m to 4 m as far as practicable.

For the measurement of the effective radiated disturbance power, steps a) to g) shall be followed.

a) The EUT shall be disconnected and removed. A half-wave dipole or antenna with similar radiation characteristics and known gain G, relative to a half-wave dipole is substituted in its place. If it is impractical to remove the EUT, a half-wave or broadband dipole (in the frequency range lower than about 150 MHz to minimize mutual coupling to the EUT) is positioned in the vicinity of the EUT. The vicinity is a range up to 3 m.
b) The half-wave (or broadband) dipole shall then be fed by a signal generator operating on the same frequency.
c) The position and polarization of the half-wave dipole (or broadband antenna) shall be such that the measuring receiver receives the highest field strength. If the EUT is not removed, then, if possible, it shall be switched off and the dipole is moved in a range up to 3 m around the EUT.
d) The power of the signal generated shall be varied until the measuring receiver shows the same reading as when the highest disturbance field strength from the EUT was measured.
e) If the front of the EUT fills a large plane surface (for example, a building with a cable-TV network) the substitution antenna (half-wave dipole) is positioned about 1 m in front of the plane surface (in front of the building). The location of the substitution should be so chosen that an imaginary line between the substitution antenna and the measuring antenna is perpendicular to the direction of the face of the building.
f) The height, polarization and distance to the plane imaginary surface enclosing the half-wave dipole (or broadband antenna) and perpendicular to the measurement axis between the antenna and the location of the measuring antenna shall be varied such that the receiver receives the highest field strength.
g) The power of the signal generator shall be varied as in d) above.

For removed EUTs and EUTs whose front face is not contained within an imaginary large plane surface, the power at the signal generator P_G plus the gain G of the transmit antenna relative to a half-wave dipole yields the effective radiated disturbance power P_r to be measured:

$$P_r = P_G + G \tag{7a}$$

For EUTs that fit within an imaginary large plane surface (for example, buildings with telecommunication networks), the increase in gain of the dipole positioned in front of this surface is given by

$$P_r = P_G + G + 4\ \text{dB} \tag{7b}$$

where

P_r is in dB(pW);

P_G is in dB(pW); and

G is in dB.

The effective radiated disturbance power can be used to calculate the disturbance field strength at the standard measurement distance d_{std}. The free-space field strength E_{free} shall be calculated using the following equation:

$$E_{free} = \frac{7\sqrt{P_r}}{d_{std}} \tag{8}$$

where

E_{free} is in μV/m;

P_r is in pW; and

d_{std} is in metres.

If the calculated free-space field strength of equation (8) is compared with limits of disturbance field strength measured in standard test sites, it must be considered that the amplitude field strength measured at standard test sites is approximately 6 dB higher than the free space field strength of equation (8) due to the reflections from the ground plane. Equation (8) can be modified to take into account this increment. The disturbance field strength at the standard distance E_{std} can therefore be calculated for the vertical polarization using the following equation:

$$E_{std} = P_r - 20 \log d_{std} + 22{,}9 \tag{9a}$$

For horizontal polarization below 160 MHz the maximum field strength is not measured at standard test sites. Therefore the 6 dB factor must be corrected as follows:

$$E_{std} = P_r - 20 \log d_{std} + 16{,}9 + (6 - c_c) \tag{9b}$$

where

E_{std} is in dB(μV/m);

f is the measuring frequency;

d_{std} is in metres;

c_c is the correction factor for horizontal polarization. This was determined assuming the radiation source at 1 m in height.

f MHz	30	40	50	60	70	90	100	120	140	160	180	200	750	1 000
c_c dB	11	10,2	9,3	8,5	7,6	5,9	5,1	3,4	1,7	0	0	0	0	0

This method for determining the disturbance field strength can mainly be used if there are obstacles between the measuring antenna and the EUT.

7.5.4.3 Frequency range 1 GHz to 18 GHz

7.5.4.3.1 Measurement distance

The measurement distance chosen shall be such that the measurement is made in the far field. The far-field condition shall be verified by measuring the radiated disturbance power with a double-ridged waveguide horn or log-periodic antenna as a function of the distance. The requirement is met if the measurement distance is equal to, or greater than, the transition distance. The transition distance is marked by the transition point which shall be determined as shown in Figure 17. The measurement results shall be plotted and two parallel lines separated by 5 dB drawn to enclose as many of the measurement results; the transition point is the point where the lines intersect and after which the radiated power decreases by 20 dB/decade.

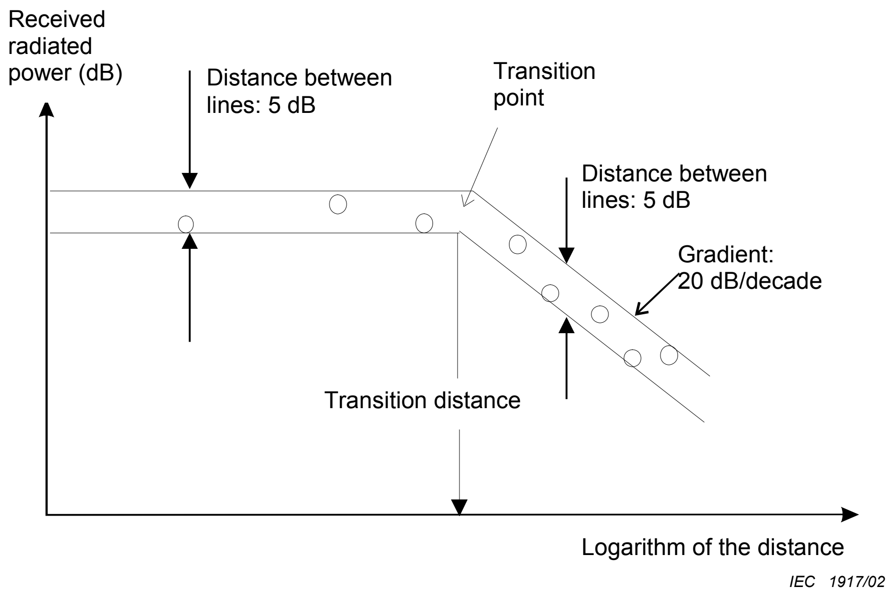


Figure 17 – Determination of the transition distance

7.5.4.3.2 Measurement method

The radiated disturbance power shall be measured in the direction of maximum radiation with the EUT in the mode of operation generating the highest disturbance field strength. A double-ridged waveguide horn or log-periodic antenna shall be used to determine the direction of maximum radiation. The measurement distance shall then be chosen according to 7.5.4.2.1 and the disturbance field strength on the selected frequency is measured. The antenna position shall be varied slightly to ensure that the measured field strength is not at a local minimum (due, for example, to reflections).

For the measurement of the radiated disturbance power the EUT shall be disconnected and a double-ridged horn or log-periodic antenna positioned either in the immediate vicinity of the EUT or in its place. The antenna shall then be fed by a signal generator operating at the same frequency. The orientation of the antenna shall be such that the test receiver receives the highest field strength. This antenna position shall be fixed. The power of the signal generated shall be varied until the test receiver receives the same power as that generated by the EUT. The power at the signal generator P_G plus the gain G of the transmitting antenna relative to a half-wave dipole yields the required radiated disturbance power P_r:

$$P_r = P_G + G \tag{10}$$

where

P_r is in dB(pW);

P_G is in dB(pW); and

G is in dB.

7.5.5 Documentation of the measurement results

The particular circumstances and conditions of the *in situ* measurements should be documented to enable the operational conditions to be reproduced if the measurements are repeated. The documentation should include

– reasons for the *in situ* measurement instead of using a standard test site;
– description of the EUT;
– technical documentation;
– scale drawings of the measurement site, showing the points at which measurements were made;
– description of the measured installation;
– details of all connections between the measured installation and the EUT: technical data and details of their location/configuration;
– description of the operating conditions;
– details of the measuring equipment
– measurement results:
  - antenna polarization;
  - measured values: frequency, measured level and disturbance level;

    NOTE The disturbance level is the level referred to the standard measuring distance.
  - assessment of the degree of interference (if applicable).

7.6 Measurement in a loop antenna system

The loop antenna system (LAS) considered in this subclause is suitable for indoor measurement of the magnetic field strength emitted by a single EUT in the frequency range 9 kHz to 30 MHz. The magnetic field strength is measured in terms of the currents induced into the LAS by the magnetic disturbance field of the EUT.

The LAS shall be validated regularly using the method described in clause E.4 of CISPR 16-1-4:2003. That annex also gives a complete description of the LAS and a relation between the measuring results obtained with the LAS and those obtained as described in 7.2.

7.6.1 General measurement method

Figure 18 shows the general concept of measurements made with the LAS. The EUT is placed in the centre of the LAS. The current induced by the magnetic field from the EUT into each of the three large loop antennas of the LAS is measured by connecting the current probe of the large loop antenna to a measuring receiver (or equivalent). During the measurements the EUT remains in a fixed position.

The currents in the three large loop antennas, originating from the three mutually orthogonal magnetic field components, are measured in sequence. Each current level measured shall comply with the emission limit, expressed in dBµA, as specified in the product standard.

The emission limit shall apply to a LAS having large loop antennas with the standardized diameter of 2 m.

7.6.2 Test environment

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

The currents induced in the LAS by an RF ambient field shall be judged in accordance with 5.4 of CISPR 16-1-4:2003.

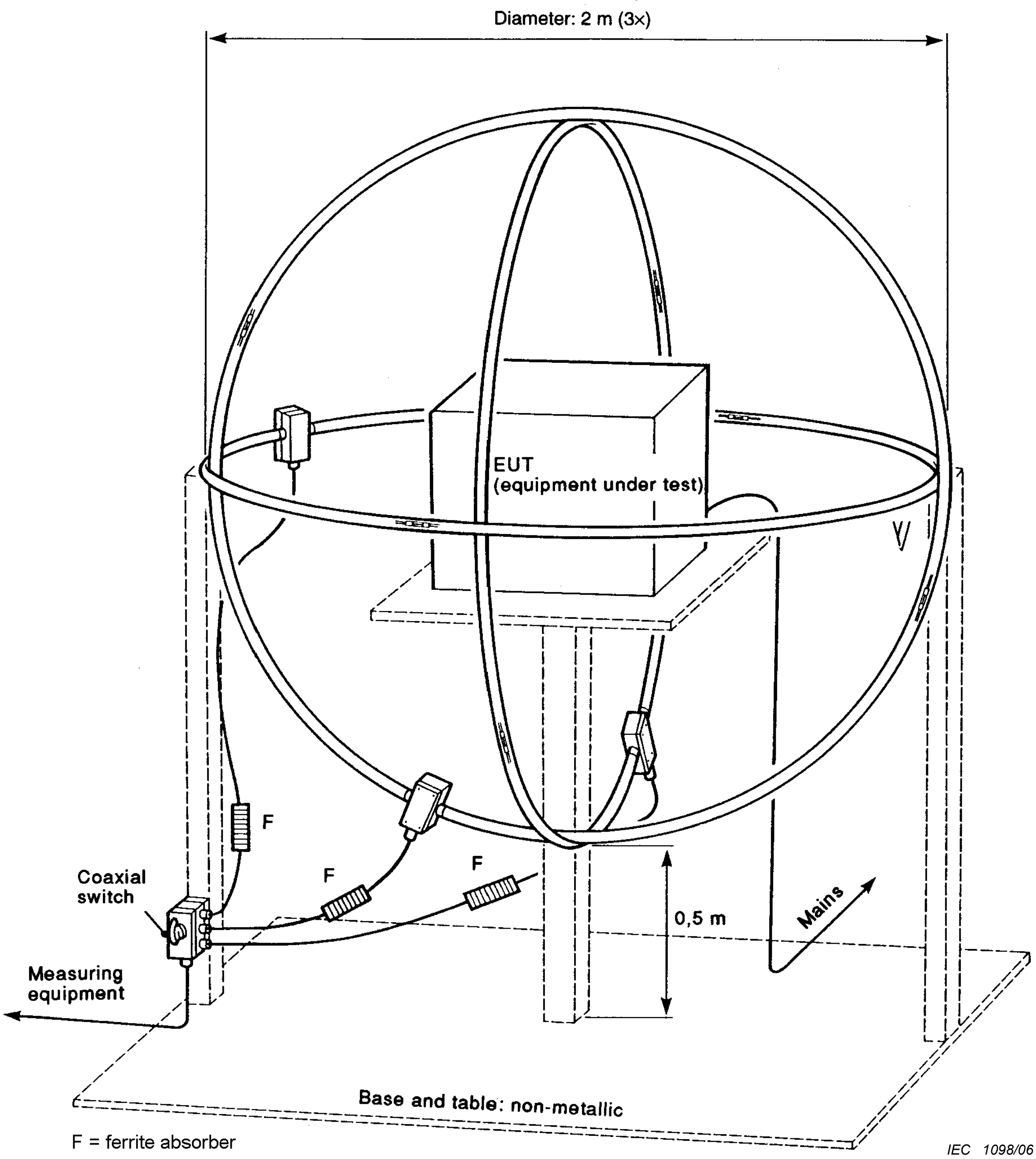


Figure 18 – Concept of magnetic field induced current measurements made with the loop antenna system

7.6.3 Configuration of the equipment under test

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

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

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

a) the current values measured shall be corrected in accordance with clause B.6 of CISPR 16-1-2:2003; and
b) the maximum dimensions of the EUT shall allow a distance between the EUT and the large loops of at least 0,1 × D m, where D is the diameter of the non-standardized loop.

8 Automated measurement of emissions

8.1 Introduction: Precautions for automating measurements

Much of the tedium of making repeated EMI measurements can be removed by automation. Operator errors in reading and recording measurement values are minimized. By using a computer to collect data, however, new forms of error can be introduced that may have been detected by an operator. Automated testing can lead, in some situations, to greater measurement uncertainty in the collected data than manual measurements performed by a skilled operator. Fundamentally, there is no difference in the accuracy with which an emission value is measured whether manually or under software control. In both cases the measurement uncertainty is based on the accuracy specifications of the equipment used in the test set-up. Difficulties may arise, however, when the current measurement situation is different from the scenarios the software was configured for.

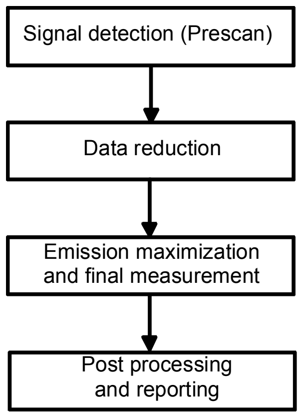
For example, an EUT emission adjacent in frequency to a high level ambient signal may not be measured accurately, if the ambient signal is present during the time of the automated test. A knowledgeable tester, however, is more likely to distinguish between the actual interference and the ambient signal; therefore the method for measuring the EUT emission can be adapted as required. However, valuable test time can be saved by performing ambient scans prior to the actual emission measurement with the EUT turned off to record ambient signals present on the OATS. In this case the software may be able to warn the operator of the potential presence of ambient signals at certain frequencies by applying appropriate signal identification algorithms.

Operator interaction is recommended if the EUT emission is slowly varying, if the EUT emission has a low on-off cycle or when transient ambient signals (e.g. arc welding transients) may occur.

8.2 Generic measurement procedure

Signals need to be intercepted by the EMI receiver before they can be maximized and measured. The use of the quasi-peak detector during the emission maximization process for all frequencies in the spectrum of interest leads to excessive test times (see 6.5.1). Time-consuming processes like antenna height scans are not required for each emission frequency. They should be limited to frequencies at which the measured peak amplitude of the emission is above or near the emission limit. Therefore, only the emissions at critical frequencies whose amplitudes are close to or exceed the limit will be maximized and measured.

The following generic process will yield a reduction in measurement time:



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8.3 Prescan measurements

This initial step in the overall measurement procedure serves multiple purposes. Prescan places the least number of restrictions and requirements upon the test system since its main purpose is to gather a minimal amount of information upon which the parameters of additional testing or scanning will be based. This measurement mode can be used to test a new product, where the familiarity with its emission spectrum is very low. In general, prescan is a data acquisition procedure used to determine where in the frequency range of interest, significant signals are located. Depending on the goal of this measurement, antenna tower and turntable movement may be necessary (for the radiated emission test) as well as improved frequency accuracy (e.g. for further processing on an OATS) and data reduction through amplitude comparison. These factors define the measurement sequence during the execution of prescan. In any case, the results will be stored in a signal list for further processing.

When a prescan measurement is made to quickly obtain information on an EUT’s unknown emission spectrum, frequency scanning can be performed by applying the considerations of 6.5.

- Determination of the required measurement time

If the emission spectrum and especially the maximum pulse repetition interval T_p of the EUT is not known, this has to be investigated to assure the measurement time T_m is not shorter than T_p. The intermittent character of the EUT's emission is especially relevant for critical peaks of the emission spectrum. First should be determined at which frequencies the amplitude of the emission is not steady. This can be done by comparing the max-hold with a min-hold or clear/write function of the measuring equipment or software, and observing the emission for a period of 15 s. During this period no change in the set-up should be made (no change of lead in case of conducted emission, no movement of absorbing clamp, no movement of turntable or antenna in case of radiated emission). Signals with e.g. more than 2 dB difference between the max-hold result and min-hold result are marked as intermittent signals. (Care should be taken not to mark noise as intermittent signals.) In case of radiated emission the polarisation of the antenna is changed and the measurement is repeated, to reduce the risk that certain intermittent peaks are not found because they remain below noise level. From each intermittent signal the pulse repetition period T_p can be measured, by applying zero span or using an oscilloscope connected to the IF-output of the measurement receiver. The correct measurement time can also be determined by increasing it until the difference between max-hold and clear/write displays is below e.g. 2 dB. During further measurements (maximization and final measurement) it has to be assured for each part of the frequency range that the measuring time T_m is not smaller than the applicable pulse repetition period T_p.

The **type of measurement** determines the definition of a prescan measurement in the following way.

– For **radiated emissions** in the frequency range from 9 kHz to 30 MHz both the loop antenna and the EUT need to be rotated to find the maximum field strength while the receiver is scanning the emission spectrum.

  In the frequency range from 30 MHz to 1 000 MHz the antenna height may be preset to fixed heights given in Table 4, based on measurement distance, frequency range and polarization. The necessary prescan measurements must be made for a sufficient number of EUT azimuths. For quick overview measurements this will yield an indication of the radiated emission amplitudes as a starting point for final maximization. If a more detailed determination of the worst case antenna height, polarization and EUT azimuth is desired, the applicable standard should be used to determine the appropriate maximization procedure.

  In the frequency range above 1 GHz the antenna needs to be positioned in horizontal and vertical polarization and the EUT rotated to find the maximum field strength while the emission spectrum is scanned. For details of the test procedure, see 7.3.6.1.

Table 4 – Recommended antenna heights to guarantee signal interception (for prescan) in the frequency range 30 MHz to 1 000 MHz

Measurement distance m	Polarization	Frequency range MHz	Recommended antenna heights for each frequency range m
3	h	30 – 100	2,5
		100 – 250	1/ 2
		250 – 1 000	1/ 1,5
	v	30 – 100	1
		100 – 250	1/ 2
		250 – 1 000	1/ 1,5/ 2
10	h	30 – 100	4
		100 – 200	2,5/ 4
		200 – 400	1,5/ 2,5/4
		400 – 1 000	1/1,5/2,5
	v	30 – 200	1
		200 – 300	1/ 3,5
		300 – 600	1/ 2/ 3,5
		600 – 1 000	1/ 1,5/ 2/ 3,5
30	h	30 – 300	4
		300 – 500	2,5/ 4
		500 – 1 000	1,5/ 2,5/ 4
	v	30 – 500	1
		500 – 800	1/ 3,5
		800 – 1 000	1/ 2,5/ 3,5

NOTE 1 The recommended antenna heights have been derived for source phase centre heights of between 0,8 m and 2,0 m for maximum errors of 3 dB (which is good for a prescan only). If the range of phase centre heights is reduced, the number of receive antenna heights may be reduced. If lobing occurs, e.g. in the upper frequency ranges, more antenna heights may be needed.

NOTE 2 For very large EUTs e.g. telecom systems, the receiving antenna may need to be positioned in several vertical and horizontal positions, depending on the antenna beam width.

8.4 Data reduction

The second step in the overall measurement procedure is used to reduce the number of signals collected during prescan and thus aimed at further reduction of the overall measurement time. These processes can accomplish different tasks, e.g., determination of significant signals in the spectrum, discrimination between ambient or auxiliary equipment signals and EUT emissions, comparison of signals to limit lines, or data reduction based on user-definable rules. Another example of data-reduction methods involving the sequential use of different detectors and amplitude versus limit comparisons is given by the decision tree in Annex C of CISPR 16-2-1. Data reduction may be performed fully automated or interactively, involving software tools or manual operator interaction. It need not be a separate section of the automated test, i.e. it may be part of a prescan.

In certain frequency ranges, especially the FM band, an acoustic ambient discrimination is very effective. This requires signals to be demodulated to be able to listen to their modulation content. If an output list of prescan contains a large number of signals and acoustic discrimination is needed, it can be a rather lengthy process. However, if the frequency ranges for tuning and listening can be specified, only signals within these ranges will be demodulated. The results of the data reduction process are stored in a separate signal list for further processing.

8.5 Emission maximization and final measurement

During the final test the emissions are maximized to determine their highest level. After the maximization of the signals, the emission amplitude is measured using quasi-peak detection and/or average detection, allowing for the appropriate measurement time (at least 15 s if the reading shows fluctuations close to the limit).

The **type of the measurement** defines the maximization process yielding the highest signal amplitudes:

– for **radiated emission** measurements:

  in the frequency range from 9 kHz to 30 MHz:
  maximization of the indicated level by variation of the EUT azimuth and the loop antenna azimuth;

  in the frequency range from 30 MHz to 1 000 MHz:
  maximization of the indicated level by variation of height and polarization of the measurement antenna as well as variation of the EUT azimuth;

  in the frequency range above 1 GHz:
  maximization of the indicated level by variation of the antenna polarization and variation of the EUT azimuth and, if the EUT surface is wider than the antenna beam, by moving the antenna along the EUT surface.

Before the actual maximization sequence can be executed, the worst-case EUT set-up has to be determined to ensure the detection of maximum emission amplitudes. The process of finding the EUT and cable configuration that yields the worst case emissions is primarily a manual operation. This can be done using a scanning receiver with a graphical display of the emission spectrum and signal max hold capability for observing the changes in amplitudes as cable and equipment layouts are manipulated. The automated final measurement of emissions should begin after the worst case EUT configuration has been set up.

The measurement of a particular radiated emission includes a maximization process involving the rotation of the EUT, scanning the receive antenna over a height range, and changing antenna polarization. This time-consuming search process can be effectively automated, but it must be recognized that a variety of search strategies may be used which can lead to different results. In case of previous knowledge of the EUT's radiation characteristics, a maximization sequence should be chosen which allows the determination of the worst-case amplitude within the search ranges of the antenna mast and the turntable. For instance, if the EUT emits highly directive signals in the horizontal plane, e.g., due to slots in the case, the turntable should be rotated continuously while taking data with the receiver. A table movement in discrete steps, on the other hand, may not allow the detection of the maximum amplitude or may cause the signal to be missed completely if the chosen angular increments of the positions are too far apart.

One search strategy might be to rotate the turntable 360° while leaving the antenna at a fixed height to find the angle for maximum emission amplitude. Next, the turntable is rotated back over the full range after the antenna polarization was changed (e.g., from horizontal to vertical). During this process test data is taken continuously with the receiver and at the end of the second table scan the highest amplitudes, based on turntable angle and antenna polarization, are determined. Then, the worst case positions of the antenna and turntable are selected and the antenna is scanned over the required height range to find the position yielding the maximum amplitude. At this point the emission level is either recorded using the receiver's quasi-peak detector after returning to the maximum emission height, or finer search continues with incremental rotation of the turntable and following incremental height search, to find the maximum emission amplitude at the given frequency with greater precision. Again, it is important to have some understanding of the radiation pattern of the EUT in order to set up the software for an optimum search strategy that finds the maximum of the EUT emission in the shortest time. Variability is introduced into the test result when the final measurement is performed on the slope of the radiation pattern rather than on its peak.

8.6 Post processing and reporting

The last part of the test procedure addresses documentation requirements. The functionality for defining sorting and comparison routines which then can be automatically or interactively applied to signal lists supports a user in compiling the necessary reports and documentation. The corrected peak, quasi-peak or average signal amplitudes should be available as sorting or selection criteria. The results of these processes are stored in separate output lists or can be combined in a single list and are available for documentation or further processing.

Results shall be available in tabular and graphics format for use in a test report. Furthermore, information about the test system itself, e.g. transducers used, measuring instrumentation, and documentation of the EUT set-up as required by the product standard should also be part of the test report.

Annex A
(informative)

Measurement of disturbances in the presence of ambient emissions

A.1 General

High ambient emissions have to be taken into account during *in situ* tests (conducted and radiated) and type tests on an open area test site (OATS). It is the purpose of this annex to describe measurement procedures for a number of different situations.

In some circumstances, the procedures will not provide a solution to the problems caused by ambient signals. In particular, the procedures cannot be expected to overcome the problems of subclause 5.4 of CISPR 16-1-4:2003. But without this requirement the document can be used.

A.2 Definitions

A.2.1
EUT disturbance
EUT emission spectrum to be measured

A.2.2
ambient emission
emission spectrum superimposed on the EUT disturbance spectrum which influences the accuracy of the EUT disturbance measurement

NOTE This method does not consider the procedures of 10.7 of CISPR 22:2005.

A.3 Problem description

During *in situ* tests and type tests on an OATS the ambient emissions frequently do not correspond to the recommendations of 5.4 (Ambient radio frequency environment of the test site) of CISPR 16-1-4:2003.

The radio disturbance of the EUT is often located within the frequency bands of ambient emissions and can not be measured with a radio disturbance measuring receiver as specified in CISPR 16-1-1 due to insufficient frequency spacing between the EUT disturbance and the ambient emission or due to superposition.

The standard CISPR measuring receiver is suitable to provide uniform test results for all kinds of radiofrequency emissions, where the EUT disturbance alone is to be measured. It is, however, not optimized to discriminate between EUT disturbance and ambient emissions or to measure the EUT disturbance in the described situation.

Since in actual interference situations there are no alternatives to the *in situ* test, a solution is described below for cases when a differentiation between EUT disturbance and ambient emission is possible.

A.4 Proposed solution

A.4.1 Overview

EUT disturbance and ambient emissions can be categorized as follows:

Table A.1 – Combinations of EUT disturbance and ambient emissions

EUT disturbance	Ambient emission
Narrowband	Narrowband
	Broadband
Broadband	Narrowband
	Broadband

Narrowband ambient emissions may be, for example, AM- or FM-modulated; broadband ambient emissions may be, for example, TV or digitally modulated signals. Here the terms "narrowband" and "broadband" are always relative to the bandwidth of the measuring receiver, as specified in CISPR 16-1-1. Narrowband signals are defined as signals that have a bandwidth less than the measuring receiver bandwidth. In this case, all the signal's spectral components are contained in the receiver bandwidth. A CW signal will always be narrowband; a narrow FM signal can be both narrow or broadband, depending on the actual receiver bandwidth. On the contrary, an impulsive signal will usually be broadband because a few of its spectral components will be within and many of its spectral components outside the receiver bandwidth.

The measurement of the EUT disturbance is a manifold problem: first, to identify EUT disturbance and ambient emission and, second, to distinguish between narrowband and broadband emission. Modern measuring receivers and spectrum analysers provide various resolution bandwidths and detector types. These can be used to analyse the combined spectrum, to distinguish between EUT disturbance and ambient emission spectra, to distinguish between narrowband and broadband emissions and to measure (or in difficult situations to estimate) the EUT disturbance.

In case of type testing on an OATS, identification and pre-measurement of the EUT disturbance may also be carried out by pretesting the EUT in a non-compliant (for example, partially) absorber-lined shielded room, and final testing on an OATS, whereby levels of emissions hidden by ambients may be determined by comparison with emissions in the vicinity.

Superposition of the emissions has to be taken into account when EUT disturbance and ambient emissions cannot be separated. The separation needs a EUT disturbance-and-ambient-emission to ambient-emission ratio of about 20 dB.

In cases where IF-bandwidths and detectors are different from the specified bandwidth and the quasi-peak (QP) detector, the QP value in the specified bandwidth is the reference for the measurement-error determination.

Figure A.1 shows a flow diagram for the selection of bandwidths and detectors and the estimated measurement errors due to that selection.

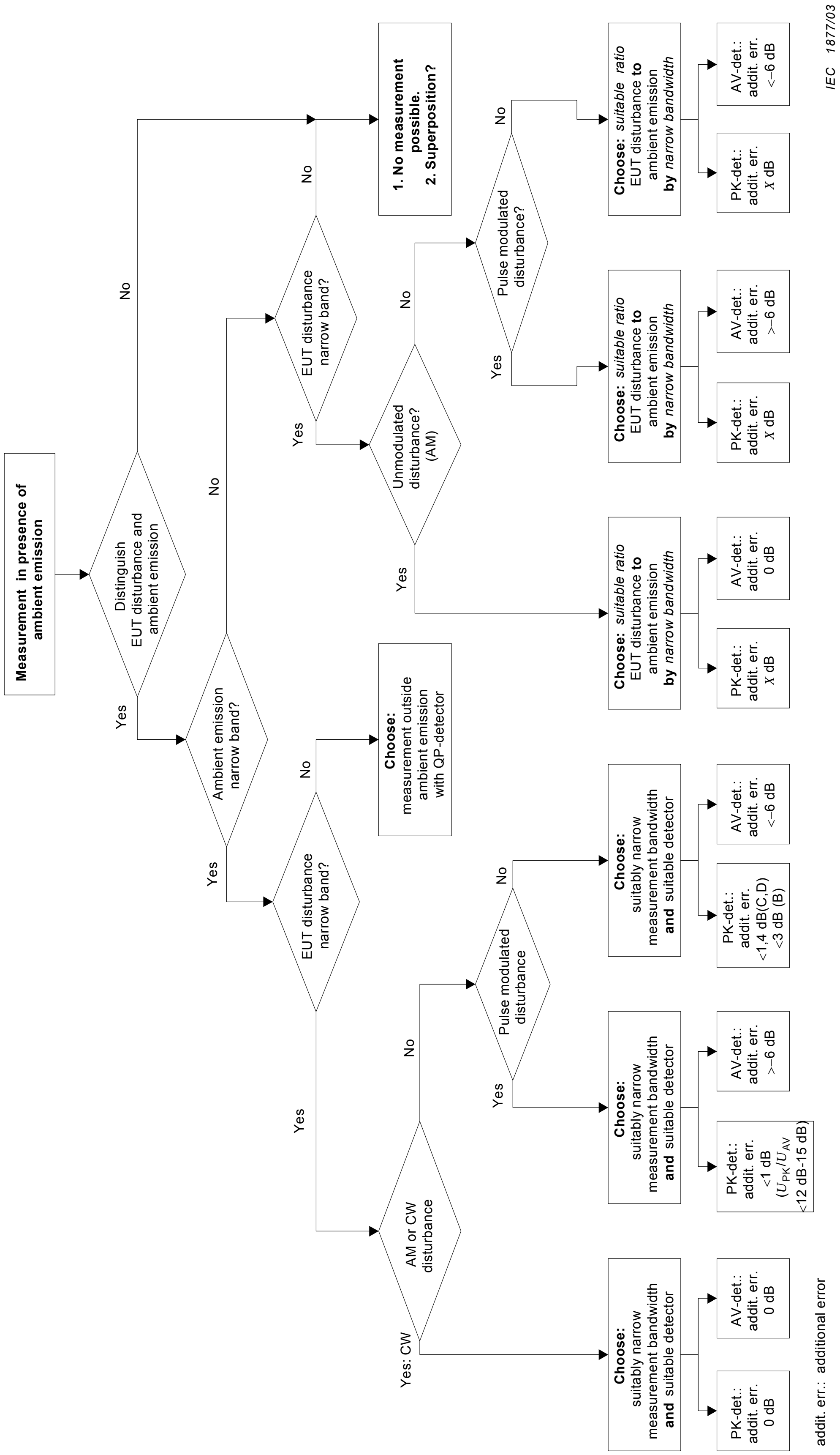


Figure A.1 – Flow diagram for the selection of bandwidths and detectors and the estimated measurement errors due to that selection

A.4.2 Pre-testing the EUT in a shielded quiet chamber

One can use the emission frequency and amplitude data, acquired in shielded quiet-chamber preliminary testing under certain restrictive conditions (since this shielded quiet chamber is an absorber-lined shielded room – semi-anechoic or anechoic – which does not meet present NSA values in Annex E of CISPR 16-1-4:2003, (Annex A of CISPR 22)). This will give the emission spectrum which has significant amplitudes. In cases of narrowband emission the product emission spectrum contains harmonics and subharmonics of any clock frequency used in the product.

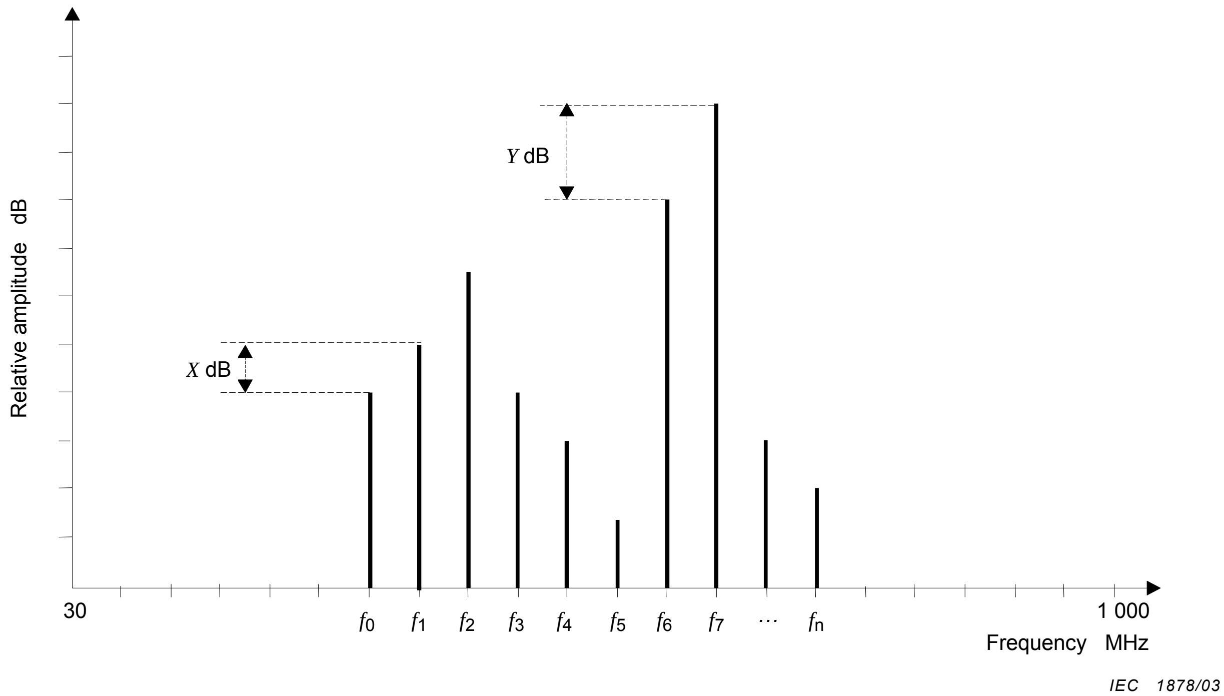
These pre-test results may be used to determine product emission amplitudes in certain restrictive situations. In particular, when the final compliance test is performed at an OATS and one (or more) of the frequencies are masked (hidden) by an RF ambient, chances are that an adjacent frequency to these masked frequencies will not coincide precisely with an RF ambient. Hence, the unmasked emission can be recorded in the usual manner using the required receiver or spectrum analyser bandwidth. Then the amplitude of the EUT emission which is masked by the high RF ambient can be judged using the preliminary quiet-chamber measurements in the following way.

Assume that during the quiet-chamber preliminary measurements two adjacent frequency emissions are X dB different in amplitude (see Figure A.2). Then one of these frequencies that are not masked by the RF ambient is measured at the OATS. The difference in amplitude ("X dB") of the masked frequency from the measurable adjacent frequency can be added to (or subtracted from, depending on the sign of the difference) the amplitude found in the quiet chamber to determine the amplitude of the adjacent frequencies. This is shown in Figure A.2, where (assuming that the frequency f1 is the masked frequency and f0 is not masked), the amplitude for f1 is shown as X dB greater than the amplitude at f0. Then to find the amplitude of f1 at the OATS, X dB is added to the value of the measurable amplitude of f0. Similarly, if the amplitude of f6 were Y dB less than that for f7 found during the quiet- chamber testing, the amplitude of f6 (if masked by an ambient) would be Y dB less than that of f7 which is assumed to be measurable at the OATS.

NOTE The above procedure amplifies what is contained in point c) of 7.2.5.1 (Test environment).

Several precautions should be taken in using this restrictive procedure.

a) The adjacent frequency found in preliminary testing should not be more than one or two adjacent frequencies (usually a subharmonic or harmonic of the basic clock frequency) away, so that the effect of the quiet- chamber irregularities will not unnecessarily enhance or depress frequencies adjacent to the frequency to be estimated on the OATS. In this case, the value of "X" (or Y in Figure A.2) may not be suitable.
b) The amplitudes of adjacent frequencies need to be measured very carefully by height scan of the receive antenna in the quiet chamber (as would be the case for the final compliance measurement). If full height scan cannot be made, alternate correlations between the quiet-chamber measurements and the corresponding OATS measurements may have to be made before applying this OATS amplitude estimation technique (for emissions masked by the RF ambient).
c) For those quiet chambers which are fully anechoically treated on all six sides of the chamber, alternate height-scan techniques might be available, such as measurements at two or three fixed heights (since the ground plane reflections are suppressed and that contribution to the received signal diminished) and using the maximum of these readings. Such techniques may need the same correlation measurements as stated in item b) above.



NOTE Generally f_n is n times f_o which is the EUT fundamental emission frequency (basic clock frequency).

Figure A.2 – Relative difference in adjacent emission amplitudes during preliminary testing

A.4.3 Method of measurement of EUT disturbances in the presence of narrowband ambient emissions

Depending on the type of EUT disturbance its measurement is based on

– the analysis of the combined spectrum with a bandwidth narrower than that of the CISPR measuring receiver;

– the determination of a suitable measurement bandwidth for the selection of narrowband disturbance close to ambient emissions;

– the use of the peak detector (if the disturbance is AM or pulse modulated) or the average detector;

– the increase of the EUT disturbance to ambient emission ratio in case of a narrowband disturbance within a relatively broadband ambient emission when a narrower measurement bandwidth is used; and

– accounting for superposition of EUT disturbance and ambient emission, if separation is not possible.

A.4.3.1 Unmodulated EUT disturbance

The unmodulated EUT disturbance (see Figure A.3) can be separated from the ambient signal carrier by choosing a suitably narrow measurement bandwidth. Either the peak or the average detector may be used. There is no additional measurement error compared with the quasi-peak detector. If the difference in level between peak and average values is very small (for example, lower than 1 dB), the measured average value is equivalent to the quasi-peak value.

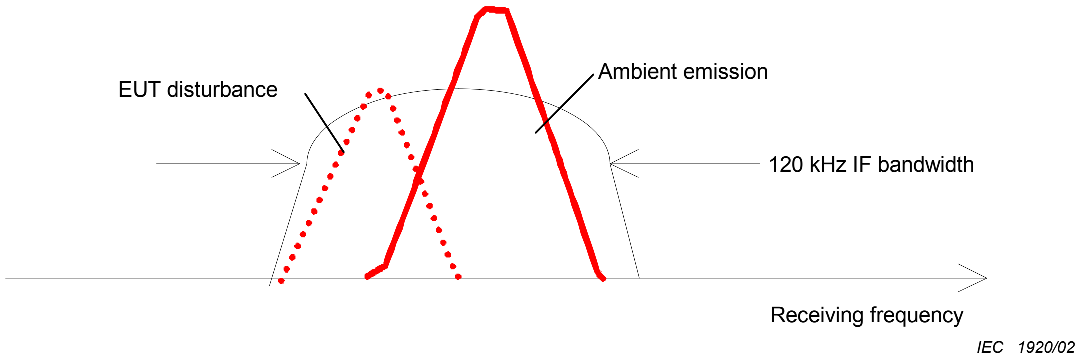


Figure A.3 – Disturbance by an unmodulated signal (dotted line)

A.4.3.2 Amplitude-modulated EUT disturbance

The amplitude-modulated EUT disturbance (see Figure A.4) can be separated from the ambient signal carrier by choosing a suitably narrow measurement bandwidth. Care should be taken to ensure that the narrow measurement bandwidth chosen does not suppress the modulation spectra of the EUT disturbance. Suppression of the modulation spectra is recognised by a decrease in the peak amplitude of the EUT disturbance as a result of the increase of selectivity.

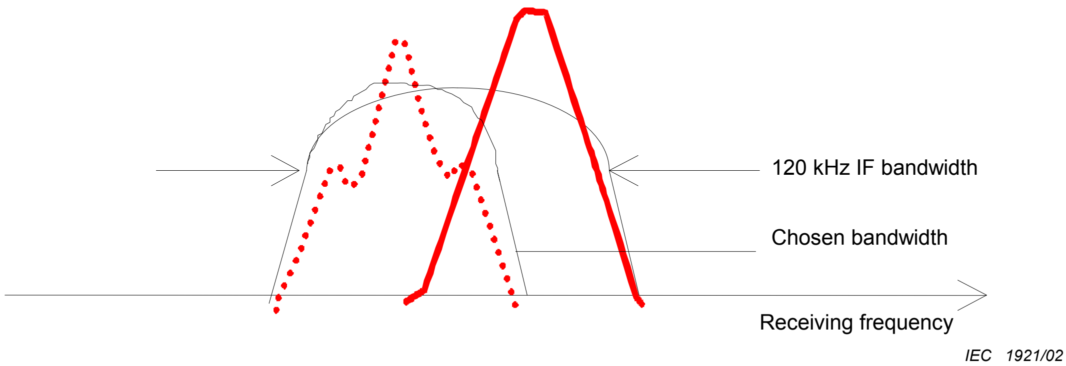


Figure A.4 – Disturbance by an amplitude-modulated signal (dotted line)

Only the peak detector with a measurement time greater than the reciprocal of the modulation frequency can be used. An additional measurement error has to be taken into account at modulation frequencies below 10 Hz (0,4 dB at 10 Hz; 1,4 dB at 2 Hz for bands C and D and 0,9 dB at 10 Hz; 3 dB at 2 Hz for band B), where the peak value is above the quasi-peak value.

The QP-value in response of the modulation frequency is shown in Figure A.5.

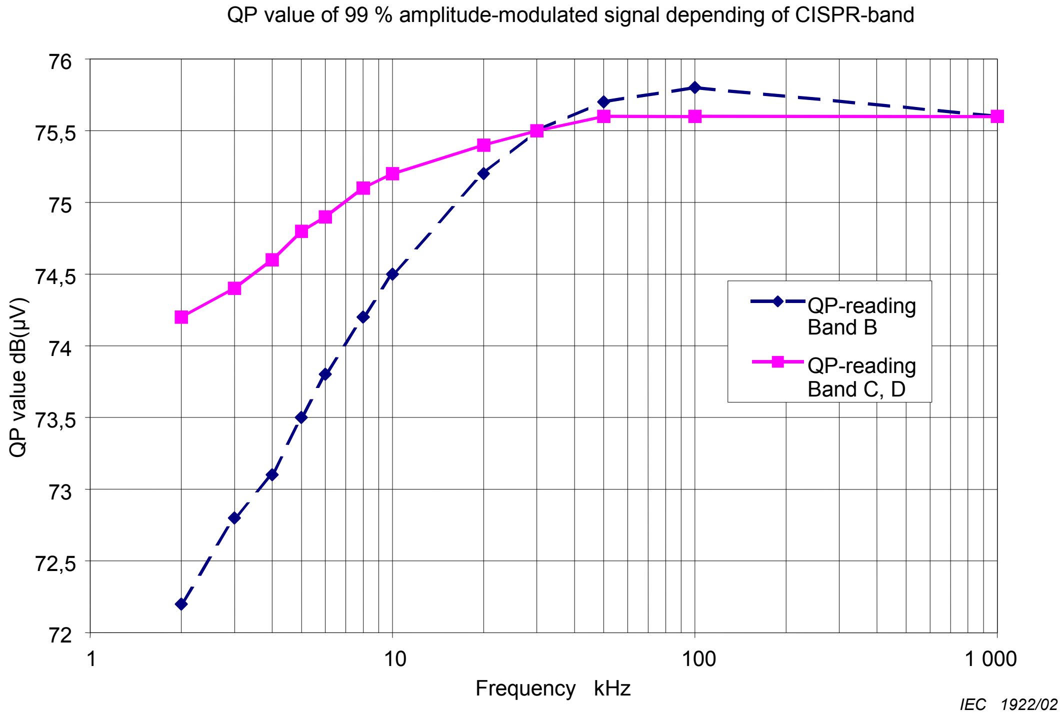


Figure A.5 – Indication of an amplitude-modulated signal as a function of modulation frequency with the QP detector in CISPR bands B, C and D

A.4.3.3 Pulse-modulated EUT disturbance

The narrowband pulse-modulated disturbance from the EUT is classified as a special case of amplitude modulation and can also be separated from the ambient signal carrier by a suitably narrow measurement bandwidth. The selectivity must not lead to a suppression of the modulation spectra. Only the peak detector can be used.

In cases of low repetition frequency, an additional error is possible, but as long as the difference between peak- and average detector reading is in the order of 12 dB to 14 dB, additional measurement errors compared with the quasi-peak value need not be taken into account.

For a pulse width t = 50 µs, Figure A.6 shows that as long as the difference between peak and average levels is less than or equal to 14 dB, the deviation between peak and QP levels is negligible. So, the comparison between peak and average levels may be used to verify the usability of the peak detector.

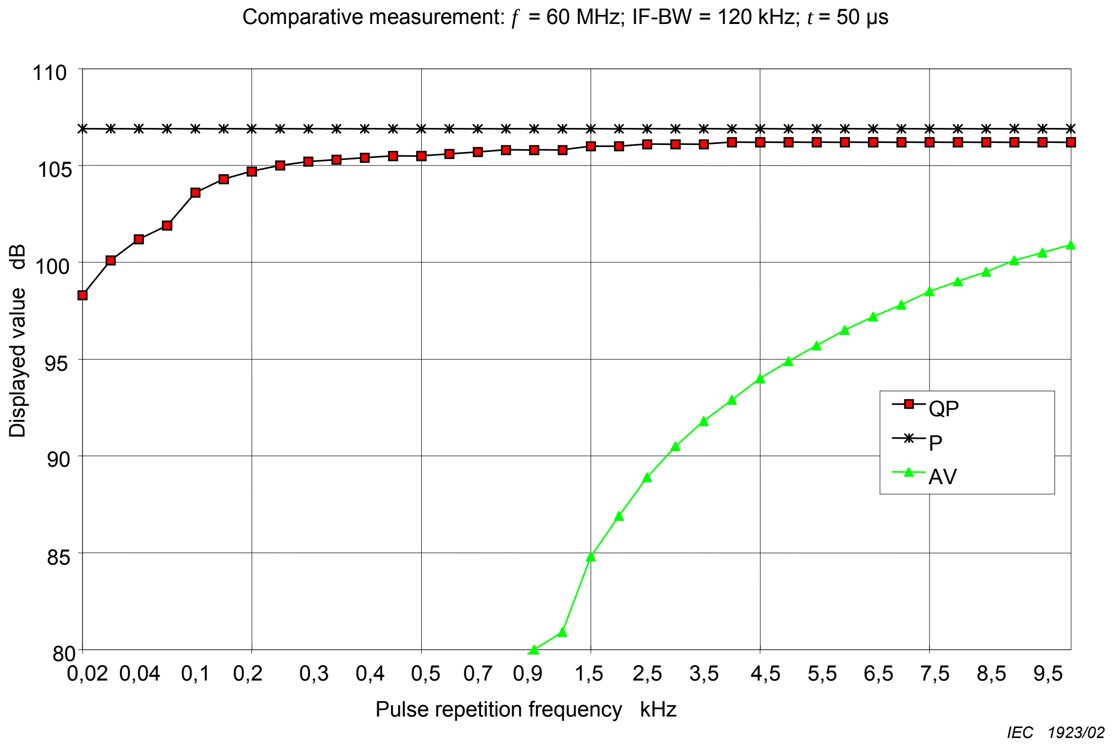


Figure A.6 – Indication of a pulse-modulated signal (pulse width 50 µs) as a function of pulse repetition frequency with peak, QP and average detectors

A.4.3.4 Broadband EUT disturbance

For the measurement of broadband disturbance (see Figure A.7) the quasi-peak detector has to be used.

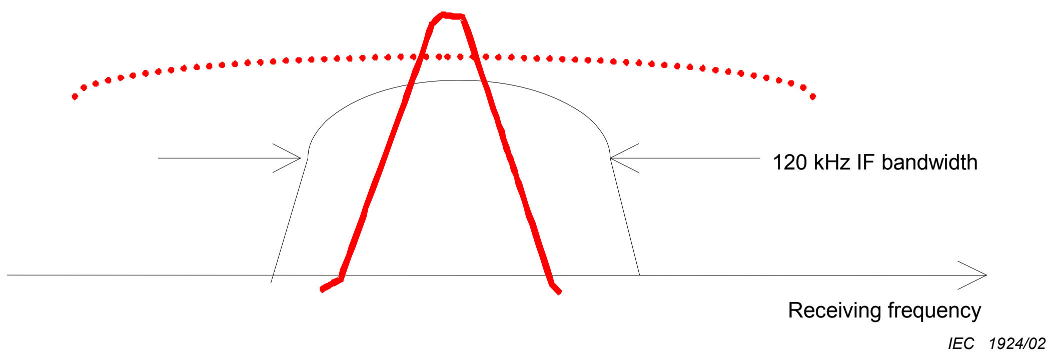


Figure A.7 – Disturbance by a broadband signal (dotted line)

As a rule it is not possible to carry out a measurement within the ambient signal band. Due to its bandwidth the disturbance can generally be measured outside the ambient signal spectrum using the quasi-peak detector.

A.4.4 Method of measurement of EUT disturbance in the presence of broadband ambient emissions

In this case the measurement method is based on

- the analysis of the combined spectrum with a bandwidth equal to the CISPR measuring receiver;
- measurement with a narrow bandwidth (in case of narrowband EUT disturbance; the use of a narrow bandwidth will increase the EUT disturbance to ambient emission ratio);
- the use of the average detector for narrowband EUT disturbance; and
- accounting for superposition of EUT disturbance and ambient emission, if separation is not possible.

A.4.4.1 Unmodulated EUT disturbance

The amplitude of the EUT disturbance (see Figure A.8) should be measured with the average detector (specified in CISPR 16-1-1). The measurement error depends on the average value of the broadband signal spectrum within the selected bandwidth. This measurement error can be minimized by choosing a measurement bandwidth which maximizes the EUT disturbance to ambient emission ratio (selectivity method).

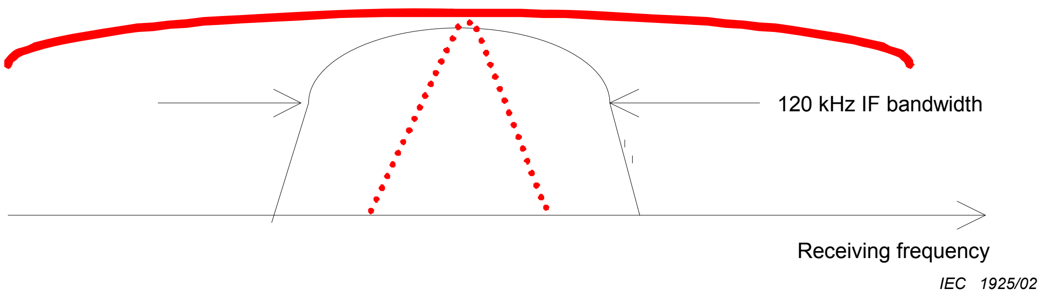


Figure A.8 – Unmodulated EUT disturbance (dotted line)

A.4.4.2 Amplitude-modulated EUT disturbance

The amplitude of the EUT disturbance (see Figure A.9) is measured with the average detector, although an additional measurement error of up to 6 dB (at 100 % modulation) compared with a quasi-peak detector has to be taken into account. The measurement bandwidths chosen should maximize the EUT disturbance to ambient emission ratio (selectivity method).

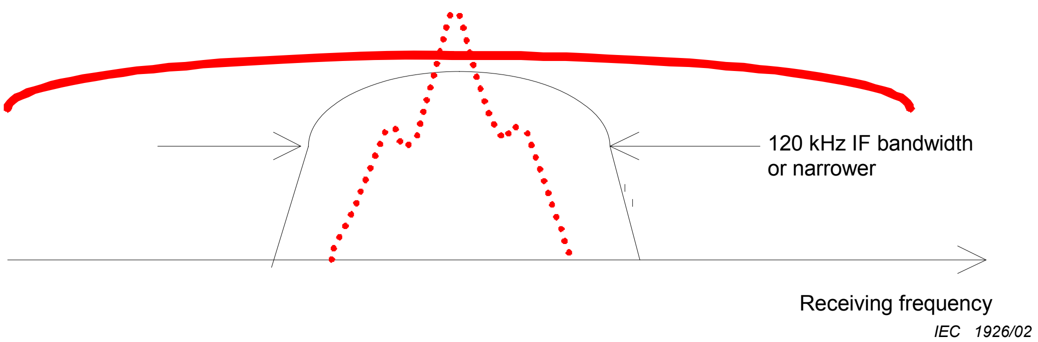


Figure A.9 – Amplitude-modulated EUT disturbance (dotted line)

A.4.4.3 Pulse-modulated EUT disturbance

It is not easy to detect and recognise a pulse-modulated EUT disturbance in a broadband ambient signal spectrum with a high level of reliability since the 100 % amplitude modulation of the disturbance may disperse the EUT disturbance in the spectrum.

The amplitude of the EUT disturbance can be measured with the average detector in case of high duty cycles. Due to the 100 % amplitude modulation depth with smaller duty cycles, the use of the average detector will cause an increasing measurement error compared with the quasi-peak detector. In the case of a duty cycle of 1:1 and use of the linear average detector, the measurement error is 6 dB. The measurement bandwidth should be such that the relationship between the measured average value of the EUT disturbance and the average value of the broadband ambient signal is maximized.

In case of low duty cycles, the average value will substantially deviate from the QP value. In this case the peak detector should be used together with a measurement bandwidth as narrow as possible but still wide enough to capture the complete disturbance bandwidth. Superposition with the ambient emission may have to be taken into account.

A.4.4.4 Broadband EUT disturbance

As a rule, broadband disturbance cannot be detected or measured in a broadband ambient signal spectrum; it may be possible to measure such a disturbance outside the ambient signal spectrum or by taking superposition into account.

The combinations of EUT disturbance with the ambient emission and the error involved in the measurement are displayed in Table A.2.

NOTE A scanning receiver or spectrum analyser will show the spectra of two different broadband signals unless the signal frequencies or pulse rates are harmonically related with each other or the sweep rate of the measuring instrument is harmonically related with the measured pulse rates.

A.5 Determination of the EUT disturbance in case of superposition

If, as a result of the selection of the EUT disturbance and the ambient emission, the measured level to ambient emission ratio is lower than 20 dB, the superposition of ambient emission and EUT disturbance needs to be taken into account. For impulsive broadband voltage the following calculation can be made.

The received signal U_r is the sum of the EUT disturbance U_i and the ambient emission U_a. U_a can be measured only when the EUT is switched off. The superposition is linear for the peak detector (Figure A.10). The following equation applies using the peak detector:

$$U_r = U_i + U_a. \tag{A.1}$$

The EUT disturbance can thus be calculated from

$$U_i = U_r - U_a \tag{A.2}$$

The amplitude ratio d of the received signal to the ambient emission can be measured easily.

$$D = \frac{U_r}{U_a} \qquad d = 20 \log D \tag{A.3}$$

The ambient emission U_a can be substituted in equation (A.2):

$$U_i = U_r - \frac{U_r}{D} = U_r \,(1-\frac{1}{D}) \tag{A.4}$$

or

$$U_i \,/\, \mathrm{dB} = U_r \,/\, \mathrm{dB} + 20 \log (1 - \frac{1}{D}) \tag{A.5}$$

"i" in equation (A.6)

$$i = -20 \log (1 - \frac{1}{D}) \tag{A.6}$$

serves to determine the amplitude of the EUT disturbance. "i" is illustrated in Figure A.11. Using "i" from Figure A.11, the amplitude of the EUT disturbance can be calculated as follows:

$$U_i \,/\, \mathrm{dB} = U_r \,/\, \mathrm{dB} - i \,/\, \mathrm{dB} \tag{A.7}$$

If the received signal is measured with the average detector, Figure A.12 can be taken into account. It is shown in Figure A.12 that in the case of unmodulated signals the following equation

$$U_r = \sqrt{U_i^2 + U_a^2} \tag{A.8}$$

can be used with an additional measurement error of up to about 1,5 dB. In case of modulation, the error decreases (see Figure A.12) but the errors in Table A.2 have to be taken into account.

By means of the average detector, the inband disturbance can be estimated by applying equation (A.7) if the curve of the average detector (Figure A.11) is used. In this case the factor i is expressed by the following equation.

$$i = -10 \log \,(1 - \frac{1}{D^2}) \tag{A.9}$$

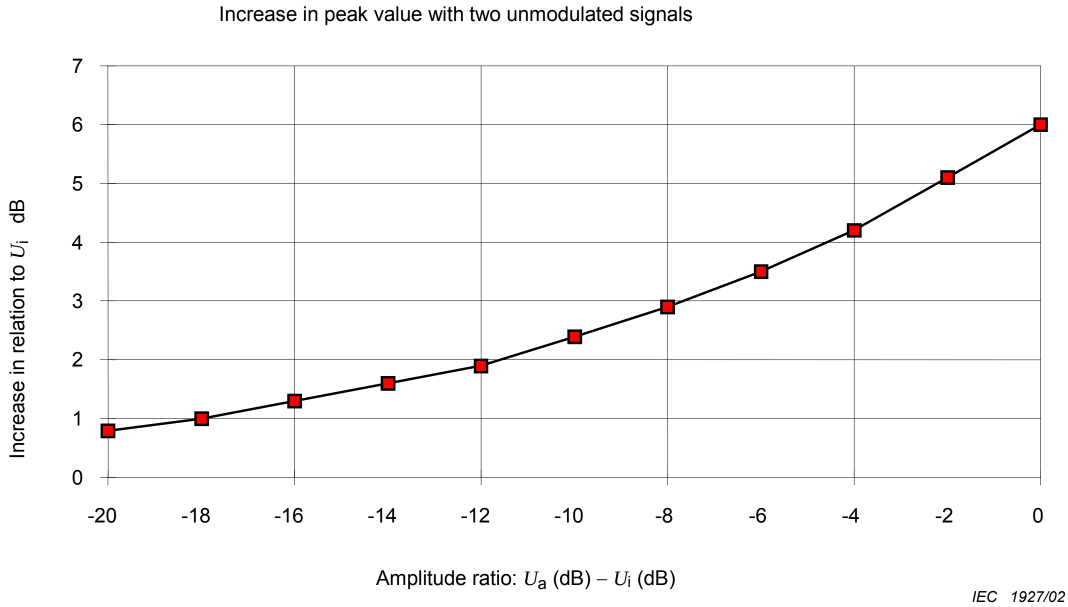
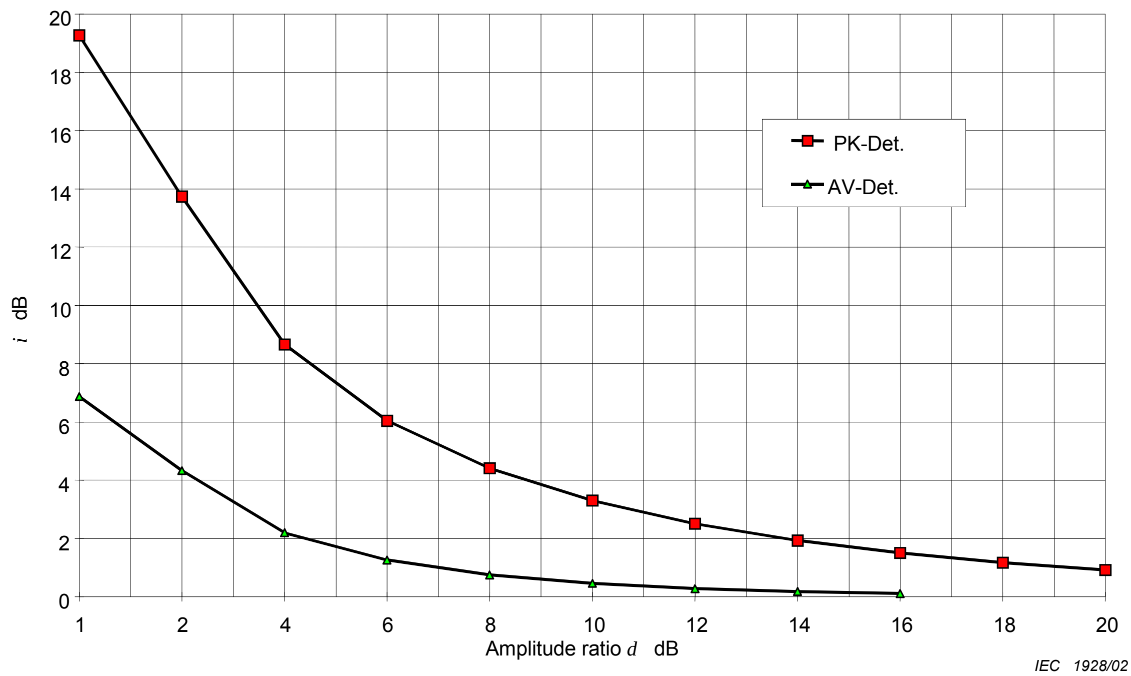


Figure A.10 – Increase of peak value with superposition of two unmodulated signals
(U_a - level of ambient emission; U_i - level of EUT disturbance)



$d = U_r - U_a$ $\qquad U_i = U_r - i$ $\qquad i = -20 \log(1 - \frac{1}{D})$

where

U_a is the ambient signal in dB

U_r is the resulting indication of received signal (by superposition) in dB

U_i is the disturbance signal in dB

Figure A.11 – Determination of the amplitude of the disturbance signal by means of the amplitude ratio *d* and the factor *i*

Figure A.11 can be used as follows:

1) measure the ambient field strength U_a in dB(μV/m) (EUT off);
2) measure the resultant field strength U_r in dB(μV/m) (EUT on);
3) determine $d = U_r - U_a$;
4) find the value of i from Figure A.11;
5) determine U_i in dB(μV/m) using $U_i = U_r - i$.

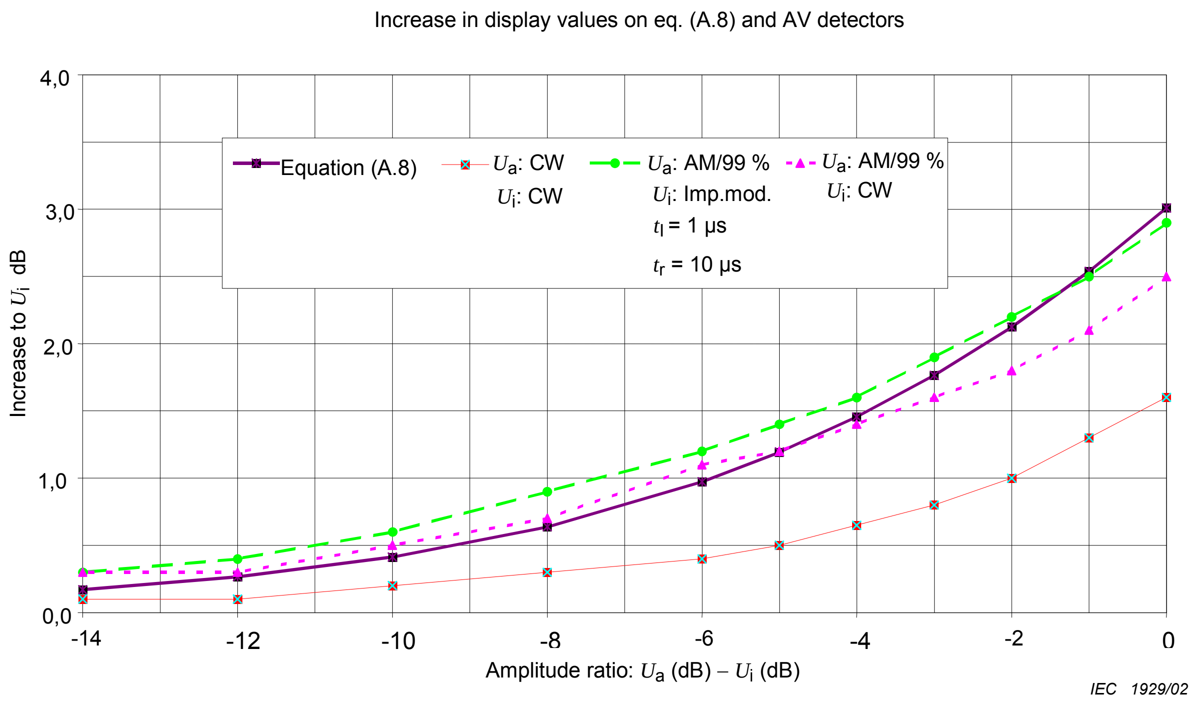


Figure A.12 – Increase of average indication measured with a real receiver and calculated from equation (A.8)

Table A.2 – Measurement error depending on the detector type and on the combination of ambient and disturbing signal spectra

Ambient emission	EUT disturbance			
	Unmodulated	Amplitude-modulated	Pulse-modulated	Broadband disturbance
Narrowband				
Steps taken to increase signal-to-noise ratio	Increased selectivity	Increased selectivity	Increased selectivity	Measurement outside ambient emission
Error of peak value $\left(\frac{PK}{QP}\right)$	0 dB	Less than or equal to +1,4 dB for bands C,D +3 dB for band B	Less than or equal to +1 dB $\left(\frac{U_{\text{PK}}}{U_{\text{AV}}} \leq 12...15 \text{ dB}\right)$	–
Error of average value $\left(\frac{AV}{QP}\right)$	0 dB	Less than or equal to –6 dB [a]	Greater than or equal to –6 dB [a]	–
Broadband				
Steps taken to increase signal-to-noise ratio	Selectivity	Selectivity	Selectivity	No measurement possible (superposition only)
Error of peak value $\left(\frac{PK}{QP}\right)$	+X dB [a]	Less than or equal to +X dB [a]	Greater than or equal to +X dB [a]	–
Error of average value $\left(\frac{AV}{QP}\right)$	0 dB	Less than or equal to –6 dB [a]	Greater than or equal to –6 dB [a]	–

[a] Measurement procedure not recommended, for compliance measurements not allowed.

NOTE 1 X is the error depending on the pulse character of the ambient emission.

NOTE 2 PK is the peak value; QP is the quasi-peak value; AV is the average value.

Annex B
(informative)

Use of spectrum analyzers and scanning receivers
(see clause 6)

B.1 Introduction

When using spectrum analyzers and scanning measuring sets, the following characteristics should be taken into account:

B.2 Overload

Most spectrum analyzers have no RF preselection in the frequency range up to 2 000 MHz; that is, the input signal is directly fed to a broadband mixer. To avoid overload, to prevent damage and to operate a spectrum analyzer linearly, the signal amplitude at the mixer should typically be less than 150 mV peak. RF attenuation or additional RF preselection may be required to reduce the input signal to this level.

B.3 Linearity test

Linearity can be measured by measuring the level of the specific signal under investigation and repeating this measurement after an X dB attenuator has been inserted at the input of the measuring set or, if used, the preamplifier ($X \geq 6$ dB). The new reading of the measuring set display should differ by X dB not more than ± 0,5 dB from the first reading when the measuring system is linear.

B.4 Selectivity

The spectrum analyzer and scanning measuring set must have the bandwidth specified in CISPR 16-1-1 to correctly measure broadband and impulsive signals and narrowband disturbance with several spectrum components within the standardized bandwidth.

B.5 Normal response to pulses

The response of a spectrum analyzer and scanning measuring set with quasi-peak detection can be verified with the calibration test pulses specified in CISPR 16-1-1. The large peak voltage of the calibration test pulses typically requires an insertion of RF attenuation of 40 dB or more to satisfy the linearity requirements. This decreases the sensitivity and makes the measurement of low repetition rate and isolated calibration test pulses impossible for bands B, C and D. If a preselecting filter is used ahead of the measuring set, then the RF attenuation can be decreased. The filter limits the spectrum width of the calibration test pulse as seen by the mixer.

B.6 Peak detection

The normal (peak) detection mode of spectrum analyzers provides a display indication which, in principal, is never less than the quasi-peak indication. It is convenient to measure emissions using peak-detection because it allows faster frequency scans than quasi-peak detection. Then those signals which are close to the emission limits need to be remeasured using quasi-peak detection to record quasi-peak amplitudes.

B.7 Frequency scan rate

The scan rate of a spectrum analyzer or a scanning measuring set should be adjusted for the CISPR frequency band and the detection mode used. The minimum sweep time/frequency or the fastest scan rate is listed in the following table:

Band	Peak-detection	Quasi-peak detection
A	100 ms/kHz	20 s/kHz
B	100 ms/MHz	200 s/MHz
C&D	1 ms/MHz	20 s/MHz

For a spectrum analyzer or scanning measuring set used in a fixed tuned non-scanning mode, the display sweep time may be adjusted independently of the detection mode and according to the needs for observing the behaviour of the emission. If the level of disturbance is not steady, the reading on the measuring set must be observed for at least 15 s to determine the maximum (see 6.4.1).

B.8 Signal interception

The spectrum of intermittent emissions may be captured with peak-detection and digital display storage if provided. Multiple, fast frequency scans reduce the time to intercept an emission compared to a single, slow frequency scan. The starting time of the scans should be varied to avoid any synchronism with the emission and thereby hiding it. The total observation time for a given frequency range must be longer than the time between the emissions. Depending upon the kind of disturbance being measured, the peak detection measurements can replace all or part of the measurements needed using quasi-peak detection. Re-tests using a quasi-peak detector should then be made at frequencies where emission maxima have been found.

B.9 Average detection

Average detection with a spectrum analyzer is obtained by reducing the video bandwidth until no further smoothing of the displayed signal is observed. The sweep time must be increased with reductions in video bandwidth to maintain amplitude calibration. For such measurements, the measuring set shall be used in the linear mode of the detector. After linear detection is made, the signal may be processed logarithmically for display, in which case the value is corrected even though it is the logarithm of the linearly detected signal.

A logarithmic amplitude display mode may be used, for example, to distinguish more easily between narrowband and broadband signals. The displayed value is the average of the logarithmically distorted IF signal envelope. It results in a larger attenuation of broadband signals than in the linear detection mode without affecting the display of narrowband signals. Video filtering in log-mode is, therefore, especially useful for estimating the narrowband component in a spectrum containing both.

B.10 Sensitivity

Sensitivity can be increased with low noise RF pre-amplification ahead of the spectrum analyzer. The input signal level to the amplifier should be adjustable with an attenuator to test the linearity of the overall system for the signal under examination.

The sensitivity to extremely broadband emissions which require large RF attenuation for system linearity is increased with RF pre-selecting filters ahead of the spectrum analyzer. The filters reduce the peak amplitude of the broadband emissions and less RF attenuation can be used. Such filters may also be necessary to reject or attenuate strong out-of-band signals and the intermodulation products they cause. If such filters are used they must be calibrated with broadband signals.

B.11 Amplitude accuracy

The amplitude accuracy of a spectrum analyzer or a scanning measuring set may be verified by using a signal generator, power meter and precision attenuator. The characteristics of these instruments, cable and mismatch losses have to be analyzed to estimate the errors in the verification test.

Annex C
(informative)

Example of the uncertainty budget

A measurement uncertainty budget for emission in a 3 m distance FAR will show the influence factors and their practical weighting (see Table C.1). It will be part of CISPR 16-4-2.

Table C.1 – Uncertainty budget for emission measurements in a 3 m FAR

Component	Probability distribution	Uncertainty dB	
		Bicon	**LPDA**
Antenna factor calibration	normal (k = 2)	± 2,0	± 2,0
Cable loss calibration	normal (k = 2)	± 0,5	± 0,5
Receiver specification according to CISPR 16-1-1	rectangular	± 1,5	± 1,5
Antenna directivity [a]	rectangular	+1,0	± 1,0
Antenna factor variation with height	rectangular	0	0
Antenna phase centre variation [b]	rectangular	0	± 0,5
Antenna factor frequency interpolation	rectangular	± 0,3	± 0,3
Measurement distance uncertainty ± 3 cm [c]	rectangular	± 0,1	± 0,1
Site imperfections [d]	rectangular	± 3,0	± 2,5
Mismatch	U-shaped	± 1,1	± 0,5
Combined standard uncertainty $u_c(y)$	normal	± 2,414	± 2,114
Expanded uncertainty U	normal (k = 2)	± 4,828	± 4,228

[a] Antenna directivity is relative to a tuned dipole that is the reference antenna stipulated by CISPR 16-1-4. For a biconical antenna the uncertainty is for vertical polarisation, it being zero for horizontal polarisation. The uncertainty is positive because it represents only loss of signal.

[b] Increasingly hybrid biconical/log. period antennas are used. Correction of field strength against phase centre position is more accurate in the absence of a ground reflection. This uncertainty term is of course less for shorter antennas.

[c] The distance uncertainty is negligible, because there is only a limited height scanning and no diagonal distance may appear.

[d] If the uncertainty due to the site alone is ± 3 dB when using a biconical as the receive antenna, it is likely to be less when using a directional log antenna, so it has been set to ± 2,5 dB for the LPDA.

Calculation of the combined uncertainty for the biconical antenna in a FAR:

$$u_c(y) = \sqrt{\left(\frac{2,0}{2}\right)^2 + \left(\frac{0,5}{2}\right)^2 + \frac{1,5^2 + 1^2 + 0^2 + 0^2 + 0,3^2 + 0,1^2 + 3,0^2}{3} + \frac{1,1^2}{2}}$$

In this example a coverage factor of k = 2 will ensure that the level of confidence will be approximately 95 %, therefore:

$$U = 2u_c(y) = 2 \times (+2,62) = \pm 4,828 \text{ dB}$$

Annex D
(informative)

Scan rates and measurement times for use with the average detector

D.1 General

This annex is intended to give guidance on the selection of scan rates and measurement times when measuring impulsive disturbance with the average detector.

The average detector serves the following purposes:

a) to suppress impulsive noise and thus to enhance the measurement of CW components in disturbance signals to be measured

b) to suppress amplitude modulation (AM) in order to measure the carrier level of amplitude modulated signals

c) to show the weighted peak reading for intermittent, unsteady or drifting narrowband disturbances using a standardized meter time constant.

Clause 6 of this standard defines the average measuring receiver for the frequency range 9 kHz to 1 GHz.

In order to select the proper video bandwidth and the corresponding scan rate or measurement time, the following considerations apply:

D.1.1 Suppression of impulsive disturbance

The pulse duration T_p of impulsive disturbance is often determined by the IF bandwidth B_{res}: T_p = 1/B_{res}. For the suppression of such noise, the suppression factor a is then determined by the video bandwidth B_{video} relative to the IF bandwidth: a = 20 lg (B_{res}/B_{video}). B_{video} is determined by the bandwidth of the lowpass filter following the envelope detector. For longer pulses, the suppression factor will be lower than a. The minimum scan time $T_{s\ min}$ (and max. scan rate $R_{s\ max}$) is determined using:

$$T_{s\,min} = (k \cdot \Delta f)/(B_{res} \cdot B_{video}) \tag{D.1}$$

$$R_{smax} = \Delta f / T_{smin} = (B_{res} \cdot B_{video})/k \tag{D.2}$$

where Δf is the frequency span and k is a proportionality factor, which depends on the speed of the measuring receiver/spectrum analyzer.

For the longer scan times, k is very close to 1. If a video bandwidth of 100 Hz is selected, the maximum scan rates and pulse suppression factors in Table D.1 will be obtained.

Table D.1 – Pulse suppression factors and scan rates for a 100 Hz video bandwidth

	Band A	Band B	Bands C and D
Frequency range	9 kHz to 150 kHz	150 kHz to 30 MHz	30 MHz to 1 000 MHz
IF bandwidth B_{res}	200 Hz	9 kHz	120 kHz
Video bandwidth B_{video}	100 Hz	100 Hz	100 Hz
Maximum scan rate	17,4 kHz/s	0,9 MHz/s	12 MHz/s
Maximum suppression factor	6 dB	39 dB	61,5 dB

This can be applied for product standards calling out quasi-peak and average limits in bands B (and C) if short pulses are expected in the disturbance signal. Compliance of the EUT with both limits has to be demonstrated. If the pulse repetition frequency is greater than 100 Hz and the quasi-peak limit is not exceeded by the impulsive disturbance, then the short pulses are sufficiently suppressed for average detection with a video bandwidth of 100 Hz.

D.1.2 Suppression of impulsive disturbance by digital averaging

Average detection may be done by digital averaging of the signal amplitude. An equivalent suppression effect can be achieved if the averaging time is equal to the inverse of the video filter bandwidth. In this case, the suppression factor a = 20 lg (T_{av}*B_{res}), where T_{av} is the averaging (or measuring) time at a certain frequency. Consequently a measurement time of 10 ms will result in the same suppression factor as the video bandwidth of 100 Hz. Digital averaging has the advantage of zero delay time, when switching from one frequency to another. On the other hand, for averaging of a certain pulse repetition frequency f_p, the result may vary depending on whether n or n+1 pulses are averaged. This effect is less than 1 dB, if T_{av}*f_p > 10.

D.2 Suppression of amplitude modulation

In order to measure the carrier of a modulated signal, the modulation has to be suppressed by signal averaging over a sufficiently long time, or by using a video filter of sufficient attenuation at the lowest frequency. If f_m is the lowest modulation frequency and if we assume that the max. measurement error due to the 100 % modulation is limited to 1 dB, then the measurement time T_m should be $T_m = 10 / f_m$.

D.3 Measurement of slowly intermittent, unsteady or drifting narrowband disturbances

In subclause 6.4.3 of CISPR 16-1-1:2003, the response to intermittent, unsteady or drifting narrowband disturbances is defined using the peak reading with meter time constants of 160 ms (for bands A and B) and 100 ms (for bands C and D). These time constants correspond to 2nd order video filter bandwidths of 0,64 Hz or 1 Hz respectively. For correct measurements, these bandwidths would require very long measurement times (see Table D.2).

Table D.2 – Meter time constants and the corresponding video bandwidths and maximum scan rates

	Band A	Band B	Bands C and D
Frequency range	9 kHz to 150 kHz	150 kHz to 30 MHz	30 MHz to 1 000 MHz
IF bandwidth B_{res}	200 Hz	9 kHz	120 kHz
Meter time constant	160 ms	160 ms	100 ms
Video bandwidth B_{video}	0,64 Hz	0,64 Hz	1 Hz
Maximum scan rate	8,9 s/kHz	172 s/MHz	8,3 s/MHz

This applies however only for pulse repetition frequencies of 5 Hz or less. For all higher pulse widths and modulation frequencies, higher video filter bandwidths may be used (see D.1.1). Figures D.1 and D.2 show the weighting function of a pulse with 10 ms pulse duration versus pulse repetition frequency f_p with peak reading ("CISPR AV") and with true averaging ("AV") for meter time constants of 160 ms (Figure D.1) and 100 ms (Figure D.2).

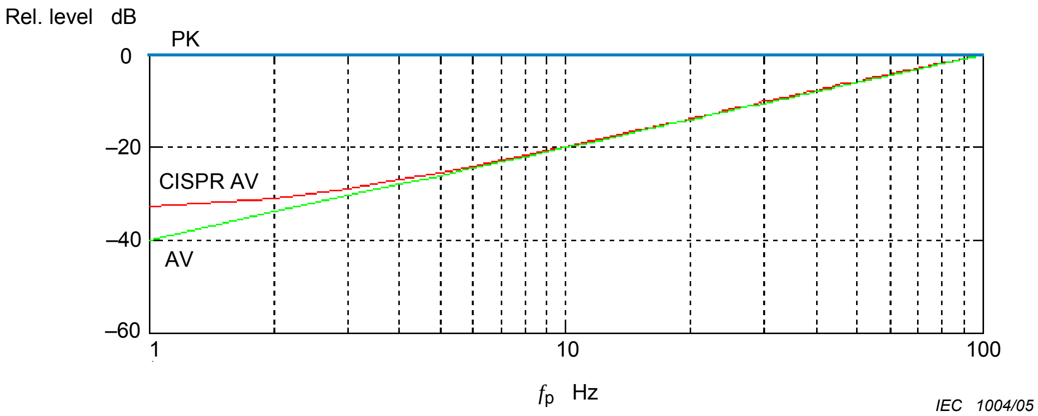


Figure D.1 – Weighting function of a 10 ms pulse for peak ("PK") and average detections with ("CISPR AV") and without ("AV") peak reading: meter time constant 160 ms

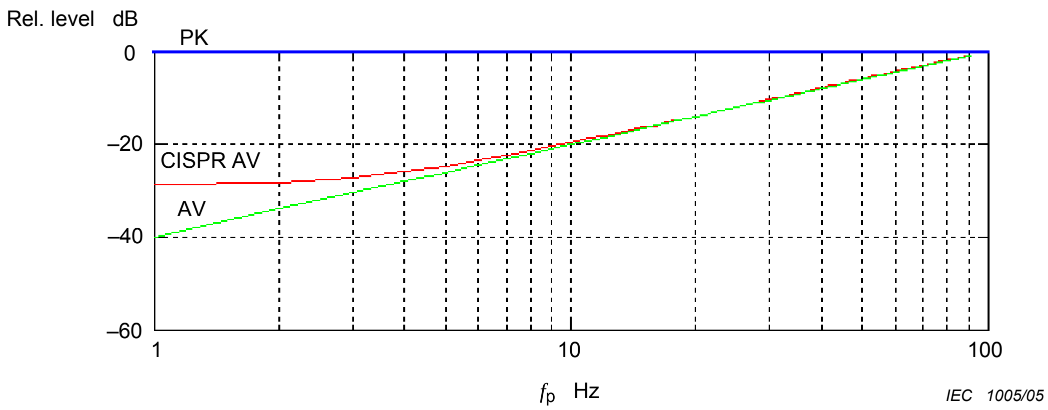


Figure D.2 – Weighting functions of a 10 ms pulse for peak ("PK") and average detections with ("CISPR AV") and without ("AV") peak reading: meter time constant 100 ms

Figures D.1 and D.2 imply that the difference between average with peak reading ("CISPR AV") and without peak reading ("AV") is increasing as the pulse repetition frequency f_p decreases. Figures D.3 and D.4 show the difference for f_p = 1 Hz as a function of pulse width.

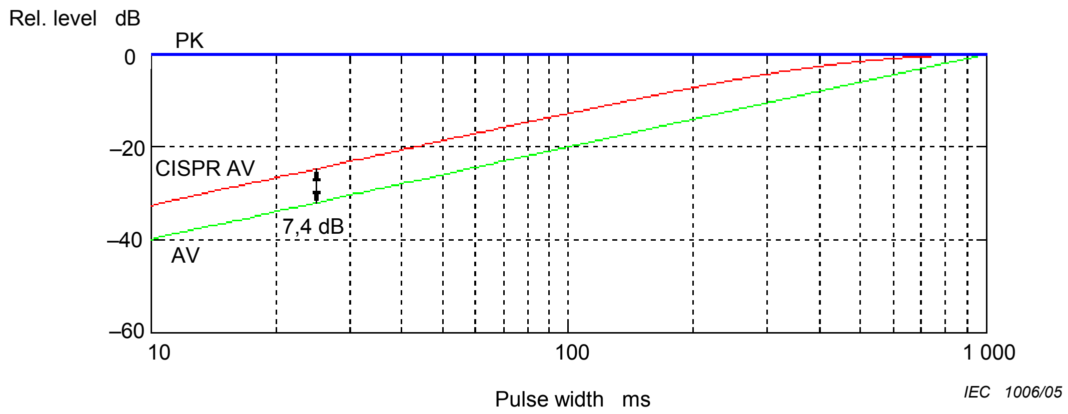


Figure D.3 – Example of weighting functions (of a 1 Hz pulse) for peak ("PK") and average detections as a function of pulse width: meter time constant 160 ms

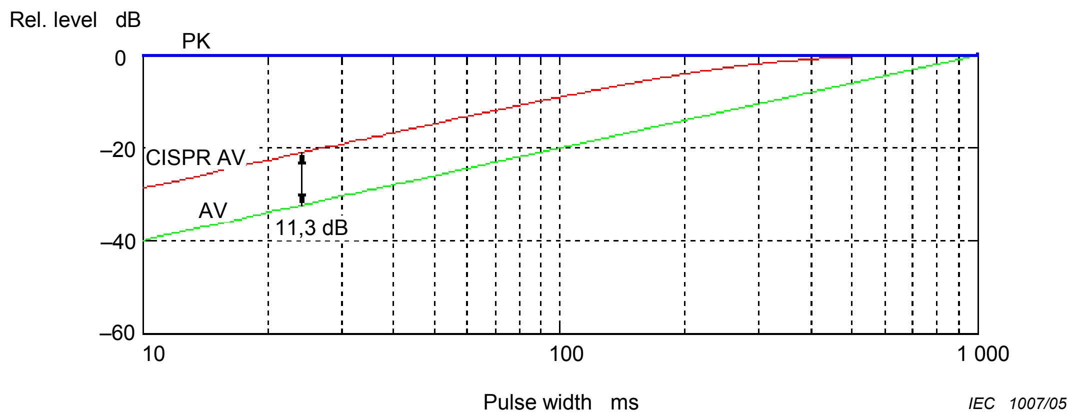


Figure D.4 – Example of weighting functions (of a 1 Hz pulse) for peak ("PK") and average detections as a function of pulse width: meter time constant 100 ms

D.4 Recommended procedure for automated or semi-automated measurements

When measuring EUTs which do not emit slowly intermittent, unsteady or drifting narrowband disturbances, it is recommended to measure with the average detector using a video filter bandwidth of e.g. 100 Hz, i.e. a short averaging time during a prescan procedure. At frequencies where the emission is found to be close to the average limit, it is recommended to make a final measurement using a lower video filter bandwidth, i.e. a longer averaging time. (For the prescan/final measurement procedure, see also Clause 8 of this standard).

For slowly intermittent, unsteady or drifting narrowband disturbances, manual measurements are the preferred solution.

Annex E
(informative)

Explanation of APD measurement method applying to the compliance test

One of the following two methods is used when the APD measurement applies to the compliance test. Figures E.1 and E.2 illustrate the specifics of the APD measurement methods, involving the measurement of the level of disturbance (i.e. method 1, see 7.3.6.5.1) and the measurement of the probability (i.e. method 2, see 7.3.6.5.2), respectively.

If the preliminary measurement results, obtained by using the maximum hold mode and peak detection, exceed the specified APD limit (the higher limit should be used if two APD limits apply) by YY dB at certain frequencies, then the APD measurement should be performed at these identified frequencies. The value YY dB is to be specified by the relevant product committee (e.g. YY = 5, 10, etc.)

In case of fluctuating disturbances, the product committee should specify the frequency range XX (= $\Delta f \times N$) MHz in which the APD measurements are to be performed, where Δf is the frequency step size and N is the number of frequencies. This frequency range should be specified according to the characteristics of the product.

At first, XX is determined by the preliminary measurement results.

Then, Δf should be equal to the resolution bandwidth (RBW = 1 MHz for the measurements above 1 GHz) of the spectrum analyzer. However, all frequencies which have an APD value within approximately 6 dB of the APD limit may require further investigation with a smaller frequency step size (i.e. $B_6/2$, where B_6 is the 6-dB bandwidth of the spectrum analyzer). RBW of the spectrum analyzer for measurements above 1 GHz is defined by the impulse bandwidth B_{imp} in place of 6-dB bandwidth B_6. The relation between B_{imp} and B_6 is dependent on the filter type and cannot be generalized. If B_{imp} can be approximated to B_6, then the smaller frequency step size $B_6/2$ is recommended to be $B_{\text{imp}}/2$ (i.e. 0,5 MHz) for the measurements above 1 GHz.

Finally, N is determined from the values of XX and Δf.

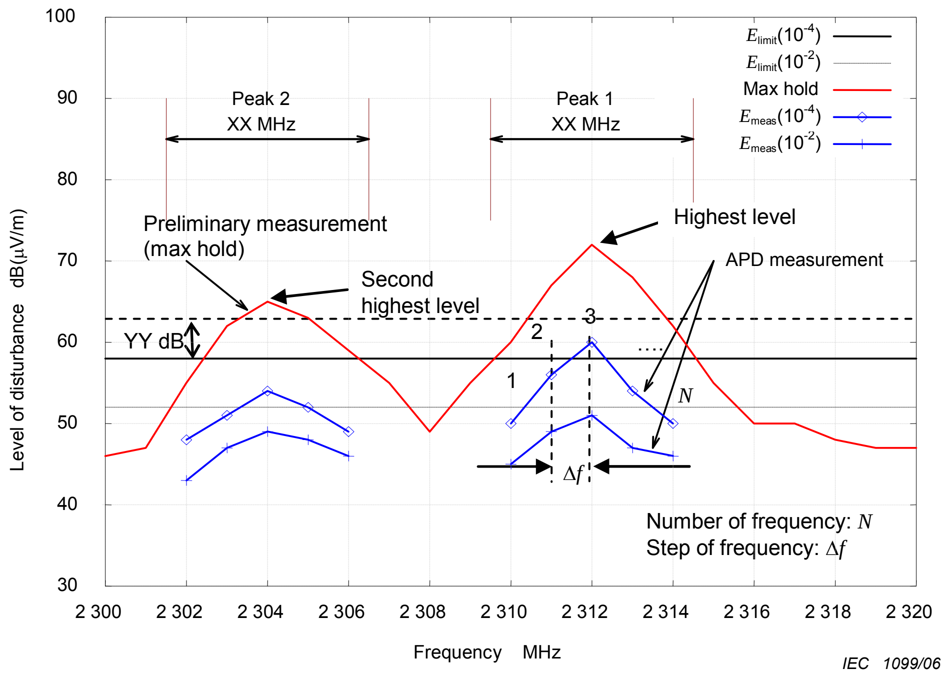


Figure E.1 – Example of APD measurement method 1 for fluctuating disturbances

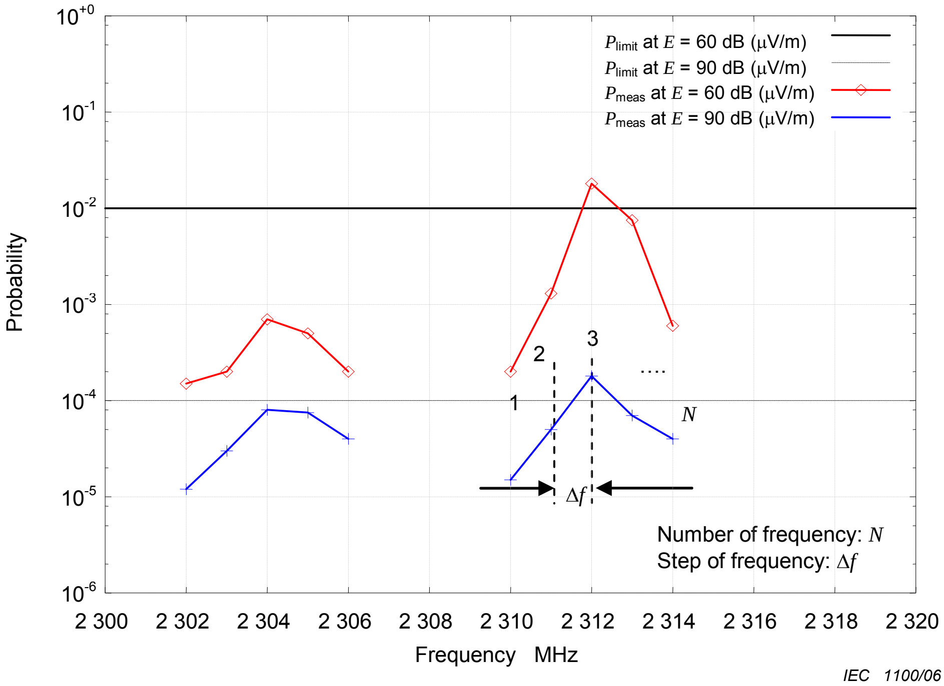


Figure E.2 – Example of APD measurement method 2 for fluctuating disturbances

Bibliography

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

CISPR 22:2005, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*