



BSI Standards Publication

Specification for radio disturbance and immunity measuring apparatus and methods

Part 1-4: Radio disturbance and immunity measuring apparatus —
Antennas and test sites for radiated disturbance measurements

National foreword

This British Standard is the UK implementation of EN IEC 55016-1-4:2025. It is identical to CISPR 16-1-4:2025. It supersedes BS EN IEC 55016-1-4:2019+A2:2023, which will be withdrawn on 30 November 2028.

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Published by BSI Standards Limited 2025

ISBN 978 0 539 16543 2

ICS 17.220.20; 33.100.10; 33.100.20

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2025.

Amendments/corrigenda issued since publication

Date	Text affected
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English Version

Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements
(CISPR 16-1-4:2025)

Spécifications des méthodes et des appareils de mesure des perturbations radioélectriques et de l'immunité aux perturbations radioélectriques - Partie 1-4: Appareils de mesure des perturbations radioélectriques et de l'immunité aux perturbations radioélectriques - Antennes et emplacements d'essai pour les mesurages des perturbations rayonnées
(CISPR 16-1-4:2025)

Anforderungen an Geräte und Einrichtungen sowie Festlegung der Verfahren zur Messung der hochfrequenten Störaussendung (Funkstörungen) und Störfestigkeit - Teil 1-4: Geräte und Einrichtungen zur Messung der hochfrequenten Störaussendung (Funkstörungen) und Störfestigkeit - Antennen und Messplätze für Messungen der gestrahlten Störaussendung
(CISPR 16-1-4:2025)

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European foreword

The text of document CIS/A/1466/FDIS, future edition 5 of CISPR 16-1-4, prepared by SC CISPR/A "Radio-interference measurements and statistical methods" of IEC/TC CISPR "International special committee on radio interference" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 55016-1-4:2025.

The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2026-11-30 level by publication of an identical national standard or by endorsement
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In the official version, for Bibliography, the following notes have to be added for the standard indicated:

IEC 61000-4-20	NOTE	Approved as EN IEC 61000-4-20
CISPR 16-4-2	NOTE	Approved as EN 55016-4-2
IEC 61000-4-21	NOTE	Approved as EN 61000-4-21
IEC 61169-8	NOTE	Approved as EN 61169-8
CISPR 11	NOTE	Approved as EN IEC 55011

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
CISPR 16-1-1	2019	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus	EN IEC 55016-1-1	2019
CISPR 16-1-2	2014	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Coupling devices for conducted disturbance measurements	EN 55016-1-2	2014
+ A1	2017		+ A1	2018
CISPR 16-1-5	2014	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-5: Radio disturbance and immunity measuring apparatus - Antenna calibration sites and reference test sites for 5 MHz to 18 GHz	EN 55016-1-5	2015
+ A1	2016		+ A1	2017
CISPR 16-1-6	2014	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-6: Radio disturbance and immunity measuring apparatus - EMC antenna calibration	EN 55016-1-6	2015
+ A1	2017		+ A1	2017
+ A2	2022		+ A2	2022
CISPR 16-2-3	2016	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements	EN 55016-2-3	2017
+ A1	2019		+ A1	2019

EN IEC 55016-1-4:2025 (E)

+ A2	2023		+ A2	2023
IEC 60050-161	2014	International Electrotechnical Vocabulary (IEV) - Part 161: Electromagnetic compatibility	-	-
IEC 60050-195	2021	International Electrotechnical Vocabulary (IEV) - Part 195: Earthing and protection against electric shock	-	-

CONTENTS

FOREWORD	9
1 Scope	11
2 Normative references	11
3 Terms, definitions and abbreviated terms	12
3.1 Terms and definitions.....	12
3.2 Abbreviated terms.....	18
4 Antennas for measurement of radiated radio disturbance	18
4.1 General.....	18
4.2 Physical parameter (measurand) for radiated disturbance measurements	19
4.3 Antennas for the frequency range 9 kHz to 150 kHz.....	19
4.3.1 General	19
4.3.2 Magnetic field antenna.....	19
4.3.3 Shielding of loop antenna	21
4.4 Antennas for the frequency range 150 kHz to 30 MHz.....	21
4.4.1 Electric field antenna	21
4.4.2 Magnetic field antenna.....	21
4.4.3 Balance and electric field discrimination of antennas	21
4.5 Antennas for the frequency range 30 MHz to 1 000 MHz.....	21
4.5.1 General	21
4.5.2 Low-uncertainty antenna for use if there is an alleged non-compliance to the electric disturbance field strength limit	22
4.5.3 Antenna characteristics	22
4.5.4 Balance of antenna.....	24
4.5.5 Cross-polar response of antenna.....	25
4.6 Antennas for the frequency range 1 GHz to 18 GHz.....	26
4.6.1 General	26
4.6.2 Receive antenna.....	27
4.7 Special antenna arrangements – large-loop antenna system.....	29
5 Test sites for measurement of radio disturbance field strength for the frequency range of 9 kHz to 30 MHz	30
5.1 General.....	30
5.2 Radio-frequency ambient environment of a test site	30
5.3 Measurement distance and test volume	30
5.4 Set-up table and antenna positioner.....	30
5.5 Validation procedure of test site.....	31
5.5.1 General	31
5.5.2 Normalized site insertion loss (NSIL)	35
5.5.3 Reference site method.....	35
5.5.4 Acceptance criterion	36
6 Test sites for measurement of radio disturbance field strength for the frequency range of 30 MHz to 1 000 MHz	36
6.1 General.....	36
6.2 OATS.....	37
6.2.1 General	37
6.2.2 Weather-protection enclosure	37
6.2.3 Obstruction-free area.....	37
6.2.4 Radio-frequency ambient environment of a test site.....	38

6.2.5	Ground plane.....	39
6.3	Suitability of other test sites.....	39
6.3.1	Other ground-plane test sites.....	39
6.3.2	Test sites without ground plane (FAR).....	39
6.4	Test site validations.....	40
6.4.1	General.....	40
6.4.2	Overview of test site validations.....	40
6.5	Basic parameters of the NSA method for OATS and SAC.....	41
6.5.1	General equation and table of theoretical NSA values.....	41
6.5.2	Antenna calibration.....	45
6.6	Reference site method for OATS and SAC.....	45
6.6.1	General.....	45
6.6.2	Antennas not permitted for RSM measurements.....	46
6.6.3	Determination of the antenna pair reference site attenuation on a REFTS.....	46
6.6.4	Determination of the antenna pair reference site attenuation using an averaging technique on a large OATS.....	47
6.7	Validation of an OATS by the NSA method.....	50
6.7.1	Discrete frequency method.....	50
6.7.2	Swept frequency method.....	51
6.8	Validation of a weather-protection-enclosed OATS or a SAC.....	52
6.9	Possible causes for exceeding site acceptability limits.....	55
6.10	Site validation for FAR sites.....	55
6.10.1	General.....	55
6.10.2	RSM for FAR sites.....	59
6.10.3	NSA method for FAR sites.....	61
6.10.4	Site validation criteria for FAR sites.....	63
6.11	Evaluation of set-up table and antenna tower.....	63
6.11.1	General.....	63
6.11.2	Evaluation procedure for set-up table influences.....	64
7	Test sites for measurement of radio disturbance field strength for the frequency range 1 GHz to 18 GHz.....	66
7.1	General.....	66
7.2	Reference test site.....	66
7.3	Test site validation.....	66
7.3.1	General.....	66
7.3.2	Acceptance criterion for site validation.....	68
7.4	Antenna requirements for S_{VSWR} standard test procedure.....	68
7.4.1	General.....	68
7.4.2	Transmit antenna.....	68
7.4.3	Antennas and test equipment for the S_{VSWR} reciprocal test procedure.....	71
7.5	Required positions for site validation testing.....	72
7.5.1	General.....	72
7.5.2	Descriptions of S_{VSWR} measurement positions in a horizontal plane (Figure 27).....	73
7.5.3	Descriptions of S_{VSWR} additional measurement positions (Figure 28).....	74
7.5.4	Summary of S_{VSWR} measurement positions.....	74
7.6	S_{VSWR} site validation – standard test procedure.....	77

7.7	S_{VSWR} site validation – reciprocal test procedure using an isotropic field probe	78
7.8	S_{VSWR} conditional measurement position requirements	79
7.9	S_{VSWR} site validation test report	80
7.10	Limitations of the S_{VSWR} site validation method	81
7.11	Alternative test sites	81
8	Cable termination devices used in radiated emission testing	81
8.1	Common-mode absorption devices	81
8.1.1	General	81
8.1.2	CMAD S -parameter measurements	82
8.1.3	CMAD test jig	82
8.1.4	Measurement method using the TRL calibration	83
8.1.5	Specification of ferrite clamp-type CMAD	85
8.1.6	CMAD performance (degradation) check using spectrum analyzer and tracking generator	86
8.2	VHF-LISN cable termination devices	88
8.2.1	General	88
8.2.2	Balanced VHF-LISN	89
8.2.3	Unbalanced VHF-LISN	90
8.2.4	Measurement of the VHF-LISN impedance	92
9	Reverberating chamber for total radiated power measurement	98
10	TEM waveguides for radiated disturbance measurements	98
Annex A	(normative) Parameters of antennas	99
A.1	General	99
A.2	Preferred antennas	99
A.2.1	General	99
A.2.2	Calculable antenna	99
A.2.3	Low-uncertainty antennas	100
A.3	Simple dipole antennas	101
A.3.1	General	101
A.3.2	Tuned dipole	101
A.3.3	Shortened dipole	101
A.4	Broadband antenna parameters	103
A.4.1	General	103
A.4.2	Antenna type	103
A.4.3	Specification of the antenna	103
A.4.4	Antenna calibration	104
A.4.5	Antenna user information	104
Annex B	(normative) Large-loop antenna system for magnetic field induced-current measurements in the frequency range of 9 kHz to 30 MHz	106
B.1	General	106
B.2	Construction of an LLAS	106
B.3	Construction of a large-loop antenna (LLA)	106
B.4	Validation of an LLAS	111
B.5	Construction of the LLAS verification dipole antenna	113
B.6	Conversion factors	114
B.6.1	General	114
B.6.2	Current conversion factors for an LLAS with non-standard diameter	115

B.6.3	Conversion of LLAS measured current to magnetic field strength	116
B.7	Examples	118
Annex C (normative)	Construction details for open area test sites in the frequency range of 30 MHz to 1 000 MHz (see Clause 6)	119
C.1	General	119
C.2	Ground plane construction	119
C.2.1	Material	119
C.2.2	Roughness	119
C.3	Services to EUT	120
C.4	Weather-protection enclosure construction	120
C.4.1	Materials and fasteners	120
C.4.2	Internal arrangements	121
C.4.3	Size	121
C.4.4	Uniformity with time and weather	121
C.5	Turntable and set-up table	121
C.6	Receive antenna mast installation	122
Annex D (informative)	Basis for the ± 4 dB site acceptability criterion (see Clause 6)	123
D.1	General	123
D.2	Error analysis	123
Annex E (informative)	Examples of uncertainty budgets for site validation of a COMTS using RSM with a calibrated antenna pair (see 6.6)	125
E.1	Quantities to be considered for antenna pair reference site attenuation calibration using the averaging technique	125
E.2	Quantities to be considered for antenna pair reference site attenuation calibration using a REFTS	126
E.3	Quantities to be considered for COMTS validation using an antenna pair reference site attenuation	126
Annex F (informative)	Definition of uncertainty in cross-polar response measurement	128
F.1	General	128
F.2	Example uncertainty estimate	131
F.3	Rationale for the estimates of input quantities in Table F.1 and Table F.3	132
F.4	Measurement of XPR below 100 MHz at an OATS	134
Annex G (informative)	Measurement uncertainties of COMTS validation results in the frequency range 9 kHz to 30 MHz	135
G.1	Quantities to be considered for COMTS validation using the NSIL method	135
G.2	Quantities to be considered for COMTS validation using the RSM method	137
Annex H (normative)	Derivation of NSIL values in the frequency range 9 kHz to 30 MHz	140
H.1	General	140
H.2	Magnetic field antenna factor	141
H.3	Site insertion loss	142
H.4	Normalized site insertion loss	144
H.5	NSIL tables	147
Annex I (informative)	Recommendations for the design of test sites in the frequency range 9 kHz to 30 MHz	152
I.1	General	152
I.2	Dimensions and quality of the ground plane	152
I.3	Obstruction free area	153
I.4	Resonance-free area	153

Annex J (informative) Accuracy of NSIL values in the frequency range of 9 kHz to 30 MHz	155
J.1 General.....	155
J.2 Cross-check of NEC with analytic formulas	155
J.3 Recommended NEC versions.....	156
J.4 Instabilities at the lower frequency end	157
J.5 Extrapolation methods to solve instabilities.....	157
J.6 Reducing the number of segments to solve instabilities	158
Annex K (informative) Example calculation for 10 m SAC sites that do not fulfil the ± 4 dB criterion within 9 kHz to 30 MHz.....	159
Annex L (normative) Calibration of the sum of magnetic field antenna factors in the frequency range of 9 kHz to 30 MHz	162
L.1 General.....	162
L.2 Calibration procedure.....	162
L.3 Measurement uncertainties	163
Bibliography.....	165
 Figure 1 – Example of size-compliant loop antenna	20
Figure 2 – Schematic of radiation from EUT reaching an LPDA antenna directly and via ground reflection at a 3 m site, showing the beamwidth half-angle, φ , at the reflected ray.....	24
Figure 3 – RX antenna E-plane radiation pattern example, with limit area shaded for 3 m distance and 2 m EUT width.....	28
Figure 4 – Determination of maximum useable EUT width using half-power beamwidth	29
Figure 5 – General arrangement of the three measurement orientations H_x , H_y and H_z , where d is the measurement distance and h is the height of the reference point.....	32
Figure 6 – Antenna positions (top view)	33
Figure 7 – Antenna positions (3D view).....	34
Figure 8 – Test set-up for V_{DIRECT} with power amplifier and attenuator	35
Figure 9 – Obstruction-free area of a test site with a turntable	38
Figure 10 – Obstruction-free area with stationary EUT	38
Figure 11 – Test point locations for 3 m and 10 m test distances	47
Figure 12 – Paired test point locations for all test distances.....	49
Figure 13 – Example of paired test point selection for a test distance of 10 m.....	49
Figure 14 – Illustration of an investigation of influence of antenna mast on A_{APR}	50
Figure 15 – Typical antenna positions for a weather-protected OATS or a SAC – vertical polarization validation measurements	53
Figure 16 – Typical antenna positions for a weather-protected OATS or a SAC – horizontal polarization validation measurements	53
Figure 17 – Typical antenna positions for a weather-protected OATS or a SAC – vertical polarization validation measurements for a smaller EUT	54
Figure 18 – Typical antenna positions for a weather-protected OATS or a SAC – horizontal polarization validation measurements for a smaller EUT	54
Figure 19 – Measurement positions for FAR site validation	57
Figure 20 – Example of one measurement position and antenna tilt for FAR site validation	58
Figure 21 – Typical quasi free-space test site reference SA measurement set-up	60

Figure 22 – Theoretical free-space NSA as a function of frequency for different measurement distances [see Equation (18)].....	63
Figure 23 – Position of the antenna relative to the edge above a rectangle set-up table (top view).....	66
Figure 24 – Antenna position above the set-up table (side view).....	66
Figure 25 – Transmit antenna E-plane radiation pattern example (this example is for informative purposes only).....	69
Figure 26 – Transmit antenna H-plane radiation pattern (this example is for informative purposes only).....	71
Figure 27 – S_{VSWR} measurement positions in a horizontal plane (see 7.5.2 for description).....	72
Figure 28 – S_{VSWR} positions (height requirements).....	74
Figure 29 – S_{VSWR} conditional measurement position requirements.....	80
Figure 30 – Definition of the reference planes inside the test jig.....	83
Figure 31 – The four configurations for the TRL calibration.....	85
Figure 32 – Limits for the magnitude of S_{11} , measured according to the provisions of 8.1.1 to 8.1.3.....	86
Figure 33 – Example of a 50 Ω adaptor construction in the vertical flange of the jig.....	87
Figure 34 – Example of a matching adaptor with balun or transformer.....	87
Figure 35 – Example of a matching adaptor with resistive matching network.....	88
Figure 36 – Example circuit diagram of a balanced VHF-LISN.....	90
Figure 37 – Example circuit diagram of an unbalanced VHF-LISN.....	91
Figure 38 – Terminal-to-reference ground impedances of the VHF-LISN at the EUT mains port.....	93
Figure 39 – Example VHF-LISN impedance measurement set-up geometry.....	95
Figure 40 – Example IMA.....	96
Figure 41 – Connection between the IMA and the VHF-LISN.....	97
Figure A.1 – Short dipole antenna factors for $R_L = 50 \Omega$	102
Figure B.1 – The LLAS, consisting of three mutually perpendicular large-loop antennas.....	108
Figure B.2 – An LLA containing two opposite slits, positioned symmetrically with respect to the current probe C.....	109
Figure B.3 – Construction of an LLA slit.....	109
Figure B.4 – Example of an LLA slit construction using a strap of printed circuit board to obtain a rigid construction.....	110
Figure B.5 – Construction of the metal box containing the current probe.....	110
Figure B.6 – Example showing the routing of several cables from an EUT to minimize capacitive coupling from the leads to the LLAS.....	111
Figure B.7 – The eight positions of the LLAS verification dipole during validation of an LLA.....	112
Figure B.8 – Reference validation factors for loops of 2 m, 3 m, and 4 m diameters.....	112
Figure B.9 – Construction of the LLAS verification dipole antenna.....	114
Figure B.10 – Sensitivity S_D of an LLA with diameter D relative to an LLA with 2 m diameter.....	116
Figure B.11 – Conversion factor C_{dA} [for conversion into dB(μ A/m)] for three standard measurement distances d	117
Figure C.1 – The Rayleigh criterion for roughness in the ground plane.....	120

Figure H.1 – Investigation of wire radius, normalized to 0,001 m.....	144
Figure H.2 – Investigation of feed point location (not to scale)	145
Figure H.3 – Variation of NSIL values for various set-ups, for a distance of 3 m, $h = 1,3$	147
Figure H.4 – Specification of feed point location for tabular values (not to scale)	148
Figure H.5 – Calculation examples, loop diameter 60 cm, feed point location per Figure H.4.....	150
Figure I.1 – Recommended minimum dimensions of the ground plane (top view)	152
Figure I.2 – Recommended obstruction free area (top view).....	153
Figure J.1 – Comparison of NSIL values by analytic formulas and computer simulation	156
Figure K.1 – Example site validation result	160
Figure K.2 – U_{lab} calculated from site validation result	161
Figure K.3 – Frequency-dependent correction factor	161
Figure L.1 – Antenna arrangement for the sum of antenna factors method	163
Table 1 – Maximum frequency step size	32
Table 2 – Acceptance criterion.....	36
Table 3 – Site validation methods applicable for OATS, OATS-based, SAC, and FAR site types	40
Table 4 – Theoretical normalized site attenuation, A_N – recommended geometries for broadband antennas ^a	43
Table 5 – Example template for A_{APR} data sets	46
Table 6 – RSM frequency steps	46
Table 7 – Maximum dimensions of test volume versus test distance	55
Table 8 – Frequency ranges and step sizes for FAR site validation.....	57
Table 9 – S_{VSWR} measurement position designations.....	75
Table 10 – S_{VSWR} reporting requirements	80
Table 11 – Specifications for the EUT mains port of the balanced VHF-LISN	89
Table 12 – Specifications for the EUT mains port of the unbalanced VHF-LISN	91
Table B.1 – Reference validation factors of Figure B.8 for loops of 2 m, 3 m, and 4 m diameters.....	113
Table B.2 – Sensitivity S_D of an LLA with diameter D relative to an LLA with 2 m diameter (Figure B.10).....	115
Table B.3 – Magnetic field strength conversion factor C_{dA} for three measurement distances (Figure B.11).....	118
Table C.1 – Maximum roughness for 3 m, 10 m and 30 m measurement distances	120
Table D.1 – Error budget	124
Table E.1 – Antenna pair reference site attenuation calibration using the large-OATS averaging technique	125
Table E.2 – Antenna pair reference site attenuation calibration using REFTS	126
Table E.3 – COMTS validation using an antenna pair reference site attenuation	127
Table F.1 – Example uncertainty estimate for XPR measurement in a FAR and assumed $a_{xpT} = 22$ dB, $a_{xpR} = 34$ dB	132
Table F.2 – Uncertainties depending on other values of A_{xpT} (other assumptions as in Table F.1).....	134

Table F.3 – Example uncertainty estimate for XPR measurement at an OATS and assumed $a_{\text{xpT}} = 22$ dB, $a_{\text{xpR}} = 34$ dB	134
Table G.1 – Example measurement uncertainty budget for COMTS validation using the NSIL method.....	135
Table G.2 – Example measurement uncertainty budget for COMTS validation using the RSM method.....	138
Table H.1 – Calculation examples (loop diameter 60 cm, $d = 3$ m, $h = 1,3$ m).....	150
Table H.2 – Calculation examples (loop diameter 60 cm, $d = 5$ m, $h = 1,3$ m).....	150
Table H.3 – Calculation examples (loop diameter 60 cm, $d = 10$ m, $h = 1,3$ m).....	151
Table I.1 – Skin depth for some practical materials at 9 kHz	153
Table J.1 – Recommended NEC implementations	157
Table J.2 – Observed instabilities	157
Table K.1 – Measurement uncertainty of radiated disturbance results from 9 kHz to 30 MHz	159
Table K.2 – Influence of δA_i on U_{lab}	159
Table L.1 – Example of an uncertainty budget for sum of antenna factors method	163

INTERNATIONAL ELECTROTECHNICAL COMMISSION

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

**Specification for radio disturbance and
immunity measuring apparatus and methods -
Part 1-4: Radio disturbance and immunity measuring apparatus -
Antennas and test sites for radiated disturbance measurements**

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CISPR 16-1-4 has been prepared by CISPR subcommittee A: Radio-interference measurements and statistical methods. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2019, Amendment 1:2020 and Amendment 2:2023. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) revision of the definition 3.1.7 and of the general introduction 8.1.1 for CMAD;
- b) introduction of a new cable termination device, the very high frequency line impedance stabilization network (VHF-LISN) in 8.2;
- c) addition of definition 3.1.34 for VHF-LISN, 3.1.20 for reference ground, 3.1.21 for reference ground plane and 3.1.31 for TN-C-S power system;
- d) various non-technical editorial, style, and wording adjustments for consistency with drafting rules.

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

Draft	Report on voting
CIS/A/1466/FDIS	CIS/A/1475/RVD

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

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

It has the status of a basic EMC publication in accordance with IEC Guide 107 [1], *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*.

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

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

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

- reconfirmed,
- withdrawn, or
- revised.

1 Scope

This part of CISPR 16 specifies the characteristics and performance of equipment for the measurement of radiated disturbances in the frequency range 9 kHz to 18 GHz. Specifications for antennas and test sites are included.

NOTE In accordance with IEC Guide 107 [1],¹ CISPR 16-1-4 is a basic EMC publication for use by product committees of the IEC. As stated in Guide 107, product committees are responsible for determining the applicability of the EMC standard. CISPR and its sub-committees are prepared to cooperate with product committees in the evaluation of the value of particular EMC tests for specific products.

The requirements of this publication apply at all frequencies and for all levels of radiated disturbances within the CISPR indicating range of the measuring equipment.

Methods of measurement are covered in CISPR 16-2-3, further information on radio disturbance is given in CISPR TR 16-3 [2], and uncertainties, statistics, and limit modelling are covered in CISPR 16-4 series [3].

2 Normative references

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

CISPR 16-1-1:2019, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus*

CISPR 16-1-2:2014, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Coupling devices for conducted disturbance measurements*
CISPR 16-1-2:2014/AMD1:2017

CISPR 16-1-5:2014, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-5: Radio disturbance and immunity measuring apparatus - Antenna calibration sites and reference test sites for 5 MHz to 18 GHz*
CISPR 16-1-5:2014/AMD1:2016

CISPR 16-1-6:2014, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-6: Radio disturbance and immunity measuring apparatus - EMC antenna calibration*
CISPR 16-1-6:2014/AMD1:2017
CISPR 16-1-6:2014/AMD2:2022

CISPR 16-2-3:2016, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements*
CISPR 16-2-3:2016/AMD1:2019
CISPR 16-2-3:2016/AMD2:2023

IEC 60050-161:2014, *International Electrotechnical Vocabulary (IEV) - Part 161: Electromagnetic compatibility*

¹ Numbers in square brackets refer to the bibliography.

IEC 60050-195:2021, *International Electrotechnical Vocabulary (IEV) - Part 195: Earthing and protection against electric shock*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms, definitions and abbreviated terms given in CISPR 16-1-1, CISPR 16-1-5, IEC 60050-161, IEC 60050-195 and the following apply.

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

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

3.1 Terms and definitions

3.1.1

antenna

transducer that converts the guided electromagnetic energy of the feed line into a radiated wave in space and vice versa

Note 1 to entry: In the context of this document, for antennas for which a balun is intrinsic to the functioning of the antenna, the term "antenna" includes the balun.

3.1.2

antenna factor

AF

F_a

ratio of the electric field strength of a plane wave incident from the direction corresponding to the mechanical boresight (i.e. the main axis of the antenna) to the voltage induced across a specified load connected to the antenna, measured in a free-space environment

Note 1 to entry: The abbreviation AF is used as a general term to denote antenna factor, whereas F_a denotes the boresight AF in free-space. AF is affected by the load impedance (typically 50 Ω) connected to the antenna, and is frequency dependent. For a biconical antenna this impedance could be up to 200 Ω . For antennas with no balun the impedance is equal to the load impedance, typically 50 Ω . AF can be affected by mutual coupling of the antenna to the ground plane, and is directivity dependent. For more details, see the definitions and 4.2 in CISPR 16-1-6:2014.

Note 2 to entry: The AF has the physical dimension of m^{-1} and measured data are normally expressed in dB relative to 1/m [dB(m^{-1})]. In radiated disturbance measurements, if F_a is known, the strength of an incident field, E , can be estimated from a reading, V , of a measuring receiver connected to the antenna as follows:

$$E = V + F_a$$

where E is in dB($\mu V/m$), V is in dB(μV) and F_a is in dB(m^{-1}).

3.1.3

antenna pair reference site attenuation

A_{APR}

30 MHz to 1 GHz site attenuation for both vertical and horizontal polarizations using a pair of antennas separated by a specified distance at an ideal open-area test site, with one antenna at a specified fixed height above the ground plane, and the other antenna scanned over a specified height range in which the minimum insertion loss is recorded

Note 1 to entry: While ideal A_{APR} is based on an ideal site, actual A_{APR} is also measured at a reference test site (REFTS) (see 6.6.3), or at a large open-area test site (OATS) (see 6.6.4), and the measured values are used as a reference for comparing corresponding site attenuation measurement results at a compliance test site (COMTS) as well as for determining the suitability of an OATS for use in the reference site method (RSM).

Note 2 to entry: Because A_{APR} is defined in terms of an ideal OATS, the difference between the actual OATS and an ideal OATS is treated as an uncertainty contribution.

3.1.4**antenna pair reference site insertion loss** A_{LPR}

9 kHz to 30 MHz site insertion loss for three orientations using a pair of antennas separated by a specified distance at an ideal open-area test site, with both antennas at a specified fixed height above the ground plane and with specified feed point locations

Note 1 to entry: While ideal A_{LPR} is based on an ideal site, actual A_{LPR} is measured at a REFTS (see 5.5.3) and the measured values are used as a reference for comparing corresponding site insertion loss measurement results at a REFTS to evaluate the performance of the COMTS.

Note 2 to entry: Because A_{LPR} is defined in terms of an ideal OATS, the difference between the actual OATS and an ideal OATS is treated as an uncertainty contribution.

3.1.5**antenna reference point**

midpoint of an antenna from which the distance to the equipment under test (EUT) or second antenna is measured

Note 1 to entry: The antenna reference point is either defined by the manufacturer using a marker on log-periodic dipole array (LPDA) antennas or by the calibration laboratory.

3.1.6**balun**

device for transforming an unbalanced transmission line to a balanced transmission line and vice versa

Note 1 to entry: A balun is used, for example, to couple balanced antenna elements to an unbalanced feed line, such as a coaxial cable. A balun may exhibit inherent impedance transformation differing from unity.

3.1.7**common mode absorption device****CMAD**

device that can be applied to cables of the EUT at the point leaving the test volume in radiated disturbance measurements to control the common-mode impedance

Note 1 to entry: The CMAD has no effect on the differential-mode current flowing through the conductors that comprise the cable in the CMAD.

3.1.8**compliance test site****COMTS**

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

3.1.9**cross-polar response****XPR**

measure of the rejection by the antenna of the cross-polarized field, when the antenna is rotated in a linearly polarized electromagnetic field that is uniform in phase and amplitude over the aperture of the antenna under test

3.1.10**EUT volume**

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

Note 1 to entry: The test volume is one of several criteria limiting the EUT volume (see CISPR 16-2-3).

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

3.1.11**feed point**

<shielded loop antenna> location of the slit in the shielding of the loop antenna

Note 1 to entry: The feed point of a shielded loop antenna is important for a correct set-up. The location of the feed point has an influence on the site insertion loss between two magnetic field antennas [4].

Note 2 to entry: For simulation using NEC [5], the source of the transmit antenna and the load of the receive antenna is placed at this location.

3.1.12**fully-anechoic room****FAR**

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

Note 1 to entry: For general radiated disturbance measurement purposes, a FAR should be constructed inside a shielded enclosure.

3.1.13**hybrid antenna**

antenna consisting of a wire-element log-periodic dipole array (LPDA) section and a broadband dipole section

Note 1 to entry: The longest element of the LPDA section is typically resonant at approximately 200 MHz, and the boom is lengthened at the open-circuit end to feed the connected broadband dipole (e.g. biconical or bowtie) section. Over the range 30 MHz to 200 MHz, the broadband dipole exhibits a performance similar to a biconical antenna, notably in the variation of height-dependent antenna factor.

Note 2 to entry: A common-mode choke is typically used at the open-circuit (i.e. rear) end of the boom to minimize parasitic (unintended) RF currents on the outer conductor of the coaxial cable flowing into the measuring receiver.

3.1.14**ideal open-area test site**

open-area test site having a perfectly flat, perfectly conducting ground plane of infinite area, and with no reflecting objects except the ground plane

Note 1 to entry: An ideal OATS is a theoretical construct that is used in the definition of the measurands A_{APR} , A_{LPR} , and in the calculation of the normalized site attenuation A_N and normalized site insertion loss A_{Ni} for ground plane sites.

3.1.15**insertion loss**

loss arising from the insertion of a device into a transmission line, expressed as the ratio of voltages immediately before and after the point of insertion of a device under test, before and after the insertion

Note 1 to entry: Insertion loss is equal to the inverse of the scattering parameter S_{21} , i.e. $|1/S_{21}|$.

3.1.16**low-uncertainty antenna**

robust biconical or LPDA antenna that meets the balance and XPR requirements of this document, and whose antenna factor has an uncertainty of less than 0,5 dB, used for the measurement of electric field strength at a defined point in space

Note 1 to entry: Low-uncertainty antennas are further described in A.2.3.

3.1.17**mechanical boresight**

boresight direction

boresight

direction of the main beam, which is defined by the geometric properties of the antenna

Note 1 to entry: For EMC antennas the direction of the main beam is usually: a) coincident with the direction in line with the mechanical longitudinal axis of LPDA antennas; b) orthogonal to the elements of monopole, dipole, and biconical antennas; and c) orthogonal to the front aperture of horn antennas. In each of these cases, the orthogonal line is passing through the centre of the antenna.

3.1.18**null**

minimum in signal level resulting from the vector sum of the direct and ground-reflected signals at the receive antenna and with the level being considerably lower than the in-phase sum of these signals

Note 1 to entry: The depth of a null is measured from the in-phase sum of the direct and ground reflected signals. A null in the received signal occurs when the antennas are above a ground plane at heights such that the direct and ground reflected signals are in anti-phase, which can result in large uncertainty in the measurement of field strength. A null extends from 90° to 180° out of phase. At 90° the null depth is approximately 6 dB. The depth is compared to the nearest adjacent maximum signal in the swept frequency response (or height scan of one antenna at a fixed frequency).

Note 2 to entry: The dip in signal level on boresight for some DRH antennas is sometimes referred to as a null. This definition does not apply to such dips.

Note 3 to entry: IEC 60050-726:1982[6], 726-02-07 defines standing-wave minimum, with synonym node (of a standing wave), as the location in a propagation medium where the vectorial sum of a specified field quantity of two waves creating a standing wave is a minimum.

3.1.19**quasi-free-space test site**

facility for radiated disturbance measurements that is intended to achieve free-space conditions

Note 1 to entry: Unwanted reflections from the surroundings are kept to a minimum, to satisfy the site acceptance criterion applicable to the radiated disturbance measurement procedure being considered.

3.1.20**reference ground****RG**

part of the Earth considered as conductive, the electric potential of which is conventionally taken as zero, being outside the zone of influence of any earthing arrangement

Note 1 to entry: The concept "Earth" means the planet and all its physical matter.

[SOURCE: IEC 60050-195:2021, 195-01-01]

3.1.21**reference ground plane****RGP**

flat conductive surface that is at the same electric potential as reference ground, which is used as a common reference, and which contributes to a reproducible parasitic capacitance with the surroundings of the equipment under test (EUT)

Note 1 to entry: A reference ground plane is needed for the measurements of conducted disturbances and serves as reference for the measurement of unsymmetrical and asymmetrical disturbance voltages.

Note 2 to entry: In some regions, the term "earth" is used in place of "ground".

[SOURCE: IEC 60050-161:2014, 161-04-36]

3.1.22**reference test site****REFTS**

open-area test site with metallic ground plane and tightly specified site attenuation performance in horizontal and vertical electric field polarizations

Note 1 to entry: Site attenuation measurements of a REFTS are used for comparison to corresponding site attenuation measurements of a compliance test site, in order to evaluate the performance of the compliance test site.

3.1.23**reflection coefficient**

ratio of a common quantity to both the reflected and incident travelling waves

Note 1 to entry: Hence, the voltage reflection coefficient is defined as the ratio of the complex voltage of the reflected wave to the complex voltage of the incident wave. The voltage reflection coefficient is equal to the scattering parameter S_{11} .

3.1.24**resonant dipole antenna**

tuned dipole antenna

antenna consisting of two straight collinear conductors of equal length, placed end to end, separated by a small gap constituting a balanced feed, with each conductor approximately a quarter-wavelength long such that at the specified frequency the input impedance of the wire antenna measured across the gap has zero reactance when the dipole is located in the free space

3.1.25**scattering parameters*****S*-parameters**

set of four parameters used to describe the properties of a two-port network inserted into a transmission line

Note 1 to entry: The four *S*-parameters used with two-port networks are designated as S_{11} , S_{12} , S_{21} , and S_{22} .

3.1.26**semi-anechoic chamber****SAC**

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

3.1.27**short-open-load-through calibration method****SOLT**

through-open-short-match calibration method

TOSM

calibration method for a vector network analyzer using three known impedance standards (short, open, and match/load) and a single transmission standard (through)

Note 1 to entry: The SOLT method is widely used and the necessary calibration kits with 50 Ω characteristic impedance components are commonly available. A full two-port error model includes six error terms for each of the forward and reverse directions, for a total of twelve separate error terms, and requires twelve reference measurements to perform the calibration.

3.1.28**site attenuation****SA** A_s

minimum site insertion loss measured between two polarization-matched antennas located at a test site when one antenna is moved vertically over a specified height range and the other is set at a fixed height

Note 1 to entry: The terms site insertion loss (see 3.1.29) and site attenuation describe essentially the same measurement, however the term site attenuation (SA) is used in the context of finding the minimum site insertion loss (SIL) between a pair of antennas when one antenna is scanned in height above a ground plane.

3.1.29**site insertion loss****SIL** A_i

transmission loss between two polarization-matched antennas when a direct electrical connection between the signal generator output and the measuring receiver input is replaced by a transmit antenna and a receive antenna placed at specified positions at a test site

Note 1 to entry: With loop antennas, the locations of their feed points shall be as specified in this document.

3.1.30**test volume**

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

Note 1 to entry: Validation procedures in this document are used to determine the test volume.

Note 2 to entry: The test volume as defined in this document is cylindrical in shape. Different test volume shapes have been defined in other documents, e.g. in cubic form in IEC 61000-4-20 (TEM waveguides) [7].

3.1.31**TN-C-S power system**

power distribution system in which the neutral and protective functions are combined in a single conductor from an earthed power source up to a point prior to a consumer's connection

3.1.32**through-reflect-line calibration****TRL calibration**

calibration method for a vector network analyzer (VNA) using three known impedance standards ("through", "reflect", and "line") for the internal or external calibration of the VNA

Note 1 to entry: Four reference measurements are needed for this calibration.

3.1.33**vector network analyzer****VNA**

network analyzer capable of measuring complex values of the four S -parameters S_{11} , S_{12} , S_{21} , and S_{22}

3.1.34**very high frequency-line impedance stabilization network****VHF-LISN**

device, bonded to the test site ground plane, that can be connected between the mains power source and the AC mains power cable of the EUT at the point leaving the test volume to control the impedance presented to that cable in the very high frequency band

Note 1 to entry: Two basic types of VHF-LISN are described in 8.2.2 and 8.2.3.

3.2 Abbreviated terms

The following are abbreviated terms used in this document that are not already given in 3.1.

AUT	antenna under test
DANL	displayed average noise level
DRH	double-ridge(d) horn
EUT	equipment under test
FSOATS	free-space OATS
HP	horizontal polarization
IMA	impedance measurement adaptor
LLA	large-loop antenna
LLAS	large-loop antenna system
LPDA	log-periodic dipole array
NSA	normalized site attenuation
NSIL	normalized site insertion loss
OATS	open-area test site
PDF	probability density function
PE	protective earth
RF	radio frequency
RG	reference ground
RGP	reference ground plane
RSM	reference site method
RX	receive
S_{VSWR}	site voltage standing wave ratio
TX	transmit
VP	vertical polarization
VSWR	voltage standing wave ratio
XP	cross polarization

4 Antennas for measurement of radiated radio disturbance

4.1 General

Antennas of the type that are used for radiated disturbance measurements, having been calibrated, shall be used to measure the field strength, taking into account their radiation patterns and mutual coupling with their surroundings. The antenna and the circuits inserted between it and the measuring receiver shall not appreciably affect the overall characteristics of the measuring receiver. When the antenna is connected to the measuring receiver, the measuring system shall comply with the bandwidth requirements of CISPR 16-1-1 appropriate to the frequency band concerned.

The antenna shall be linearly polarized. It shall be orientable so that all polarizations of incident radiation can be measured. The height of the centre of the antenna above ground or above the absorber in a FAR can have to be adjustable according to a specific measurement procedure.

The accuracy of field-strength measurement of a uniform field of a sine-wave signal shall be better than ± 3 dB when an antenna meeting the requirements of this subclause is used with a measuring receiver meeting the requirements of CISPR 16-1-1.

NOTE This requirement does not include the effect due to a test site.

For additional information about the parameters of broadband antennas, see Annex A.

4.2 Physical parameter (measurand) for radiated disturbance measurements

The physical parameter for radiated disturbance measurements made against a disturbance limit expressed in volts per metre is electric field strength measured at a defined point in space relative to the position of the equipment under test (EUT). More specifically, for measurements in the frequency range 30 MHz to 1 000 MHz on an OATS or in a SAC, the measurand is the maximum field strength as a function of horizontal and vertical polarization and at heights between 1 m and 4 m, and at a horizontal distance of 10 m from the EUT, while the EUT is rotated over all angles in the azimuth plane.

4.3 Antennas for the frequency range 9 kHz to 150 kHz

4.3.1 General

Experience has shown that, in this frequency range, it is the magnetic field component that is primarily responsible for observed instances of interference.

4.3.2 Magnetic field antenna

4.3.2.1 General

A shielded loop antenna of dimensions such that the loop antenna can be completely enclosed by a square having sides of 60 cm in length shall be used. The shielding, but not the electronic unit including mechanical mounting features and connected cables, shall be taken into account when applying the size criterion; see Figure 1.

For site validation in accordance with 5.5, the loop antenna shall have a single turn.

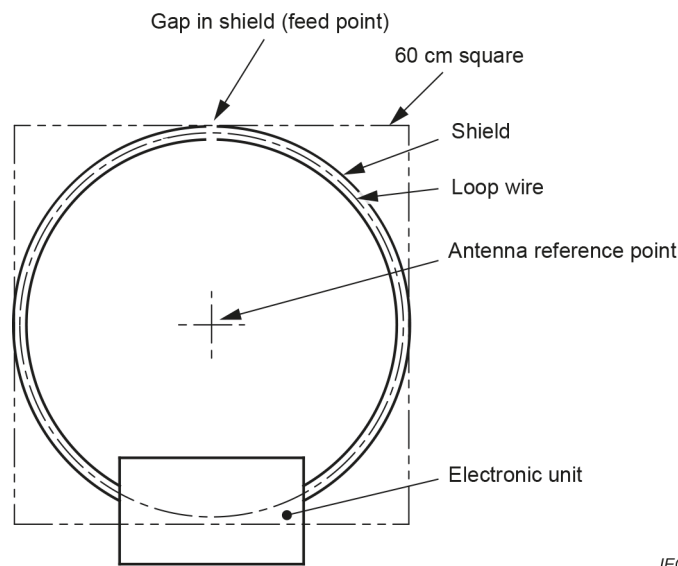
NOTE 1 Derivation of NSIL values, as described in Annex H, is less complicated and more accurate for single-turn loops.

The unit of magnetic field strength is $\mu\text{A/m}$. In logarithmic units H is in $\text{dB}(\mu\text{A/m})$, or 20 times the logarithm of the measured field strength. The associated disturbance limit shall be expressed in the same units.

NOTE 2 Direct measurements can be made of the strength of the magnetic component, in $\text{dB}(\mu\text{A/m})$ or $\mu\text{A/m}$, of a radiated field under all conditions, that is, both in the near field and in the far field [8].

The reference point of the shielded loop antenna is specified as the centre point of the circle or rectangle formed by the loop, ignoring any attached balun or mechanical mounting feature.

The magnetic field antenna shall be calibrated according to CISPR 16-1-6 for determination of the magnetic field antenna factor. The magnetic field antenna factor is required for site validation in accordance with 5.5, and also for radiated disturbance measurements in accordance with CISPR 16-2-3.



NOTE This example illustrates the maximum diameter circular-shaped loop antenna that still complies with the size criterion.

Figure 1 – Example of size-compliant loop antenna

4.3.2.2 Considerations on active antennas

In principle, an active antenna can be seen as a passive antenna with a preamplifier. Annex J of CISPR 16-1-1:2019 describes the problems that can arise when preamplifiers are used. Especially when pulsed signals are measured, a larger dynamic range is required.

When using active antennas, it is recommended to use those types that are equipped with an overload indicator. In this case, the indicator shall be observed such that any overload condition is detected, and actions are taken to correct it.

Alternatively, the output voltage of the antenna shall be checked simultaneously with an oscilloscope by using a tee connector to split the receive cable. This tee connector shall be connected directly to the input of an oscilloscope and the second output to the receiver via a cable. The oscilloscope shall be set to high input impedance to minimise any influence on the measurement result. The trigger point of the oscilloscope shall be set to a voltage that corresponds to the 1 dB compression point of the active antenna. The measurement is assumed to be valid if no trigger event occurs during the entire measurement.

NOTE The influence of the input impedance of the oscilloscope to the measurement result is negligible. For impedances of 1 M Ω in parallel with 20 pF, the error is less than 0,04 dB.

A resistive power divider can be used instead of a tee connector. In this case the input impedance of the oscilloscope shall be set to 50 Ω . The noise floor of the system might be increased by the insertion of 6 dB loss between antenna and receiver. The loss through the power divider shall be accounted for when determining the measured magnetic field strength level (i.e. added to the level measured by the receiver).

The highest measurable field strength is usually given in the datasheet of the antenna, which shall be checked to ensure that it is valid for the entire measurement frequency range.

The ratio between the peak value of the field strength and power of the fundamental frequency depends on the type of disturbance. For pulse-width modulated signals especially, this value can reach 30 dB or more; see [9]. When considering overload, the peak value of a disturbance signal shall be taken into consideration.

Use of an active antenna is not necessary at measurement distances of 3 m or 5 m. Passive antennas can be suitable to provide a sufficient signal-to-noise ratio.

4.3.3 Shielding of loop antenna

Inadequate shielding of a loop antenna can result in electric field response. The electric field discrimination of the antenna shall be evaluated by rotating the antenna in a uniform field, such that the plane of the loop remains parallel to the electric field vector. When the plane of the loop antenna is perpendicular to the magnetic flux and then the antenna is rotated so that its plane is parallel to the magnetic flux, the measured response shall decrease by at least 20 dB.

4.4 Antennas for the frequency range 150 kHz to 30 MHz

4.4.1 Electric field antenna

For the measurement of the electric component of the radiation, either a balanced or an unbalanced antenna can be used. If an unbalanced antenna is used, the measurement will refer only to the effect of the electric field on a monopole (rod) antenna. The type of antenna used shall be stated with the results of the measurements.

Information pertaining to calculating the performance characteristics of a monopole (rod) antenna and the characterization of its matching network is specified in CISPR 16-1-6. CISPR 16-1-6 states that the antenna factor derived by the Equivalent Capacitance Substitution Method (ECSM) has greater uncertainties for monopole lengths greater than one-eighth of a wavelength.

The unit of electric field strength shall be $\mu\text{V/m}$. In logarithmic units, E shall be expressed in $\text{dB}(\mu\text{V/m})$, or 20 times the logarithm of the measured field strength level. The associated disturbance limit shall be expressed in the same units.

4.4.2 Magnetic field antenna

For the measurement of the magnetic component of the radiation, an electrically-screened loop antenna, as described in 4.3.2 shall be used.

NOTE Tuned electrically balanced loop antennas can be used to make measurements of magnetic field strengths as low as $-51,5 \text{ dB}(\mu\text{A/m})$ using quasi-peak (QP) detection in the frequency range 1,6 MHz to 30 MHz, i.e. lower than with untuned electrically-screened loop antennas where the noise level is approximately 25 dB higher.

4.4.3 Balance and electric field discrimination of antennas

If a balanced electric field antenna is used, it shall comply with the requirement of 4.5.4. If a balanced magnetic field antenna is used, it shall comply with the requirement of 4.3.3.

4.5 Antennas for the frequency range 30 MHz to 1 000 MHz

4.5.1 General

In this frequency range, the measurements are of the electric field strength, so magnetic field antennas are not included. The antenna shall be a dipole-like antenna designed to measure the electric field strength, and the free-space antenna factor shall be used. The antenna types include:

- tuned dipole antennas, whose element pairs are either straight rods or conical in shape;
- dipole arrays such as the log-periodic dipole array (LPDA) antennas, comprising a series of staggered sets of straight rod elements;
- hybrid antennas.

4.5.2 Low-uncertainty antenna for use if there is an alleged non-compliance to the electric disturbance field strength limit

For lower measurement uncertainty, the value of electric field strength measured by a typical biconical antenna or LPDA antenna is preferred, in particular over hybrid antennas. Typical biconical and LPDA antennas are described in Annex A, and only calibrated antennas shall be used.

NOTE 1 Improved uncertainties are achieved by using a biconical antenna over the frequency range 30 MHz to 250 MHz and an LPDA antenna over the range 250 MHz to 1 GHz. Alternatively, a change-over frequency of 200 MHz can be used, but uncertainties due to phase centre variations of the LPDA will be higher.

NOTE 2 The measurement uncertainty of radiated disturbance from an EUT depends on many different influence factors such as the quality of the site, antenna factor uncertainty, antenna type, and the measuring receiver characteristics. The reason for defining low-uncertainty antennas is to limit other antenna influences on the measurement uncertainty, such as the effect of mutual coupling with a ground plane, the radiation pattern with respect to height scanning, and the variable phase centre position. Verification of effects of these influences is accomplished by a comparison of the readings of the two antennas at the selected change-over frequency, which gives the same value of electric field strength within a margin of ± 1 dB.

4.5.3 Antenna characteristics

Given that the sensitivity of the simple dipole antenna is low in the frequency range 300 MHz to 1 000 MHz, a more complex antenna can be used. Such an antenna shall have characteristics as follows:

- a) The antenna shall be linearly polarized, which shall be evaluated by applying the cross-polarization test procedure of 4.5.5.
- b) Balanced dipole antennas, such as tuned-dipole and biconical antennas, shall have validated balun performance, which shall be evaluated by applying the balance test procedure of 4.5.4. This requirement also applies to hybrid antennas below 200 MHz.
- c) The return loss of the antenna with the antenna feeder connected shall not be less than 10 dB. A matching attenuator can be part of the antenna feeder cable for antennas if needed to meet this requirement.
- d) An antenna factor (AF) shall be given making it possible to fulfil the accuracy requirements of 4.1.

Accounting for the antenna directivity: a test site with a conducting ground plane is assumed for the following antenna characteristic description. The amplitude of the received signal will be reduced if either or both the direct and ground-reflected signals from the EUT to the antenna are not entering the main lobe of the radiation pattern of the antenna at its peak. The peak is usually in the boresight direction of the antenna. This reduction in amplitude is taken to be an error in the radiated disturbance measurement result; the ensuing uncertainty tolerance is based on the beamwidth, 2φ (see Figure 2).

Conditions for ensuring that this error is no larger than +1 dB are given in 1) for a 10 m site, and in 4.5.3 2) for a 3 m site. Alternatively, a condition based on antenna gain is given in 4.5.3 3) in lieu of the rigorous radiation pattern conditions.

Radiated disturbance measurements are performed with the antenna horizontally and vertically polarized in turn. If it is chosen to measure the radiation patterns in only one plane, the narrower beamwidth pattern results shall be used, and with the condition that the pattern of the antenna shall be verified in the horizontal plane while orienting it for horizontal polarization.

- 1) For a 10 m OATS or SAC, the antenna response in the direction of the direct ray differs negligibly from the boresight amplitude when the antenna is aligned such that its boresight direction is parallel to the ground plane. The directivity component of the uncertainty in the disturbance measurement can be kept to less than +1 dB if the antenna response in the direction of the reflected ray is no more than 2 dB lower than the antenna boresight response. To ensure this condition, the total vertical beamwidth 2φ of the measurement antenna, within which the antenna gain is within 2 dB of its maximum, shall be such that:

$$\varphi > \tan^{-1} \frac{h_1 + h_2}{d} \quad (1)$$

where

h_2 is the height of the equipment under test;

h_1 is the measurement antenna height;

d is the horizontal distance between the phase centre of the measurement antenna and the device under test.

- 2) For sites with less than 10 m separation, typically 3 m, the total vertical beamwidth 2φ of the measurement antenna, within which the antenna gain is within 1 dB of its maximum, shall be such that:

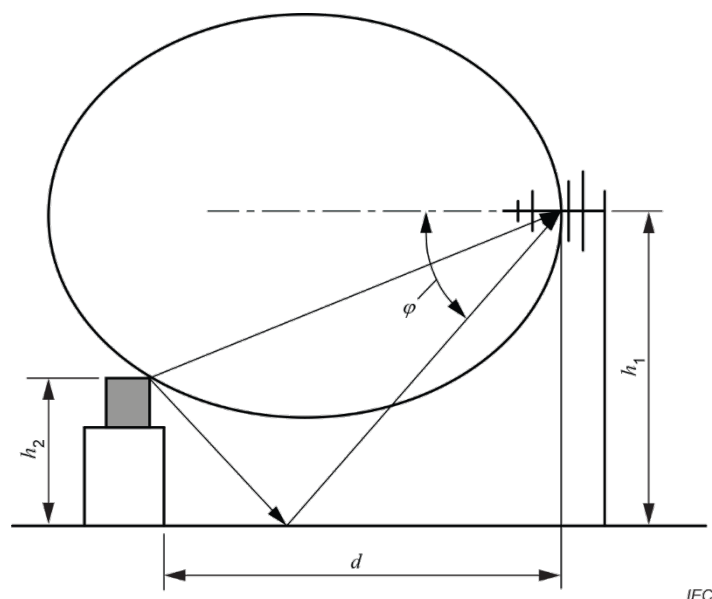
$$2\varphi > \left(\tan^{-1} \frac{h_1 + h_2}{d} \right) - \left(\tan^{-1} \frac{h_1 - h_2}{d} \right) \quad (2)$$

Antenna down-tilting can reduce the associated uncertainties; if that is not employed, the reduction in received signal shall be calculated from the radiation patterns and applied as a correction with associated directivity uncertainties. Example uncertainty budgets are given in CISPR 16-4-2 [10].

NOTE 1 Assuming an E-plane radiation pattern normalized to unity on boresight (i.e. peak of the main lobe) record the electric field at the angles of declination from the antenna for the direct ray, E_D , and reflected ray, E_R . The error, compared to an electric field of unity magnitude for each of the direct and reflected rays, is given in decibels by $20 \lg [2/(E_D + E_R)]$.

NOTE 2 The reduction in signal strength caused by reduced directivity at angles off antenna boresight is a systematic error and therefore can be corrected. If a correction is applied, from knowledge of the radiation patterns at each frequency and polarization, the uncertainty of field-strength measurement can be reduced accordingly.

- 3) For the broad beamwidth antenna types typically used for radiated disturbance measurements, such as biconical, LPDA, and hybrid antennas, the beamwidth is inversely related to the antenna directivity. An alternative to the criterion based on beamwidths in 4.5.3 1) and 4.5.3 2) is to specify the maximum gain of an antenna, then refer to generic uncertainty tolerances for the directivity component in the uncertainty budget for the disturbance measurement results. The generic uncertainties, based on the narrowest beamwidths in the frequency range used for a specific antenna, are given in CISPR 16-4-2 [10]. The maximum isotropic antenna gain for biconical antennas shall be 2 dB, and shall be 8 dB for LPDA and hybrid antennas. For V-type LPDA antennas, whose H-plane beamwidth is equal to the E-plane beamwidth, the maximum permitted isotropic gain shall be 9 dB.



NOTE Parameters are defined in Equation (1).

Figure 2 – Schematic of radiation from EUT reaching an LPDA antenna directly and via ground reflection at a 3 m site, showing the beamwidth half-angle, ϕ , at the reflected ray

4.5.4 Balance of antenna

4.5.4.1 General

In radiated disturbance measurements, common-mode (CM) currents can be present on the cable attached to the receive antenna (antenna cable). In turn, these CM currents create electromagnetic fields that can be picked up by the receive antenna if the balun is not perfectly balanced. Consequently, the radiated disturbance measurement results can be influenced.

The major contributions to the antenna cable CM currents are caused by:

- the electric field strength to be measured, if it has a component parallel to the antenna cable, and
- the conversion of the differential mode (DM) antenna signal (the desired signal) into a CM signal by the imperfection of the balun of the receive antenna.

In general, LPDA antennas do not exhibit significant DM/CM (DM to CM) conversion. Therefore, the following check applies for dipole and biconical antennas over their entire operating frequency range, and to hybrid antennas over the frequency range of the broadband dipole section (in most cases 30 MHz to 200 MHz).

4.5.4.2 Balun DM/CM conversion check

The following method describes the measurement of two voltages V_1 and V_2 . The ratio of these voltages, both expressed in identical units, e.g. μV , is a measure of the DM/CM conversion (also known as the balun imbalance, balun symmetry, or antenna symmetry).

- Set the receive AUT vertically polarized with its centre at a height of 1,0 m above the ground plane of an OATS or SAC. The tip of the antenna shall be at least 0,25 m above the ground plane. Extend a 1,5 m $\pm$ 0,1 m length of the antenna cable horizontally behind the rear active element of the receive antenna at a height of 1,0 m above the ground plane, and then allow it to drop vertically to the ground plane.

- b) For a standard characterization of the receive antenna imbalance, place a second (transmit) antenna vertically polarized at a horizontal distance of 10 m from the centre of the AUT. The centre of the transmit antenna shall be at a height of 1,0 m above the ground plane, and its tip shall be at least 0,25 m above the ground plane. The transmit antenna shall be linearly polarized, and have a cross-polar rejection greater than 20 dB over the frequency range of the balun test. For the frequency range above 200 MHz, transmit antenna height variation shall be used to avoid nulls in the SIL response. Measurements at shorter distances (e.g. 3 m and 5 m) can be made to determine the uncertainty contribution of balun imbalance at these distances.
- c) Connect the transmit antenna to a signal source (for example, a tracking generator or the source output of a network analyzer). Next, set the output level of that signal source so that over the frequency range of interest, and for both vertical orientations of the antenna, the signal-to-ambient noise ratio at the receiver is 34 dB (17 dB for average detection) or more.
- d) Record the voltage V_1 at the receiver over the frequency range of interest.
- e) Invert the receive antenna (i.e. rotate that antenna through 180°) without changing anything else in the set-up, in particular the receive antenna cable, and without changing the setting of the signal source.
- f) Record the voltage V_2 at the receiver over the frequency range of interest.
- g) The DM/CM conversion is sufficiently low if $|20 \lg (V_1/V_2)| < 1$ dB.

NOTE 1 For the purpose of radiated disturbance measurements, if the DM/CM conversion criterion is not met, ferrite rings around the antenna cable can reduce the DM/CM conversion. The EMC test laboratory can repeat the test with four ferrite rings spaced approximately 20 cm apart; the first placed within 10 cm of the input to the balun. If the criterion is met by using these ferrite rings, then the ferrite rings also apply in the actual disturbance measurements. Likewise, the interaction with the cable can be reduced by extending the cable several metres horizontally behind the antenna before dropping to the ground plane.

NOTE 2 If the receive antenna is used in a FAR, the DM/CM check can be performed in that FAR, with the receive antenna at its usual location and the transmit antenna at least 3 m away. The antennas are best positioned centrally in the room with a clearance behind the antennas of at least 1 m between the vertical portion of cable and the tips of the absorbers.

NOTE 3 The measuring site and its conducting ground plane (OATS or SAC), or the FAR, are assumed to comply with the respective site validation requirements.

NOTE 4 The horizontal distance of 1,5 m over which the antenna cable runs horizontally behind the centre of the antenna is understood as kept as the minimum distance allowed during the actual vertically polarized radiated disturbance measurements.

NOTE 5 In general it is not necessary to strictly define a test set-up, because the imbalance effect is dominated by the interaction of the antenna and that part of the antenna cable that lies parallel to the antenna elements. Also there is a much smaller effect that is dependent on the uniformity of the field incident on the receive antenna in normal EMC measurement set-ups at an OATS or in a FAR.

NOTE 6 For baluns that have the receive cable connector mounted on the side (90° to the antenna boom), a right angle connector can be used to reduce the movement of the cable.

NOTE 7 The uncertainty of the balun DM/CM measurement result will be caused only by any nonlinearity of the receiver, because everything else remains unchanged during the V_1 and V_2 measurements. A nonlinearity of less than 0,1 dB within the ± 1 dB range from the reference indication V_1 is good enough to meet the 1 dB criterion.

4.5.5 Cross-polar response of antenna

When an antenna is placed in a linearly-polarized electromagnetic field, the terminal voltage when the antenna and field are cross-polarized shall be at least 20 dB below the terminal voltage when they are co-polarized. This requirement applies over the entire frequency range of 30 MHz to 18 GHz. In practice, this requirement is not satisfied by some types of LPDA antennas for which the two halves of each dipole are in echelon, which intrinsically generates a cross-polar response (XPR).

The majority of testing with LPDA antennas is above 200 MHz. To achieve free-space conditions, a high-quality fully anechoic room, or antenna support towers of sufficient height above ground on an outdoor range can be used; see 6.3.2 of this document and Clause 6 of CISPR 16-1-5:2014 for associated site characteristics. A uniform field shall be set up across the effective length of the AUT. The separation between the centre of the AUT and the transmit antenna shall be greater than one wavelength. For an LPDA antenna, the separation is to its centre mark. When the lowest frequency is 200 MHz, a fixed separation of 1,5 m over the entire frequency range is recommended.

Set the transmit antenna and the AUT vertically polarized and note the signal strength over the frequency range. Rotate the transmit antenna by 90° and note the difference in signal strength relative to the co-polar reading.

NOTE A good-quality site is used to set up a uniform field across the effective area of the AUT. The cross-polar discrimination afforded by the linearly-polarized wave can be proven by transmitting between a pair of standard-gain horn antennas or open-ended waveguides as test antennas, and checking that the combination of site error and inherent cross-polar performance with the test antennas yields a suppression of the horizontal component by more than 30 dB. If the site errors are very low, and if the test antennas have identical performance, the cross-polar rejection of one test antenna is approximately 6 dB lower than the combined cross-polar coupling of the pair of test antennas. For example, if the combined cross-polar level is 30 dB, then the level for a single test antenna is 36 dB. The criterion for the site set-up, including antenna separation and site performance, is the achievement of a combined cross-polar level of 30 dB. A pair of horn antennas can be set up, horizontally polarized, with a separation between their front apertures of 1,5 m. The site insertion loss (SIL) is recorded over the frequency range of interest. One of the antennas is rotated by 90° so that it is vertically polarized. The change in SIL of at least 30 dB will provide acceptable measurement uncertainty. For frequencies below 1 GHz, V-shaped LPDA antennas can be used in place of horn antennas to prove the suitability of the site. It is possible to use dipole or biconical antennas, but due to their uniform H-plane radiation patterns a greater antenna height would be used.

An interfering signal 20 dB lower in level than the desired signal gives a maximum error on the desired signal of $\pm 0,9$ dB. The maximum error occurs when the cross-polar signal is in phase with the co-polar signal. If the XPR of the LPDA is worse than 20 dB, the operator shall calculate the uncertainty and declare it with the result. For example, a cross-polar level of 14 dB implies a maximum uncertainty of +1,6 dB to -1,9 dB; the larger value and an assumed rectangular distribution shall be used when calculating the standard uncertainty.

To add a signal of 0 dB to another of -14 dB, first convert to relative voltages by dividing by 20 and taking the anti-logarithm. Then add the smaller signal to the unity signal. Take the logarithm and multiply by 20. The result is the positive decibel error. Repeat, but subtract the smaller signal from the unity signal to give the negative decibel error.

For the purpose of calculating the uncertainty of a radiated disturbance measurement, if the signal level measured in one polarization exceeds the signal measured in the orthogonal polarization by 6 dB or more, then an LPDA whose XPR is only 14 dB will have been deemed to have met the specification of 20 dB. If the difference between the vertically and horizontally polarized signal levels is less than 6 dB, additional uncertainty shall be calculated if the sum of this difference and the XPR is less than 20 dB.

Considerations on measurement uncertainty for XPR measurement results can be found in Annex F. Annex F provides an example of an XPR of an AUT sufficient to meet the 20 dB XPR requirement in the measurement.

4.6 Antennas for the frequency range 1 GHz to 18 GHz

4.6.1 General

Radiated disturbance measurements above 1 GHz shall be made using calibrated linearly polarized antennas. Examples are LPDA antennas, double-ridged guide horn antennas, and standard gain horn antennas. The "beam" or main lobe of the pattern of any antenna used shall be wide enough to encompass the EUT when located at the measuring distance. The width of the main lobe is defined as the 3 dB beamwidth of the antenna, and information allowing determination of this parameter should be given in the antenna documentation. For horn antennas, the condition of Equation (3) shall be satisfied:

$$d \geq \frac{D^2}{2\lambda} \quad (3)$$

where

d is the measurement distance (m);

D is the largest dimension of the aperture of the antenna (m); and

λ is the free space wavelength at the frequency of measurement (m).

The requirement for the XPR of the antenna in 4.5.5 also applies for the 1 GHz to 18 GHz frequency range.

4.6.2 Receive antenna

4.6.2.1 General

The receive antenna shall be linearly polarized and for site validation be the same type as used for EUT disturbance measurements.

Some antenna models can have different versions with possibly different radiation patterns, and users are advised to verify the preceding condition.

NOTE 1 "Antenna type" means a shape or a kind of antenna, for example horn antenna or LPDA antenna.

NOTE 2 "Antenna model" means the specified manufacturer's model number.

NOTE 3 "Version" means the specified manufacturer's revision number, if applicable, of a particular antenna model number.

4.6.2.2 Receive antenna radiation pattern

E-plane and H-plane radiation patterns shall be measured with reference to the antenna boresight. The measurand is the antenna pattern in dB, presented using a polar-coordinate plot such as in Figure 3. Radiation pattern plots should be normalized to 0 dB. The 0° angle shall be equal to the mechanical boresight.

E-plane and H-plane radiation patterns of each individual antenna shall be recorded over the frequency range of the antenna with a step size of 500 MHz or less, per Annex I of CISPR 16-1-6:2014/AMD1:2017.

Type-test results, including statistical data, supplied by the manufacturer can be used to provide evidence that the receive antenna radiation pattern requirements are met. Service measures shall be taken to assure pattern stability during the antenna life.



Figure 3 – RX antenna E-plane radiation pattern example, with limit area shaded for 3 m distance and 2 m EUT width

NOTE In general, the boresight direction is the direction of maximum radiation from the antenna. However, it can happen that the pattern has two radiation maxima but with none of the maxima in the direction of the mechanical boresight, e.g. as in Figure 3.

4.6.2.3 Receive antenna radiation pattern requirements

The grey-shaded areas shown in the polar plots of Figure 4 are defined by the maximum height, h , and the maximum width, w , of the EUT, and the test distance, d .

For the receive antenna to sufficiently illuminate the EUT, the half-power beamwidth of the receive antenna shall not fall inside the shaded area in the E-plane and H-plane pattern cuts shown in Figure 4.

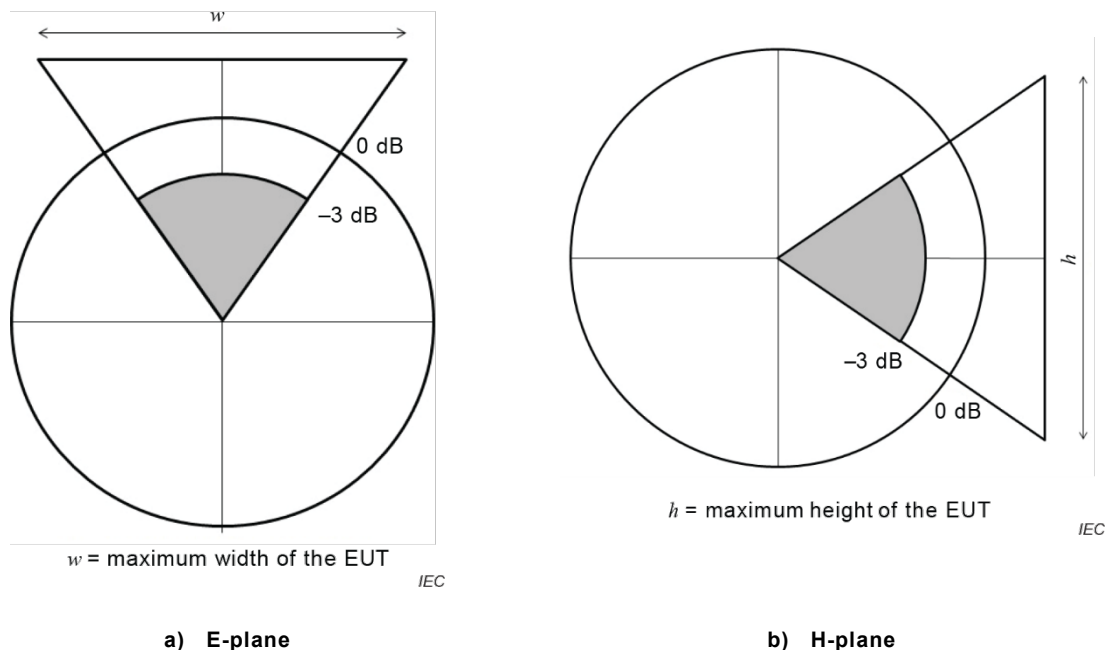


**Figure 4 – Determination of maximum useable
EUT width using half-power beamwidth**

4.7 Special antenna arrangements – large-loop antenna system

In the frequency range 9 kHz to 30 MHz, the interference capability of the magnetic field component of the radiation of a single EUT can be determined by using a large-loop antenna system (LLAS). In the LLAS, the interference capability is measured in terms of the currents induced by the magnetic field in each LLA of the LLAS. The LLAS measures the current induced by the magnetic field component of a single EUT. The LLAS allows indoor measurements.

The LLAS consists of three circular mutually-perpendicular large-loop antennas, each having a diameter of 2 m, supported by a non-metallic base. A full description of the LLAS is given in Annex B.

The EUT shall be positioned in the centre of the LLAS on a non-conductive support table. The maximum dimensions of the EUT are limited so that the distance between the EUT and each LLAS loop is at least 0,20 m. Guidelines for routing of EUT cables are given in Clause B.3 and Figure B.6. Cables shall be routed together, leave the LLAS volume in the same octant of the LLAS, and be no closer than 0,4 m to any of the LLAS loops.

The LLAS can be placed in any environment. Placement inside a shielded room, SAC, FAR, or weather-protected OATS is permitted. Placement in a shielded environment is recommended to eliminate ambient signals allowing for better sensitivity to EUT emissions. A minimum distance of 0,5 m between the LLAS and any metallic plane is recommended. The validation of the LLAS shall be performed at the location where the LLAS measurements normally take place to take into account the effect of the environment (see Clause B.4).

The three mutually-perpendicular LLAS loops allow measurement of the interference capability of all polarizations of the radiated field with the prescribed accuracy, and without rotation of the EUT or changing the orientation of the LLAS loops.

Each of the three LLAS loops shall comply with the validation requirements given in Clause B.4.

Circular LLAS loops with diameters different from the standard diameter of 2 m can be used provided their diameter D is ≤ 4 m and the distance in metres between the EUT and any of the three LLAS loops is at least $0,10 \times D$. Conversion factors for non-standard diameters are given in Clause B.6.

5 Test sites for measurement of radio disturbance field strength for the frequency range of 9 kHz to 30 MHz

5.1 General

An environment shall ensure valid, repeatable measurement results of the disturbance field strength from an EUT. The provisions in this clause are not intended for measurements on EUTs at their place of use (in that case, see, e.g. the in situ measurement procedures in CISPR 16-2-3).

In the frequency range below 30 MHz, a semi-free space environment is required. Such a semi-free-space environment shall be an OATS, an OATS with a weather-protection enclosure, or a SAC.

5.2 Radio-frequency ambient environment of a test site

The test site shall allow disturbances from an EUT to be distinguished from ambient noise. Its suitability in this respect can be determined by measuring the ambient noise levels with the EUT inoperative and ensuring that the ambient noise levels are at least 6 dB below the limits that apply for the measurement being carried out.

It is not necessary to reduce the ambient noise level to 6 dB below the specified limit where the combination of the ambient noise plus the disturbance from the EUT does not exceed the specified limit. Under those conditions, the EUT is considered to comply with the specified limit.

5.3 Measurement distance and test volume

The test site shall be validated at the measurement distances that are used for disturbance measurements in accordance with the methods of CISPR 16-2-3:2016/AMD2:2023. The measurement distance shall be 3 m, 5 m, or 10 m.

NOTE According to CISPR 16-2-3, measurements at 30 m distance are considered in situ measurements.

The test volume is determined by the locations of the transmit antenna used during test site validation, where the site meets the criteria in 5.5.4. The maximum size of the EUT shall not exceed the validated test volume (the maximum volume is also limited by Table 10 of CISPR 16-2-3:2016/AMD1:2019).

5.4 Set-up table and antenna positioner

The shape and construction of the set-up table and the antenna positioner for the receive antenna are not critical in the frequency range below 30 MHz provided that non-conductive material is used. In this case, the influence of the set-up table and antenna positioner shall not be evaluated.

5.5 Validation procedure of test site

5.5.1 General

For an OATS, an OATS with a weather-protection enclosure or a SAC, a single site insertion loss measurement is insufficient to determine possible reflections from ground plane edges, the construction material and the RF-absorbing material comprising the walls and ceiling of the facility. Evaluating H_x , H_y , and H_z antenna orientations (as illustrated in Figure 5) requires 15 separate SIL measurements, i.e. five positions for each of the three orientations of the loop antennas [11].

Loop antennas conforming to the requirements of 4.3 and 4.4 shall be used for these measurements. Distances are measured with respect to the reference points of the antennas. The measurement heights for the transmit antenna and the receive antenna are fixed at 1,3 m from the ground plane to reference points of the loop antennas. Height scanning is not required for either antenna. The reference point of the transmit antenna shall be placed at the required locations in turn: centre and four locations (left, right, front, rear) on the perimeter of the test volume to be validated, in accordance with Figure 6 and Figure 7.

For each measurement made with a spectrum analyzer or a network analyzer, the procedure requires two different measurements of the received voltage V_R . The first reading of V_R is with the two coaxial cables disconnected from the two loop antennas and connected to each other via an adaptor. The second reading of V_R is taken with the coaxial cables reconnected to their respective loop antennas. For both of these measurements, the signal source voltage, V_I , remains unchanged. The first reading of V_R is called V_{DIRECT} and the second is called V_{SITE} .

An acceptable signal to noise ratio shall be maintained; however, a requirement is not specified because the receive level depends on the antennas used, the available transmit power, the noise level of the receiver, and the ambient level. A value of 20 dB is recommended. The achieved values shall be used in the uncertainty budget given in Annex G.

Special care shall be taken to avoid coupling between the receive system and the transmit system. Typically a ground loop is formed if the transmit antenna and receive antenna cables are routed through the chamber shielding using standard bulkhead connectors; see [12]. There are several possible methods to avoid this ground loop. One of them is to operate the signal generator inside and the measuring receiver outside the shielded room. It is also possible to use an isolating transformer in the transmit path. It is recommended to check the dynamic range of the system before use. This check is done by connecting a termination instead of the transmit antenna and recording the receive level. If an active receive antenna is used it should be turned on during a dynamic range test to take the noise of the preamplifier into account.

If the cables have an influence on the measurement result, they shall be equipped with ferrite cores. It is highly recommended that ferrites with a minimum impedance of 50 Ω at 25 MHz are placed on the transmit antenna and receive antenna cables every 20 cm along their entire length within the test volume being validated.

Three different loop antennas orientations shall be measured according to Figure 5. The measurements shall be performed in the frequency range from 9 kHz to 30 MHz, with frequency steps less than or equal to those specified in Table 1.

Figure 6 and Figure 7 illustrate the measurement positions in the test volume. Five positions in the test volume shall be measured. The measurement distance d shall be kept constant.

Table 1 – Maximum frequency step size

Frequency range	Maximum step size
9 kHz to 20 kHz	1 kHz
20 kHz to 150 kHz	5 kHz
150 kHz to 1 MHz	50 kHz
1 MHz to 30 MHz	100 kHz

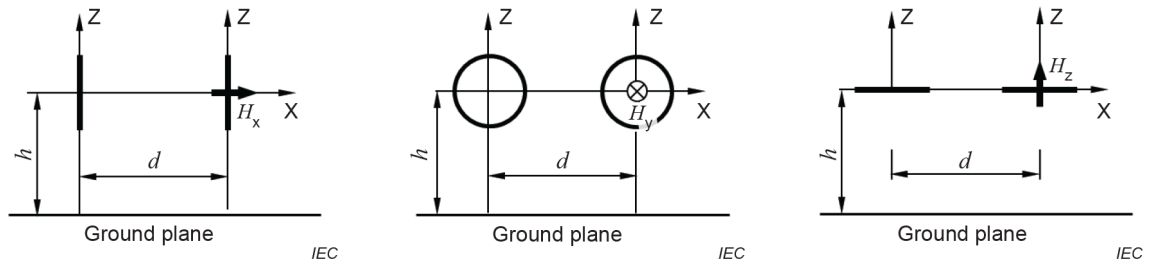
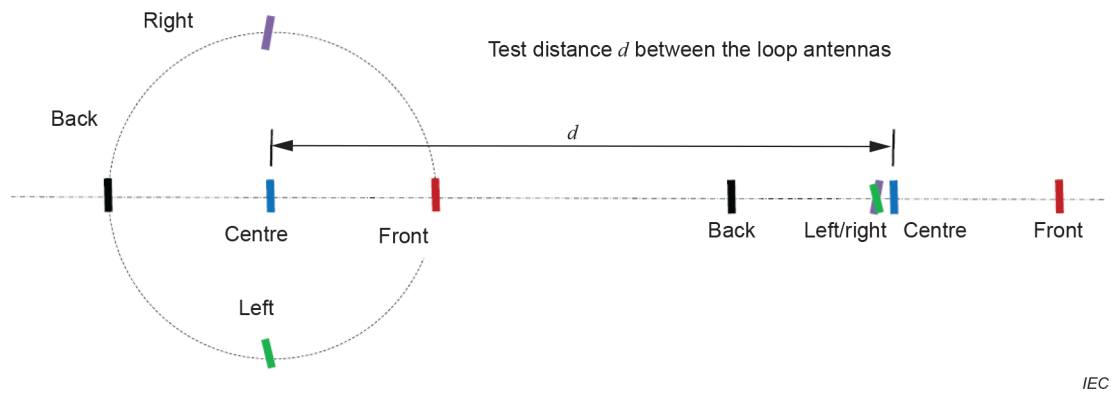
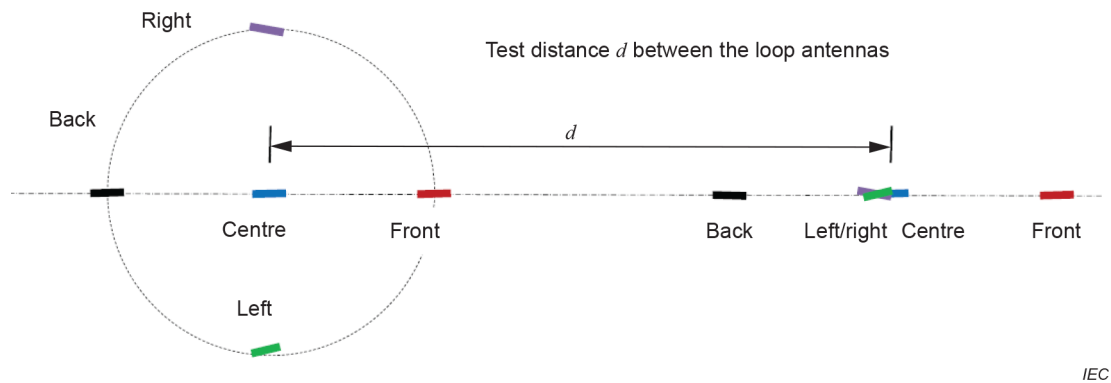
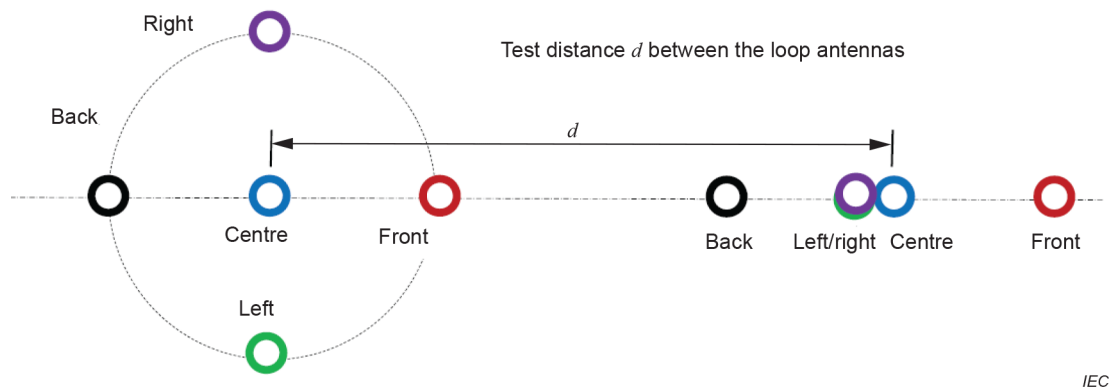
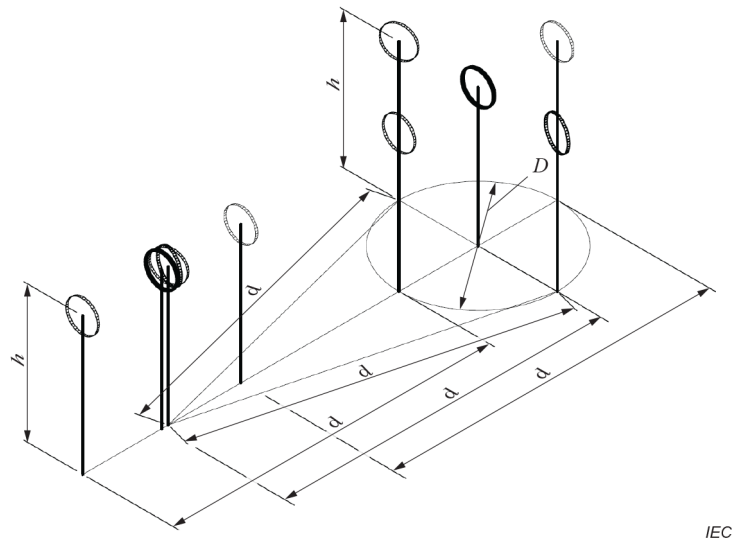


Figure 5 – General arrangement of the three measurement orientations H_x , H_y and H_z , where d is the measurement distance and h is the height of the reference point

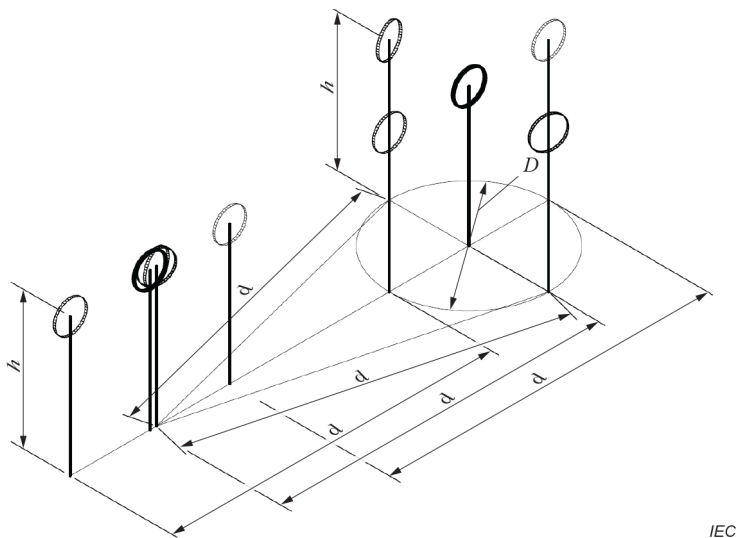
a) H_x validation measurement with loop antennasb) H_y validation measurement with loop antennasc) H_z validation measurement with loop antennas

NOTE The receive loop antenna positions corresponding to the left and right transmit antenna positions, shown with green and magenta colors respectively, are one and the same. However, these are shown with a slight offset in the diagram so that both are visible.

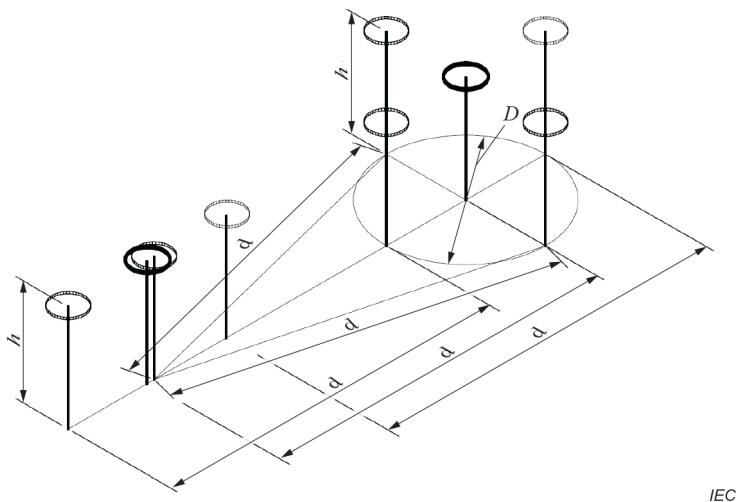
Figure 6 – Antenna positions (top view)



a) H_x validation measurement with loop antennas



b) H_y validation measurement with loop antennas



c) H_z validation measurement with loop antennas

Figure 7 – Antenna positions (3D view)

5.5.2 Normalized site insertion loss (NSIL)

The site insertion loss deviation is calculated using Equation (4):

$$\Delta A_i = V_{\text{DIRECT}} - V_{\text{SITE}} - F_{\text{aH,T}} - F_{\text{aH,R}} - A_{\text{Ni}} \quad (4)$$

where

V_{DIRECT} is the level recorded by the receiver when transmit antenna and receive antenna cables are connected via an adaptor, in dBm or dB(μV);

V_{SITE} is the level recorded by the receiver when transmit antenna and receive antenna cables are connected to the antennas, in dBm or dB(μV); the same unit shall be used as for V_{DIRECT} ;

$F_{\text{aH,T}}$ is the magnetic field antenna factor of the transmit antenna, in dB(S/m);

$F_{\text{aH,R}}$ is the magnetic field antenna factor of the receive antenna, in dB(S/m);

A_{Ni} is the normalized site insertion loss, in dB(m²/S²), calculated in accordance with Annex H;

ΔA_i is the site insertion loss deviation, in dB.

$F_{\text{aH,T}}$ and $F_{\text{aH,R}}$ shall be calibrated according to CISPR 16-1-6 with frequency steps less than or equal to those specified in Table 1.

Due to the required sensitivity at 10 m measurement distance, the use of a transmit power amplifier can be required. To avoid overloading the receiver in the V_{DIRECT} measurement mode, an additional attenuator can be necessary; see Figure 8. If such an attenuator is used in the V_{DIRECT} measurement, but not in the V_{SITE} measurement, a calibrated attenuator shall be used and its attenuation a_{ATT} shall be taken into account in accordance with Equation (5).

$$\Delta A_i = V_{\text{DIRECT}} + a_{\text{ATT}} - V_{\text{SITE}} - F_{\text{aH,T}} - F_{\text{aH,R}} - A_{\text{Ni}} \quad (5)$$

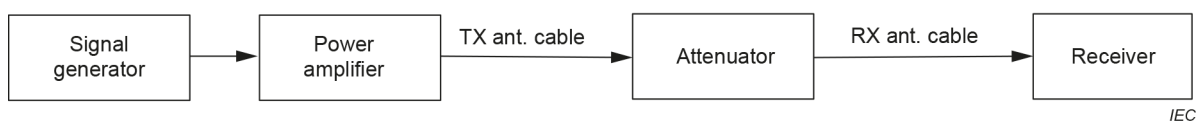


Figure 8 – Test set-up for V_{DIRECT} with power amplifier and attenuator

5.5.3 Reference site method

The site insertion loss deviation is calculated using Equation (6).

$$\Delta A_i = V_{\text{DIRECT}} - V_{\text{SITE}} - A_{\text{LPR}} \quad (6)$$

The antenna pair reference A_{LPR} is calibrated at a REFTS by using Equation (7).

$$A_{LPR} = V_{DIRECT,R} - V_{SITE,R} \quad (7)$$

A REFTS suitable for this purpose shall have a site insertion loss deviation less than 1 dB for a measurement distance of 3 m, and less than 2 dB for the other measurement distances. Compliance to this requirement shall be shown using the NSIL method given in 5.5.2.

5.5.4 Acceptance criterion

The site insertion loss deviation ΔA_i , calculated in accordance with 5.5.2 or 5.5.3, depending on which site validation method was used, shall comply with the applicable criterion specified in Table 2 at all frequencies, for all three antenna orientations, and at all five test positions.

Table 2 – Acceptance criterion

Measurement distance m	Maximum deviation dB
3	±4 dB
5	±4 dB
10	±4 dB ^a
^a Measurements of 10 m SAC sites show that in some cases the criterion of ±4 dB is not fulfilled over the complete frequency range. Therefore, use of such a SAC is accepted, even if it is not compliant with the ±4 dB criterion. In this case, the increased uncertainty shall be taken into account for compliance with the applicable limit. For each frequency, the maximum of $ \Delta A_i $ of all points where the criterion is exceeded shall be taken as δA_i to calculate U_{lab} . U_{lab} is calculated separately for each orientation. See Annex K and CISPR 16-4-2 [10] for further information. More information about measurement at various distances can be found in [11].	

6 Test sites for measurement of radio disturbance field strength for the frequency range of 30 MHz to 1 000 MHz

6.1 General

An environment is required that assures valid and reproducible measurement results of disturbance field strength from an EUT. For an EUT that can only be tested at its place of use, other provisions shall be utilized (i.e. see details on in-situ measurements in CISPR 16-2-3).

In the frequency range 30 MHz to 1 GHz, a semi-free space environment is required. Such a semi-free space environment shall be an OATS, an OATS with a weather-protection enclosure, or a SAC. However, measurements in this frequency range can also be performed in a free-space environment (i.e. in a FAR).

6.2 OATS

6.2.1 General

An OATS is an area characterized by cleared level terrain and with the presence of a conducting ground plane. To meet the validation requirements of this document, a metallic ground plane is recommended. Such a test site shall be free of buildings, electric lines, fences, trees, etc. and free from underground cables, pipelines, etc., except as required to supply and operate the EUT. Refer to Annex C for specific construction recommendations of an OATS for disturbance field-strength measurements in the range of 30 MHz to 1 000 MHz. The site validation procedures for an OATS are given in 6.6 and 6.7. Annex D explains the basis for the acceptability criterion.

6.2.2 Weather-protection enclosure

Weather protection is desirable if the test site is used throughout the year. A weather-protection structure can protect either the entire test site (including EUT and field-strength measuring antenna) or the EUT only. The materials used shall be RF-transparent, to preclude undesirable reflections and attenuation of the emitted field from the EUT (see 6.3.1).

The structure of a weather-protection enclosure shall be shaped to allow easy removal of snow, ice, or water. See Annex C for further details.

6.2.3 Obstruction-free area

For open-area test sites, an obstruction-free area surrounding the EUT and field-strength measuring antenna is required. The obstruction-free area shall be free from significant scatterers of electromagnetic fields, and shall be large enough so that scatterers outside the obstruction-free area will have little effect on the fields measured by the field-strength measuring antenna. To determine the adequacy of an obstruction-free area, site validation tests shall be performed.

Because the magnitude of the field scattered from an object depends on many factors (size of the object, distance from the EUT, orientation with respect to the EUT, conductivity and permittivity of the object, frequency, etc.), it is impractical to specify a reasonable obstruction-free area that is necessary and sufficient for all applications. The size and shape of the obstruction-free area are dependent upon the measurement distance, and whether or not the EUT will be rotated. If the site is equipped with a turntable, the recommended obstruction-free area is an ellipse with the receive antenna and EUT at the two foci, with a major axis equal to twice the measurement distance and a minor axis equal to the product of the measurement distance and $\sqrt{3}$ (see Figure 9).

For this ellipse, the length of the path taken by the undesired indirect ray reflected from any object on the perimeter is twice the length of the path taken by the direct ray between the foci. If a large EUT is installed on the turntable, the obstruction-free area shall be expanded so that the obstruction clearance distances are established relative to the perimeter of the EUT.

If the site is not equipped with a turntable, i.e. the EUT is stationary, the recommended obstruction-free area is a circular area such that the radial distance from the boundary of the EUT to the boundary of the area is greater than or equal to the measurement distance multiplied by 1,5 (see Figure 10). In this case, the antenna is moved around the EUT at the measurement distance.

The terrain within the obstruction-free area shall be flat. Small slopes needed for adequate drainage are acceptable. The flatness of the metallic ground plane, if used, is discussed in Clause C.2. Measuring apparatus and all personnel shall be situated outside the obstruction-free area.

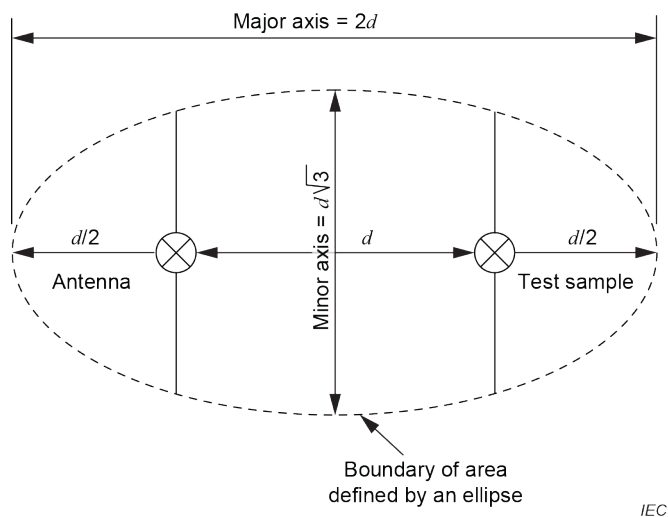


Figure 9 – Obstruction-free area of a test site with a turntable

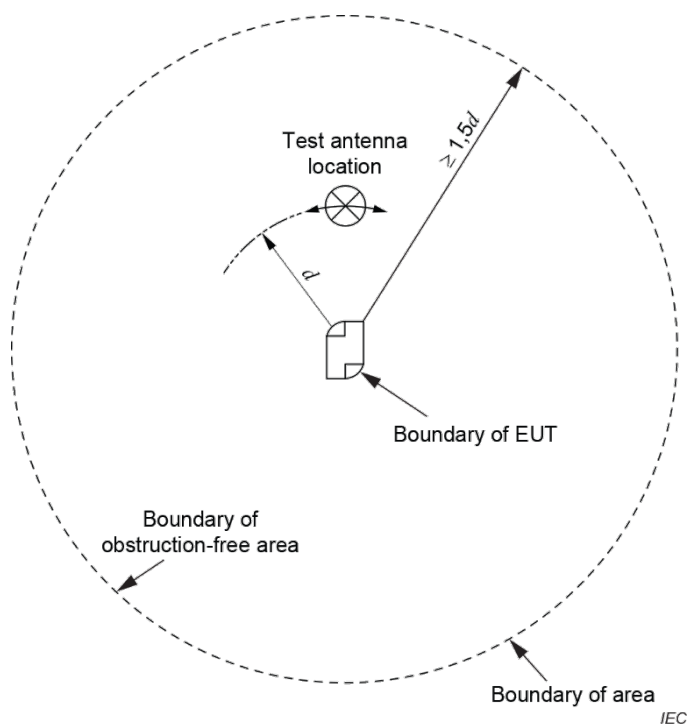


Figure 10 – Obstruction-free area with stationary EUT

6.2.4 Radio-frequency ambient environment of a test site

The radio-frequency ambient levels at an OATS shall be sufficiently low compared to the levels of the disturbance measurements to be performed. The quality of the site for this condition can be evaluated under four categories, listed as follows in order of merit:

- the ambient emissions are 6 dB or more below the measurement levels;
- some ambient emissions are within 6 dB of the measurement levels;
- some ambient emissions are above the measurement levels, but are either aperiodic (i.e. sufficiently long in time between transmissions to allow a measurement to be made) or continuous, but only on limited identifiable frequencies;
- the ambient levels are above the measurement levels over a large portion of the measurement frequency range and occurring continuously.

The selection of a test site should ensure that the accuracy of the measurement is maintained, given the ambient environment and the degree of engineering skill available.

In addition to the RF ambient environment, the receiver intrinsic noise floor contributes to the uncertainty of the results of radiated disturbance measurements. Hence both the RF ambient emissions and the receiver intrinsic noise shall be minimized, to allow a valid comparison of the measured disturbance level with the disturbance limit.

6.2.5 Ground plane

The OATS ground plane can be at earth level, or elevated on a suitably-sized platform or horizontal rooftop site. A metal ground plane is preferred, but for certain equipment and applications, product publications can recommend other site types. Adequacy of the metal ground plane will be dependent on whether the test site meets the site validation requirements of 6.4. If metallic material is not used for the ground plane, caution is required to select a site that does not change its reflective characteristics with time, weather conditions, or effects due to buried metallic material, such as pipes, conduits, and non-homogeneous soil. Such sites generally give different SA characteristics compared to those with metallic surfaces.

6.3 Suitability of other test sites

6.3.1 Other ground-plane test sites

There are many different test sites and facilities that have been constructed and used to make radiated disturbance measurements. Most are protected from the weather and the adverse effects of the RF ambient. For example in a SAC, all walls and the ceiling are equipped with appropriate RF absorbing material, while the floor consists of a metallic ground plane to emulate an OATS. A SAC isolates the receive antenna from the ambient RF environment, and permits EUT testing independent of weather conditions.

Whenever construction material encloses a ground-plane test site, it is possible that the results of a validation measurement at a single location, as specified in 6.7, are not adequate to show acceptability of such an alternative site.

Therefore to evaluate suitability of an alternative ground-plane test site, the procedure of 6.8 shall be used, which is based on making validation measurements at multiple positions throughout a volume occupied by the EUT. For a site to be judged suitable as an equivalent to an OATS, the results of these validation measurements shall all be within a tolerance of ± 4 dB.

NOTE SAC sites typically meet site quality category 6.2.4 a).

6.3.2 Test sites without ground plane (FAR)

A fully-absorber-lined shielded enclosure, also known as a fully-anechoic room (FAR), can be used for radiated disturbance measurements. When a FAR site is used, appropriate radiated disturbance limits shall be defined in relevant standards (generic, product, or product family standards). Compliance of an EUT with the requirements for the protection of radio-services (i.e. limits) shall be evaluated at FAR sites using similar methods as with measurements done at an OATS.

A FAR is intended to simulate a free-space environment, such that only the direct ray from the transmit antenna or EUT reaches the receive antenna. All indirect and reflected ray waves shall be minimized by appropriate placement of RF absorbing material on all walls, ceiling, and floor of a FAR. Like a SAC, a FAR isolates the receive antenna from the RF ambient environment, and permits EUT testing independent of weather conditions.

NOTE FAR sites typically meet site quality category 6.2.4 a).

6.4 Test site validations

6.4.1 General

Three methods for site validation of a COMTS can be used for the purposes of this document:

- NSA method with tuned dipoles;
- NSA method with broadband antennas;
- reference site method (RSM) with broadband antennas.

The NSA method with tuned dipoles is not specifically described, but it can be used for the purposes of this document. Theoretical NSA tables for tuned dipoles, including tables of the theoretical mutual impedance correction factors, are given in [13].

Validations for test sites with a ground plane (i.e. OATS and SAC) are introduced in 6.4.2 and 6.5.1, followed by detailed procedures for the RSM in 6.6 and for the NSA method in 6.7. Validation of a SAC and a weather-protection enclosed OATS requires additional measurements as described in 6.8.

Table 3 summarizes the site validation methods applicable for these specific test site types. As shown in this table, two or three site validation methods are described for each of these test site types. These methods are deemed to be equivalent for the purposes of this document; meaning compliance with the validation criterion can be evaluated using only one method. Furthermore, no one of these documented methods is defined as the reference method.

The site validation methods in this document provide a measure of uniformity of the validated test volume using a comparison between ideal (theoretical) and measured site attenuation between the transmit antenna and the receive antenna. The transmit antenna does not simulate the EUT; therefore, the validation procedure does not define the maximum EUT volume. Considerations on EUT sizes depending on measurement distance are given in CISPR 16-2-3.

Table 3 – Site validation methods applicable for OATS, OATS-based, SAC, and FAR site types

Test site type	Applicability of site validation methods		
	Tuned dipoles NSA	Broadband antennas NSA	Broadband antennas RSM
OATS	Yes	Yes	Yes
OATS with weather protection	No	Yes	Yes
SAC	No	Yes	Yes
FAR	No	Yes	Yes

6.4.2 Overview of test site validations

The validation of a test site is performed using two co-polarized antennas. The validation shall be performed separately for both horizontal and vertical polarizations.

SA is obtained from the difference of:

- the source voltage level, V_i , applied to a transmit antenna;
- the maximum received voltage level, V_R , measured on the terminals of a receive antenna during a specified antenna height scan.

The voltage measurements are performed in a 50 Ω system.

The measured SA of an OATS (as in 6.2) and other ground-plane test sites (as in 6.3.1) is compared to the SA characteristics obtained at an ideal OATS – this is the definition of the measurand for test site validations. The result of this comparison is the SA deviation, ΔA_s , in dB; see Equation (8) (in 6.5.1) and Equation (9) (in 6.6.1). The site is considered suitable when the SA deviation results are within a tolerance of ± 4 dB.

If the ± 4 dB tolerance is exceeded, the test site configuration shall be investigated as described in 6.9.

NOTE The basis for the ± 4 dB site acceptability criterion is given in Annex D.

Additionally, SA deviations shall not be used to correct field-strength measurement data for an EUT. The procedures of 6.4 shall be used only for test site validations.

6.5 Basic parameters of the NSA method for OATS and SAC

6.5.1 General equation and table of theoretical NSA values

NSA values calculated at specific frequencies are provided in Table 4 for broadband antennas. The quantities d , h_1 , h_2 , f_M , and A_N used are identified at the end of Table 4.

NOTE 1 NSA values for frequencies other than shown in Table 4 can be obtained using linear interpolation between the tabulated values.

NOTE 2 The spacing d between LPDA antenna pairs is measured from the projection on the ground plane of the mid-point of the longitudinal axis of each antenna.

NOTE 3 The spacing d between biconical antennas is measured from the element centreline axes at the feedpoint.

For measurements in each polarization, the NSA method requires two different measurements of the received voltage, V_R .

The first reading of V_R (V_{DIRECT}) is taken with the two coaxial cables disconnected from the two antennas and connected to each other via an adaptor. The second reading of V_R (V_{SITE}) is taken with the coaxial cables reconnected to their respective antennas, then the maximum signal is measured when the receive antenna is scanned in height (1 m to 4 m; for 3 m, 5 m, 10 m and 30 m separation distances). For both measurements, the signal source voltage, V_i , is kept constant. The measured results, along with the theoretical NSA (A_N), are used in Equation (8) to obtain the SA deviation results. All terms are in dB.

$$\Delta A_s = V_{\text{DIRECT}} - V_{\text{SITE}} - F_{aT} - F_{aR} - A_N \quad (8)$$

where

ΔA_s is the SA deviation;

F_{aT} is the transmit antenna factor;

F_{aR} is the receive antenna factor;

A_N is the theoretical NSA, according to Table 4;

F_{aT} and F_{aR} shall be calibrated as free-space antenna factors; see 6.5.2.

Note that the first two terms represent the actual measurement of SA, i.e. in the classical view SA is equal to $(V_{\text{DIRECT}} - V_{\text{SITE}})$, which is the insertion loss of the propagation path with the inclusion of the properties of the two antennas used.

To confirm the absence of voltage drift due to temperature changes in measurement devices or cables, re-measure V_{DIRECT} after a suitable time period to confirm stability of the results.

For the respective NSA measurement method used (swept frequency method per 6.7.2, or discrete frequency method per 6.7.1), the validation criterion shall be satisfied at all frequencies in the desired frequency range.

Table 4 lists NSA values for broadband antennas, such as biconical and LPDA, for both horizontal and vertical polarizations relative to the ground plane.

If ΔA_s is greater than ± 4 dB, proceed as described in 6.9.

Table 4 – Theoretical normalized site attenuation, A_N – recommended geometries for broadband antennas ^a

Polariza- tion	Horizontal												Vertical											
	3	3	5	5	5	10	10	10	10	10	30	30	3	3	5	5	5	10	10	10	10	10	30	30
d m	15,8	11,0	20,7	15,6	14,3	29,8	24,1	21,3	19,7	47,8	41,7	8,2	9,3	11,4	12,0	12,7	16,7	16,9	17,4	18,2	26,0	26,0	30	30
h_1 m	13,4	8,8	18,2	13,3	12,2	27,1	21,6	18,9	17,4	45,1	39,1	6,9	8,0	10,1	10,7	11,5	15,4	15,6	16,1	16,9	24,7	24,7	1	1,5
$h_{2,min}$ m	11,3	7,0	16,0	11,4	10,5	24,9	19,4	16,9	15,6	42,8	36,8	5,8	7,0	8,9	9,6	10,4	14,2	14,4	15,0	15,8	23,5	23,5	1	1
$h_{2,max}$ m	9,4	5,5	14,1	9,8	9,1	22,9	17,5	15,2	14,2	40,8	34,7	4,9	6,1	7,9	8,6	9,5	13,2	13,4	14,0	14,9	22,5	22,5	1	1
f_M MHz	7,8	4,2	12,4	8,5	7,9	21,1	15,9	13,7	13,1	38,9	32,9	4,0	5,4	7,1	7,8	8,7	12,3	12,5	13,2	14,1	21,6	21,6	4	4
	A_N dB(m ²)																							
30	15,8	11,0	20,7	15,6	14,3	29,8	24,1	21,3	19,7	47,8	41,7	8,2	9,3	11,4	12,0	12,7	16,7	16,9	17,4	18,2	26,0	26,0	30	30
35	13,4	8,8	18,2	13,3	12,2	27,1	21,6	18,9	17,4	45,1	39,1	6,9	8,0	10,1	10,7	11,5	15,4	15,6	16,1	16,9	24,7	24,7	1	1,5
40	11,3	7,0	16,0	11,4	10,5	24,9	19,4	16,9	15,6	42,8	36,8	5,8	7,0	8,9	9,6	10,4	14,2	14,4	15,0	15,8	23,5	23,5	1	1
45	9,4	5,5	14,1	9,8	9,1	22,9	17,5	15,2	14,2	40,8	34,7	4,9	6,1	7,9	8,6	9,5	13,2	13,4	14,0	14,9	22,5	22,5	1	1
50	7,8	4,2	12,4	8,5	7,9	21,1	15,9	13,7	13,1	38,9	32,9	4,0	5,4	7,1	7,8	8,7	12,3	12,5	13,2	14,1	21,6	21,6	4	4
60	5,0	2,2	9,5	6,3	6,0	18,0	13,1	11,5	11,3	35,8	29,8	2,6	4,1	5,6	6,3	7,4	10,7	11,0	11,7	12,7	20	20	20	20
70	2,8	0,6	7,2	4,6	4,4	15,5	10,9	9,9	9,9	33,1	27,2	1,5	3,2	4,3	5,2	6,4	9,4	9,7	10,5	11,7	18,7	18,7	1	1,5
80	0,9	-0,7	5,3	3,2	3,2	13,3	9,2	8,6	8,7	30,8	24,9	0,6	2,6	3,3	4,3	5,6	8,3	8,6	9,5	10,9	17,5	17,5	1	1,5
90	-0,7	-1,8	3,7	2,0	2,1	11,4	7,8	7,5	7,7	28,8	23,0	-0,1	2,1	2,4	3,5	5,1	7,3	7,6	8,7	10,2	16,5	16,5	1	1,5
100	-2,0	-2,8	2,3	1,0	1,1	9,7	6,7	6,6	6,7	27	21,2	-0,7	1,9	1,6	2,9	4,7	6,4	6,8	8,0	9,6	15,6	15,6	1	1,5
120	-4,2	-4,4	0,1	-0,7	-0,5	7,0	5,0	4,9	5,1	23,9	18,2	-1,5	1,3	0,3	2,1	3,4	4,9	5,4	7,0	8,8	14,0	14,0	1	1,5
140	-6,0	-5,8	-1,7	-2,1	-1,9	4,8	3,5	3,5	3,8	21,2	15,8	-1,8	-1,5	-0,6	1,7	1,0	3,7	4,3	6,2	8,2	12,7	12,7	1	1,5
160	-7,4	-6,7	-3,1	-3,3	-3,1	3,1	2,3	2,4	2,6	19	13,8	-1,7	-3,7	-1,3	1,0	-0,7	2,6	3,4	4,1	5,9	11,5	11,5	1	1,5
180	-8,6	-7,2	-4,3	-4,4	-4,1	1,7	1,2	1,3	1,6	17	12,0	-1,3	-5,3	-1,8	-1,0	-2,2	1,8	2,7	2,8	4,8	10,5	10,5	1	1,5
200	-9,6	-8,4	-5,3	-5,3	-4,7	0,6	0,3	0,4	0,6	15,3	10,6	-3,6	-6,7	-2,0	-2,6	-3,3	1,0	2,1	1,6	1,7	9,6	9,6	1	1,5
250	-11,7	-10,6	-7,5	-6,7	-6,7	-1,6	-1,7	-1,6	-1,2	11,6	7,8	-7,7	-9,1	-3,2	-5,5	-5,6	-0,5	0,3	-0,6	-0,3	7,7	7,7	1	1,5
300	-12,8	-12,3	-9,2	-8,5	-8,4	-3,3	-3,3	-3,0	-2,8	8,8	6,1	-10,5	-10,9	-6,2	-7,5	-7,3	-1,5	-1,9	-2,4	-1,9	6,2	6,2	1	1,5
400	-14,8	-14,9	-11,8	-11,2	-11,0	-5,9	-5,8	-5,6	-5,4	4,6	3,5	-14,0	-12,6	-10,0	-10,5	-10,0	-4,1	-5,0	-5,1	-4,5	3,9	4,3	1	1,5
500	-17,3	-16,7	-13,0	-13,3	-13,0	-7,9	-7,6	-7,6	-7,3	1,8	1,6	-16,4	-15,1	-12,5	-12,6	-11,6	-6,7	-7,2	-7,1	-6,3	2,1	2,8	1	1,5
600	-19,1	-18,3	-14,9	-14,9	-14,5	-9,5	-9,3	-9,2	-8,9	0,0	0,0	-16,3	-16,9	-14,4	-13,5	-13,4	-8,7	-9,0	-8,7	-8,0	0,8	1,8	1	1,5

Polariza- tion		Horizontal												Vertical											
d	m	3	3	5	5	5	10	10	10	10	30	30	3	3	5	5	5	10	10	10	10	30	30		
h_1	m	1	2	1	2	2,5	1	2	3	4	1	2	1	1,5	1	1,5	2,0	1	1,5	2,5	3,5	1	1,5		
$h_{2,\min}$	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
$h_{2,\max}$	m	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4		
f_M	MHz	A_N																							
		dB/(m ²)																							
700		-20,6	-19,7	-16,4	-16,1	-15,9	-10,8	-10,6	-10,5	-10,2	-1,3	-1,4	-18,4	-18,4	-15,9	-15,1	-14,8	-10,2	-10,4	-9,9	-9,3	-0,3	-0,9		
800		-21,3	-20,8	-17,6	-17,3	-17,1	-12,0	-11,8	-11,6	-11,4	-2,5	-2,5	-20,0	-19,3	-17,2	-16,5	-16,0	-11,5	-11,6	-11,1	-10,5	-1,1	-2,3		
900		-22,5	-21,8	-18,7	-18,4	-18,0	-12,8	-12,9	-12,7	-12,4	-3,5	-3,5	-21,3	-20,4	-17,4	-17,6	-16,9	-12,6	-12,7	-12,1	-11,5	-1,7	-3,4		
1 000		-23,5	-22,7	-19,7	-19,3	-19,0	-13,8	-13,8	-13,6	-13,6	-4,4	-4,5	-22,4	-21,4	-18,5	-18,6	-17,9	-13,6	-13,6	-13,1	-12,4	-3,5	-4,3		
These data apply to antennas that have at least 25 cm of ground plane clearance when the centre of the antennas is 1 m above the ground plane in vertical polarization.																									
Values at other frequencies are found via linear interpolation.																									
is the horizontal separation between the projection of the transmit antenna and receive antenna midpoints on the ground plane;																									
is the height of the centre of the transmit antenna above the ground plane;																									
is the range of heights of the centre of the receive antenna above the ground plane. The maximum received signal in this height scan range is used for NSA results;																									
is the frequency;																									
is the NSA.																									