



BSI Standards Publication

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

National foreword

This British Standard is the UK implementation of EN 55016-1-5:2015+A1:2017. It is identical to CISPR 16-1-5:2014, incorporating amendment 1:2016 and corrigendum August 2020. It supersedes BS EN 55016-1-5:2015, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CISPR text carry the number of the CISPR amendment. For example, text altered by CISPR amendment 1 is indicated by **A1** **A1**.

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English Version

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)

Spécification des méthodes et des appareils de mesure des
perturbations radioélectriques et de l'immunité aux
perturbations radioélectriques -
Partie 1-5: Appareils de mesure des perturbations
radioélectriques et de l'immunité aux perturbations
radioélectriques - Emplacements d'étalonnage d'antenne et
emplacements d'essai de référence pour la plage comprise
entre 5 MHz et 18 GHz
(CISPR 16-1-5:2014)

Anforderungen an Geräte und Einrichtungen sowie
Festlegung der Verfahren zur Messung der hochfrequenten
Störaussendung (Funkstörungen) und Störfestigkeit -
Teil 1-5: Geräte und Einrichtungen zur Messung der
hochfrequenten Störaussendung (Funkstörungen) und
Störfestigkeit - Messplätze für die Antennenkalibrierung und
Referenz-Messplätze für den Frequenzbereich
von 5 MHz bis 18 GHz
(CISPR 16-1-5:2014)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

European foreword

The text of document CISPR/A/1086A/FDIS, future edition 2 of CISPR 16-1-5, prepared by CISPR SC A "Radio-interference measurements and statistical methods" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 55016-1-5:2015.

The following dates are fixed:

- latest date by which the document has to be (dop) 2015-10-21
implemented at national level by
publication of an identical national
standard or by endorsement
- latest date by which the national (dow) 2018-01-21
standards conflicting with the
document have to be withdrawn

This document supersedes EN 55016-1-5:2004.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard CISPR 16-1-5:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

CISPR 16-1-1:2010	NOTE	Harmonized as EN 55016-1-1:2010 (not modified).
CISPR 16-1-1:2010/A1:2010	NOTE	Harmonized as EN 55016-1-1:2010/A1:2010 (not modified).
CISPR 16-2-3:2010	NOTE	Harmonized as EN 55016-2-3:2010 (not modified).
CISPR 16-2-3:2010/A1:2010	NOTE	Harmonized as EN 55016-2-3:2010/A1:2010 (not modified).
CISPR 16-4 Series	NOTE	Only Part 4-2 harmonized as EN 55016-4-2.

Foreword to amendment A1

The text of document CISPR/A/1183/FDIS, future CISPR 16-1-5:2014/A1, prepared by CISPR SC A "Radio-interference measurements and statistical methods" of CISPR "International special committee on radio interference" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 55016-1-5:2015/A1:2017.

The following dates are fixed:

- latest date by which the document has to be implemented at (dop) 2017-11-26
national level by publication of an identical national
standard or by endorsement
- latest date by which the national standards conflicting with (dow) 2020-05-26
the document have to be withdrawn

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Endorsement notice

The text of the International Standard CISPR 16-1-5:2014/A1:2016 was approved by CENELEC as a European Standard without any modification.

Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When 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 16-1-4	2010	Specification for radio disturbance	EN 55016-1-4	2010
+A1	2012	and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements	+A1	2012
CISPR 16-1-6	2014	Specification for radio disturbance and	EN 55016-1-6	2015
+ A1	2017	immunity measuring apparatus and methods - Part 1-6: Radio disturbance and immunity measuring apparatus - EMC-antenna calibration	+ A1	2017
IEC 60050	Series	International Electrotechnical Vocabulary	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION
INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

**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**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard CISPR 16-1-5 has been prepared by CISPR subcommittee A: Radio-interference measurements and statistical methods.

This second edition cancels and replaces the first edition published in 2003, and its Amendment 1 (2012). It constitutes a technical revision.

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

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

- site validation methods for other sites covered in CISPR 16-1-6 are added;
- smaller step sizes are specified for swept-frequency measurements;
- the minimum ground plane size is increased;
- other miscellaneous technical and editorial refinements are included.

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

FDIS	Report on voting
CISPR/A/1086A/FDIS	CISPR/A/1097/RVD

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

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

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

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

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

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

The contents of the corrigendum of August 2020 have been included in this copy.

INTRODUCTION

This standard describes validation procedures for Calibration Test Sites (CALTS) that are used to calibrate antennas in the frequency range 5 MHz to 18 GHz. The associated antenna calibration procedures are described in CISPR 16-1-6.

Due to problems with suppressing ground reflections in the frequency range 30 MHz to 200 MHz, the main function of a reflecting ground plane is for the calibration of dipole, biconical, and hybrid antennas over the frequency range for which their H-plane patterns are uniform. The free-space antenna factor, F_a , for dipole antennas may be measured in a free-space environment above 200 MHz. Because of the difficulty of reducing reflections from objects that surround an antenna, and in particular the ground surface, a flat metal ground plane is used to ensure reproducibility of results and to enable the ground reflected signal to be precisely removed mathematically.

Requirements for the construction of a CALTS are given in Annex A. The specifications and validation procedures for a CALTS are given in Clause 4. The most precise way of validating a CALTS is to use calculable dipole antennas, which are the basis of the validation procedure in this standard. The design principles of calculable antennas are given in Annex B, and the theory and methods for calculating site insertion loss (SIL) are given in Annex C and Annex D.

Validation procedures for other antenna calibration sites are given in Clause 5 through Clause 7. Where an antenna calibration method utilizes the ground reflection, a CALTS is required. The validation methods are summarized in Table 1 with reference to the associated antenna calibration methods in CISPR 16-1-6.

All site validation methods involve the measurement of SIL between two antennas. It is critical that the validation of the site itself not be unduly compromised by reflections from antenna supports; see A.3 for associated guidance.

Table 1 – Summary of site validation methods by subclause number

Calibration site(s)	CISPR 16-1-5 validation method(s) Subclause	CISPR 16-1-6:2014 calibration method(s) Subclause	Frequency range MHz	Antenna type(s)	Polarization	Notes
1 CALTS for monopoles	4.10	G.1	5 to 30	Monopole	VP	With tolerance of ± 1 dB
2 CALTS or SAC ^a	4, 7.2	8.4	30 to 1000	Biconical, LPDA, hybrid	HP	SSM
3 CALTS or SAC	4	9.2.2	30 to 300	Biconical, hybrid, dipole	HP or VP	At large height or with absorber on ground
4 FAR	5.3.2	9.2.2	30 to 300 60 to 1000	Biconical, hybrid, dipole Biconical, dipole	HP	
5 REFTS CALTS	4.7 4.9	9.3	30 to 300	Biconical, hybrid	VP	
6 Free space	6.1	9.4.2 9.4.3	200 to 18000	LPDA, hybrid, horn	VP	HP with greater height
7 Free space	6.2	9.4.4	200 to 18000	LPDA, hybrid, horn	VP (or HP)	With absorber on ground
8 FAR	5.3.3	9.5	1000 to 18000	Horn, LPDA	HP or VP	
9 FAR	5.3.2	9.2 and 9.4	140 to 1000	LPDA, hybrid	HP or VP	
10 CALTS	4.6	B.4, B.5	30 to 300	Biconical, dipole	HP	
11 Transfer of properties of a validated site to a site not validated by methods in other clauses	7.1 (excluding 5.3 FAR)	A.9.4	30 and above	Any, but not monopole or loop	HP or VP	Use primarily for SAM and FAR, for particular antenna types and frequencies, except 5.3
^a A CALTS is well specified as being free of reflecting obstacles, and if the antenna supports have negligible reflections the ground plane itself is likely to provide results that agree with the theoretical performance to better than 0,5 dB. However for a Semi Anechoic Chamber (SAC), it is important that the entire allowed acceptance criterion of 1 dB is not taken up by wall reflections, leaving no latitude for other uncertainty components such as reducing reflections from masts and cables.						

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

1 Scope

This part of CISPR 16 specifies the requirements for calibration sites in the frequency range 5 MHz to 18 GHz used to perform antenna calibrations according to CISPR 16-1-6. It also specifies the requirements for reference test sites (REFTS) that are used for the validation of compliance test sites (COMTS) in the frequency range 30 MHz to 1000 MHz according to CISPR 16-1-4.

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

Measurement instrumentation specifications are given in CISPR 16-1-1 [1]¹ and CISPR 16-1-4. Further information and background on uncertainties in general is given in CISPR 16-4 [3], which can also be helpful in establishing uncertainty estimates for the calibration processes of antennas and site validation measurements.

2 Normative references

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

CISPR 16-1-4:2010, *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 16-1-4:2010/AMD 1:2012

[A₁] 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/AMD1:2016 [A₁]

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <<http://www.electropedia.org>>)

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

NOTE Full terms for abbreviations not already given in 3.1 are listed in 3.2.

¹ Numbers in square brackets refer to the bibliography.

3.1.1 Antenna terms

3.1.1.1

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 standard, for antennas for which a balun is intrinsic to the functioning of the antenna, the term "antenna" includes the balun.

3.1.1.2

biconical antenna

symmetric antenna formed by two conical radiating elements having a common axis, and adjacent vertices at which they are fed

Note 1 to entry: For use in the VHF band, biconical antennas are usually made of two conical-shaped wire cages. Often each cage has a cross-bar connecting the centre conductor and one of the peripheral wires to remove a narrowband resonance. Such shorting cross-bars can affect the characteristics of the antenna above 215 MHz. For more details, see also A.4.3 of CISPR 16-1-6:2014.

3.1.1.3

broadband antenna

antenna having acceptable characteristics over a wide range of radio frequencies

3.1.1.4

calculable antenna

dipole-like antenna of which the antenna factor of a single antenna, and the site insertion loss between a pair of antennas, may be calculated using either analytical or numerical (method of moments) techniques based on the dimensions, load impedance and geometrical parameters, and that can be verified by measurement

Note 1 to entry: An example of a calculable antenna is that specified in Annex B. Another example is a simple loop antenna.

Note 2 to entry: Effects of the balun are typically accounted for by *S*-parameters measurements of the balun network, or the balun structure can be modelled.

3.1.1.5

horn antenna

antenna consisting of a waveguide section in which the cross-sectional area increases towards an open end, which is known as the aperture

Note 1 to entry: Rectangular-waveguide pyramidal horn antennas are popular in the microwave frequency range above about 1 GHz. Double-ridged-waveguide horn antennas (DRH; sometimes also referred to as DRG horn, for double-ridged-guide) cover a very wide frequency range. The mainlobe of some DRH antennas splits into several beams at higher frequencies.

3.1.1.6

hybrid antenna

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

Note 1 to entry: The longest element of the LPDA section (see 3.1.1.7) 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 end (i.e. rear) of the boom to minimize parasitic (unintended) RF currents on the outer conductor of the coaxial cable flowing into the measuring receiver.

3.1.1.7

log-periodic dipole array antenna LPDA antenna

antenna comprising an array of linear dipole elements whose dimensions and spacings increase logarithmically with frequency from the tip to the rear end of the antenna

3.1.1.8

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 antenna measured across the gap has zero reactance when the dipole is located in free space

Note 1 to entry: A resonant dipole antenna is also a calculable antenna (see 3.1.1.4). In this standard the term "linear dipole" implies "two straight collinear conductors," in contrast to the biconical dipole, or array of dipoles as in the LPDA antenna.

3.1.1.9

standard antenna STA

antenna for which the AF is calculated or measured precisely

Note 1 to entry: Precision is attainable by a calculable antenna such as specified in 4.3. Alternatively an STA may be an antenna of a type similar to the AUC that has been calibrated to lower uncertainties than required for the AUC, e.g. by the three antenna method.

Note 2 to entry: An STA is used for measurements by the standard antenna method (see 4.3.5, etc. of CISPR 16-1-6:2014). An STA is mechanically robust such that reproducibility of AF to better than $\pm 0,2$ dB is maintained with continuous use of the STA. Balance and cross-polar criteria applicable to the STA are found in 6.3.2 and 6.3.3 of CISPR 16-1-6:2014.

3.1.1.10

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.

3.1.1.11

test antenna

combination of the resonant dipole antenna and the specified balun

Note 1 to entry: The definition is for the purposes of this standard only (see also 3.1.1.8 resonant dipole antenna, and 3.1.1.12 wire antenna). The test antenna is described in 4.3.

3.1.1.12

wire antenna

a specified structure consisting of one or more metallic wires or rods for radiating or receiving electromagnetic waves

Note 1 to entry: A wire antenna does not contain a balun.

Note 2 to entry: In the context of this standard, a wire antenna connected to a balun is called a "test antenna" (see 3.1.1.11).

3.1.1.13

antenna factor

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. 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 in dB relative to 1/m [dB(m⁻¹)]. In radiated emission measurements, if F_a is known, the strength of an incident field, E , can be calculated from a reading, V , of a measuring receiver connected to the antenna as follows:

$$E = V + F_a$$

where E is in dB(μ V/m), V is in dB(μ V) and F_a is in dB(m⁻¹).

3.1.2 Measurement site terms

3.1.2.1 calibration site

any site at which an antenna is calibrated

Note 1 to entry: Calibration sites include a CALTS (see 3.1.2.2) on which the ground reflection is intentionally used, a FAR (see 3.1.2.5), and an open-area calibration site (see Clause 6) at which the antennas are high enough above the ground to reduce the ground reflection. For each of these, any reflections from all directions meet the appropriate site acceptance criteria for antenna calibration.

3.1.2.2 calibration test site CALTS

calibration site with a metallic ground plane and tightly specified site insertion loss in horizontal electric field polarization

Note 1 to entry: A CALTS is used for the measurement of height dependent AF, and to measure free-space AF by the standard site method.

Note 2 to entry: A CALTS can also be validated for: a) vertical polarization using the method of 4.7 (see also 3.1.2.7 definition of REFTS); and b) use for other specific CISPR 16-1-6 calibration methods using the methods of 4.9 and 4.10 (see also Table 1).

3.1.2.3 compliance test site COMTS

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

Note 1 to entry: Requirements for a COMTS, including those for site validation, are specified in CISPR 16-1-4.

3.1.2.4 free space

environment where it has been shown that the effect of any obstacle, including the ground, on the radiated signals passing directly between two antennas is below a specified uncertainty contribution for the measurement of F_a

3.1.2.5 fully-anechoic room FAR

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

Note 1 to entry: A FAR suitable for antenna calibration has a tighter field uniformity specification compared with that for EMC radiated disturbance measurement specified in CISPR 16-1-4. If ambient RF interference prevents the required signal to noise ratio, the FAR should be built inside a shielded enclosure. The site acceptance criteria are given in the FAR validation methods in this standard.

3.1.2.6

ideal open-area test site

ideal OATS

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 calculation of the theoretical normalized site insertion loss for ground plane sites.

Note 2 to entry: For an ideal OATS the absolute value of the reflection coefficient of the ground plane is $r = 1$, and the phase difference of the incoming and reflected EM waves at the ground plane is $\phi = \pi$ radians for horizontal polarization, and zero radians for vertical polarization.

3.1.2.7

reference test site

REFTS

test site with metallic ground plane and tightly specified site insertion loss in horizontal and vertical electric field polarizations

3.1.3 Other terms

3.1.3.1

measuring receiver

signal measuring instrument, such as a stepping receiver, a spectrum analyzer, or the receiving part of a network analyzer, that fulfils the selectivity and linearity requirements of the relevant calibration method

Note 1 to entry: The term measuring receiver may also imply the full functions of a vector network analyzer. In this standard, the term signal means an RF sinusoidal signal with constant amplitude. For the purposes of antenna calibration and site validation, this definition is a modification of that found in CISPR 16-1-1 [1] and CISPR 16-2-3 [2].

3.1.3.2

null

node 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 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 2 to entry: IEC 60050-726:1982, 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.

3.1.3.3

site attenuation

SA

minimum site insertion loss measured between two polarization-matched antennas located above a conducting ground plane on a calibration 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 3.1.3.4) 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.

3.1.3.4 site insertion loss SIL

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

Note 1 to entry: In this standard, the symbol $A_{i\ c}$ signifies the theoretical SIL in dB, and the symbol $A_{i\ m}$ signifies measured SIL in dB.

Note 2 to entry: The symbol A_i uses A as the conventional symbol for attenuation, with the subscript i denoting insertion; for A_i the subscript is not to be confused with usage in this standard of i as an index symbol, e.g. $i = 1, 2, 3$.

Note 3 to entry: The SIL, A_i , in dB is given by the difference between the received voltages, V_{DIRECT} and V_{SITE} , in dB(μV) that are measured with direct connection and with antennas connected, respectively:

$$A_i = V_{\text{DIRECT}} - V_{\text{SITE}}$$

SIL is defined as a loss factor, so that the antenna geometry giving minimum SIL (see also 3.1.3.3 site attenuation) means the maximum signal is being received.

3.2 Abbreviations

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

AF	antenna factor
AUC	antenna under calibration
DRH	double-ridged horn antenna
EM	electromagnetic
EMC	electromagnetic compatibility
EUT	equipment under test
HP	horizontal polarization
MoM	method of moments
NSA	normalized site attenuation
NSIL	normalized site insertion loss
OATS	open-area test site
RF	radio frequency
RSM	reference site method
RSS	root sum square
SAC	semi anechoic chamber
SAM	standard antenna method
SSM	standard site method
TAM	three antenna method
VNA	vector network analyzer

VP vertical polarization

VSWR voltage standing wave ratio

4 Specifications and validation procedures for CALTS and REFTS from 5 MHz to 1 000 MHz

4.1 General

This clause specifies the requirements and a validation procedures for a site suitable for the calibration of antennas above a conducting flat metal plane in the frequency range of 5 MHz to 1 000 MHz. A calibration site meeting these requirements in horizontal polarization is referred to as a CALTS. A CALTS that meets the requirements in vertical polarization may be used as a REFTS. The validation of a CALTS in VP for the calibration of monopole antennas is described in 4.10.

NOTE 1 Although a CALTS and a REFTS are validated by the same methods, a CALTS is used for antenna calibration, whereas a REFTS is used as a reference for validation of a COMTS. Consequently a REFTS may have a less tight acceptance criterion than a CALTS.

NOTE 2 A method for validating a CALTS in VP is given in 4.7.3. The primary validation in HP proves that the ground plane is sufficiently flat and conducting, and this validation applies equally for HP and VP. However in VP there can be larger reflections from antenna supports and cables, therefore validation in VP is needed to support antenna calibrations that use VP.

NOTE 3 For sites at which the SSM is only used to calibrate LPDA antennas, i.e. which are directional, dipole antennas are not essential for site validation. Use of the reference site method (i.e. see CISPR 16-1-4) with a pair of LPDA antennas is suitable. However, a site that is validated by dipoles will be well within the site acceptance criterion required for the SSM performed with pairs comprised of three LPDA antennas.

A method for the validation of a SAC for antenna calibration purposes using the RSM (RSM is described in CISPR 16-1-4) is given in 7.2.

The annexes to this standard contain informative material for a CALTS, and for a calculable dipole to be used in the CALTS validation procedures. They give an analytical model in detail for calculating theoretical site insertion loss (SIL) using resonant dipole (tuned dipole) antennas, together with numerical examples, and a checklist for the validation procedure. The annexes also describe method of moments (MoM) computations of the SIL of a pair of broadband calculable dipole antennas, from which AF can be derived.

NOTE 4 The implementation of Clause 4 is considerably aided by the use of for example the CAP2010 software [24], as described in C.2.

4.2 Antenna calibration test site (CALTS) specification

4.2.1 General

The CALTS comprises the following main components:

- an electrically conducting flat metal plane (the reflecting plane);
- an electromagnetically obstruction-free area surrounding the reflecting plane.

In addition, the following ancillary equipment is needed:

- two antenna masts supporting the antennas;
- the cables to be connected to these antennas; and
- electronic equipment, such as an RF signal generator and a measuring receiver, or a VNA.

The normative specification for a CALTS is given in 4.2.2 (with the associated acceptance criterion in 4.5.3), while Annex A contains a number of informative specifications as guidance

to construct and situate a CALTS in such a way that the acceptance criteria will be met. Annex A also gives details of additional stringent CALTS validation test methods (i.e. A.4).

4.2.2 Normative specification

A CALTS shall comply with the acceptance criterion given in 4.5.3. A subset of the frequency range 30 MHz to 1 000 MHz may be used if the CALTS is only used for antenna calibration in that subset.

Compliance at the 24 frequencies from 30 MHz to 1 000 MHz of Table 3 (see 4.4.3.1), measured by calculable dipoles (see 4.4.4), establishes that the ground plane is of sufficient size, flatness and conductivity, and sufficiently free of reflections from obstacles at those 24 frequencies. Compliance at all other frequencies required for antenna calibration, either by calculable dipoles or by the reference site method (RSM) according to 4.4.5, establishes whether or not abnormalities exist in the electrical characteristics of the CALTS, e.g. reflections from obstacles such as buildings, wires, fences and trees, and also antenna masts and cables.

Where vertical polarization is used for the calibration of antennas or reference SIL measurements, the CALTS shall comply with the acceptance criterion in 4.7.3.5.

NOTE 1 A more stringent test of site validation is given in A.4, in which a null signal is recorded in a search either of antenna height or frequency.

NOTE 2 In the CALTS validation procedure, equipment is used that is also subject to normative specifications, i.e. see 4.3 and 4.4.

NOTE 3 The CALTS validation report (see 4.8) will contain information on how compliance with the requirements is maintained, so that the CALTS is deemed to comply with the requirements during its actual use.

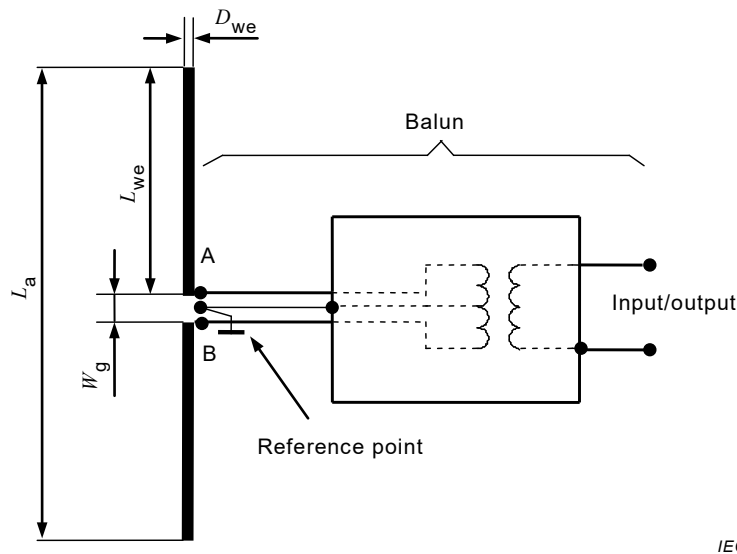
4.3 Test antenna specification

4.3.1 General

Antennas that can be accurately modeled are needed for the (numerical) computation of the theoretical site insertion loss A_{ic} used in the validation procedure. Therefore, the test antenna shall be a dipole connected to a balun with specified properties. The normative test antenna specifications are given in 4.3.2. An example of the construction of a test antenna is given in Annex B.

The test antenna consists of a balun and two collinear wire elements (conductors) each having a diameter D_{we} and length L_{we} . These elements are connected to the two feed terminals (A and B in Figure 1) at the balun. The gap between these feed terminals has a width W_g . The tip-to-tip length L_a of the antenna is given by $L_a = 2L_{we} + W_g$. The centre of the test antenna is in the middle of the feed-terminal gap on the centre-line of the two collinear wire elements.

The balun has an unbalanced input/output (transmit/receive antenna) port and a balanced port at the two feed terminals A and B. As an example, in Figure 1 the purpose of the balun is indicated schematically by the balance/unbalance transformer.



NOTE The centre of the test antenna is in the middle of the gap on the centre-line of the two wire elements.

Figure 1 – Schematic diagram of the test antenna

4.3.2 Details of the required characteristics of the test antenna

In the following list, a quantity ΔX represents the maximum tolerance allowed in the antenna structure with respect to a parameter value X . The quantitative data specifications for these tolerances are summarized in Table 2.

Table 2 – Maximum tolerances for $d = 10$ m

Parameter (X)	Maximum tolerance (ΔX)	Subclause
L_a	$\pm 0,002\ 5\ L_a$ or $\pm 0,001$ (m) if $L_a < 0,400$ (m)	4.3.2 d)
D_{we}	$\pm 0,002\ 5\ D_{we}$	4.3.1
Z_{AB}	VSWR $\leq 1,10$	4.3.2 e) 1)
A_b	$\pm 0,3$ dB ^a	4.3.2 e) 2)
ϕ_b	$\pm 4^\circ$ ^a	4.3.2 e) 3)
d	$\pm 0,04$ m	4.4.2.3
h_t	$\pm 0,01$ m	4.4.2.4
h_r	$\pm 0,01$ m	4.4.2.5
f	$\pm 0,001f$	4.4.3.2
^a The tolerances on A_b and ϕ_b are yet to be verified but may be relaxed when proven by experimentation or modeling to have an effect $< 0,05$ dB on A_i . Alternatively, the uncertainties on A_i may be quantified for higher values of A_b and ϕ_b .		

- The test antenna shall have identical wire elements of length L_{we} which can be disconnected from the balun to enable the balun parameters to be validated, and to allow the balun heads of the two antennas used in site insertion loss measurements to be connected together.
- With λ signifying wavelength, the tip-to-tip length $L_a(f, D_{we})$ of the approximately $\lambda/2$ wire antenna is determined by the condition that, at the specified frequency f and in free space, the absolute value of the imaginary part of the input impedance at the feed terminals is smaller than $1\ \Omega$.

NOTE 1 If the wire elements have a constant diameter and if $D_{we} \ll L_a$, then $L_a(f, D_{we})$ is calculated from Equation (C.3), or using MoM computations (see C.2.3).

NOTE 2 If the diameter is not a constant, e.g. when a telescopic antenna is used, $L_a(f)$ is calculated using MoM (see C.2.3). The telescopic elements are tuned in such a way that the elements having the largest diameter are used first (see Figure 2), and the MoM computations can account for this approach.

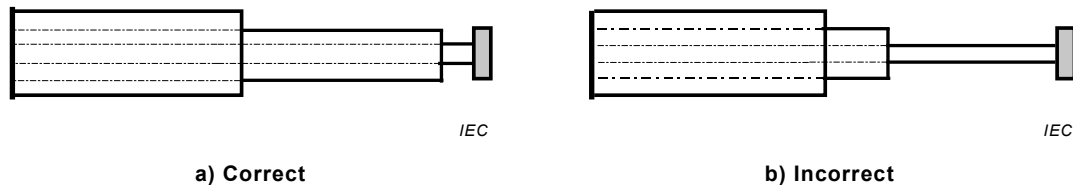


Figure 2 – Adjustment of a telescopic wire element to the length L_{we}

NOTE 3 The analytical formulation of C.1 applies only to SIL for resonant wire elements. The MoM formulation of C.2 agrees to less than 0,1 dB with the analytical calculation of SIL for resonant elements above an ideal ground plane or in free space, but for thin wires the agreement is better than 0,05 dB (see C.1.1). The MoM formulation has been applied to a fixed length wire element over a broad bandwidth [12], [23]. The accuracy of linear elements has been proved (see NOTE 4), but the elements could be of other designs, such as open structure (i.e. non cage) biconical elements, if it can be proven that these give the same or better performance.

- c) The feed-terminal gap shall be small enough that an agreement of less than 0,4 dB is achieved between measured and theoretical SIL between two resonant dipoles of the same length.

NOTE 4 The condition of $SIL < 0,4$ dB has been proved to be met using a gap of $W_g = 9$ mm from 30 MHz to 599 MHz and $W_g = 3$ mm from 600 MHz to 1 GHz.

- d) If the tip-to-tip length $L_a(f)$ of the actual wire antenna is within ΔL_a of the length $L_a(f)$ specified for that antenna (see Table 2), that length is presumed to be validated when the width of the feed-terminal gap complies with item c).
- e) The balanced port of the balun shall have:

- 1) an impedance Z_{AB} with a VSWR less than the maximum tolerance specified in Table 2, when the unbalanced port is terminated in the impedance Z_e (see NOTE 6) presented to it by the external circuitry (the antenna feed cable);
- 2) an amplitude balance with respect to the balun reference point better than ΔA_b dB (see Table 2), when both feed terminals are terminated in an impedance $Z_{AB}/2$ with respect to the balun reference point;
- 3) a phase balance of $(180^\circ \pm \Delta \phi_b)$ (see Table 2), when both feed terminals are terminated in an impedance $Z_{AB}/2$ with respect to the balun reference point.

NOTE 5 Connectors at the balun ports enable RF measurements to be made at the three balun ports. For example, SMA push-on connectors at the wire feed ports can be used.

NOTE 6 The impedance Z_e presented by the external circuitry is usually 50 Ω , and which is the preferred value. Z_{AB} is the impedance at the port on the balun at A and B attaching to the two halves of the dipole element in Figure 1. The preferred value of this impedance is $Z_{AB} = 100 \Omega$ (real), i.e. the addition of 50 Ω for each of the terminals A and B.

NOTE 7 The amplitude and phase balance requirements ensure that the signals at the feed terminals A and B are sufficiently equal in amplitude and opposite in phase with respect to the balun reference point. When the balanced port meets these requirements, the isolation between the two feed terminals will be more than 26 dB when the unbalanced port is terminated in the impedance Z_e .

NOTE 8 As far as practical, the balun components are oriented to present the minimum co-polarized reflecting surface to the wire antenna.

NOTE 9 The components of the balun are electrically shielded, so that their (parasitic) properties cannot be influenced by the surroundings. The balun reference point and the ground terminal of the output/input port are connected to that shield. An example balun is a 3 dB hybrid coupler with anti-phase outputs.

- f) The balun properties required in 4.3.2 e) may be determined from S -parameter measurements and, partly, from insertion loss measurements. Provided the balun properties are incorporated in the A_i calculation, the head-to-head connection of the

baluns in 4.4.4.2.1 and 4.4.4.2.3 (i.e. for insertion loss; see Figure 3) may be replaced by a cable-to-cable connection referenced to the balun inputs, when the full set of balun S -parameters are known.

NOTE 10 The port mismatches presented to the baluns by the generator and the receiver are sufficiently minimized using padding attenuators, where necessary.

NOTE 11 S -parameters and insertion loss measurements are described in B.3.1 and B.3.3, respectively.

- g) In the CALTS validation procedure, if test antennas and/or test equipment is used with Z_{AB} and/or Z_e differing from the preferred values of 100 Ω and 50 Ω , respectively, this should be explicitly mentioned in the validation report (see 4.8).

4.4 Antenna calibration test site validation procedure

4.4.1 General

In the CALTS validation procedure, the measured site insertion loss A_{im} is compared with the theoretically calculated site insertion loss A_{ic} of an ideal OATS (see 3.1.2.6). The procedure thus verifies whether a CALTS sufficiently meets the properties assumed in the SIL calculations.

The properties of ground plane flatness and size, reflection coefficient magnitude, and influence of surroundings constituting an ideal OATS are verified simultaneously in a SIL measurement procedure using fixed antenna heights (see 4.4.4), after which the measured and calculated SIL results are compared.

The properties of ground plane flatness and size, phase difference of incoming and reflected waves, and influence of surroundings constituting an ideal OATS may additionally be verified simultaneously in a scanned frequency or scanned height measurement procedure (see A.4).

In the following subclauses, a quantity $\pm \Delta X$ represents the maximum tolerance allowed in the validation procedure of a parameter value X . The quantitative specifications for the tolerances are summarized in Table 2.

4.4.2 Test set-up

4.4.2.1 The centres of the test antennas, the antenna masts, and the antenna coaxial cables are positioned in a plane perpendicular to the reflecting plane, and centrally located on the reflecting plane.

NOTE 1 The centre of the test antenna is defined in 4.3.1 (see also Figure 1).

4.4.2.2 The collinear wire elements are positioned parallel to the reflecting plane (i.e. horizontal polarization) throughout these tests (i.e. perpendicular to the (vertical) plane mentioned in 4.4.2.1).

At the lower end of the frequency range, e.g. 30 MHz to 40 MHz, the relatively long wire elements can droop, thus influencing the measurement results. This influence may be eliminated by physically propping up the wire elements, or the influence shall be accounted for in the calculation of the theoretical site insertion loss.

4.4.2.3 The horizontal distance between the centres of the test antennas is

$$d = 10,00 \text{ m} \pm \Delta d \text{ m } (\Delta d \text{ per Table 2}).$$

4.4.2.4 The height of the centre of the transmit antenna above the reflecting plane is

$$h_t = 2,00 \text{ m} \pm \Delta h_t \text{ m } (\Delta h_t \text{ per Table 2}).$$

4.4.2.5 The height of the centre of the receive antenna above the reflecting plane shall be adjustable to the heights $h_r \pm \Delta h_r$, as specified in Table 3 (4.4.3.1) and Table 2 (4.3.2).

4.4.2.6 The coaxial cables connected to the baluns of the transmit and receive antennas run perpendicular to the wire elements and parallel to the reflecting plane, over a distance of at least 1 m from the wire elements. After that, the cables may drop vertically down to the reflecting plane and (preferably) continue to run underneath the reflecting plane, or on top of that plane perpendicularly to the wire elements until they reach the edge of the plane. When the cables run partly underneath the reflecting plane, the conductive sheath of the cable should be bonded (360° around) to the reflecting plane at the penetration point through that plane.

Where unbalance is known or suspected, ferrite loading of the coaxial cables connected to the baluns is advised to reduce common mode coupling. A method of quantifying the effect of the cable reflection is given in A.2.3 of CISPR 16-1-6:2014, the outcome of which may be a lesser distance than 5 m or an uncertainty to be added to the antenna calibration results.

NOTE 2 Use of cables with low transfer impedance can minimize influence on the measured results of the induced cable sheet currents through that impedance.

NOTE 3 When the basic test set-up provisions of 4.4.2 are used for testing vertically polarized antennas, e.g. per 4.7, similar cable layout considerations generally apply; see also 4.7.3.3.

4.4.2.7 The RF signal generator and RF measuring receiver shall not be elevated above the level of the reflecting plane if they are within 20 m from the antennas.

4.4.2.8 The RF signal generator shall have good frequency and output level stability throughout the duration of the site insertion loss measurements; see also 4.4.4.2.3.2.

A warm-up time (normally indicated by the equipment manufacturer, e.g. one hour) of the RF signal generator and RF measuring receiver may be included in the measuring procedure, for a sufficient long-term stability of the equipment.

4.4.2.9 The RF measuring receiver shall have its linearity calibrated over a dynamic range of at least 50 dB; see also 4.4.4.2.1.3. The associated uncertainty of the measuring receiver linearity is denoted as ΔA_r (i.e. used in 4.5.2.2); a reasonable value for the measuring receiver linearity uncertainty is 0,2 dB.

If the linear dynamic range is less than 50 dB then a substitution method may be followed, using a calibrated precision attenuator as described in 4.4.4.3.2.

4.4.3 Test frequencies and receive antenna heights

4.4.3.1 Further to the normative specification of 4.2.2, the site validation measurements described in 4.4.4 shall be carried out at a minimum of the 24 frequencies cited in CISPR 16-1-4 over the range 30 MHz to 1 000 MHz, i.e. listed in Table 3, using the fixed heights of the centre of the receive antenna h_r (m) above the reflecting plane as also listed in Table 3. For the calibration of antennas using the methods of CISPR 16-1-6, site validation measurements shall also be carried out using the swept-frequency measurements described in 4.4.5.

Table 3 – Frequency and fixed receive antenna height data for SIL measurements at 24 frequencies, with $h_t = 2$ m and $d = 10$ m (specified in 4.4.2.3 and 4.4.2.4)

Frequency MHz	h_r m	Frequency MHz	h_r m	Frequency MHz	h_r m
30	4,00	90	4,00	300	1,50
35	4,00	100	4,00	400	1,20
40	4,00	120	4,00	500	2,30
45	4,00	140	2,00	600	2,00
50	4,00	160	2,00	700	1,70
60	4,00	180	2,00	800	1,50
70	4,00	200	2,00	900	1,30
80	4,00	250	1,50	1 000	1,20

4.4.3.2 The frequency of the RF signal generator providing the signal for the transmit antenna shall be adjusted to within Δf (see Table 2), of a test frequency specified in Table 3 or in A.4.

4.4.3.3 If narrow-band noise, such as that originating from broadcast transmitters, impedes accurate measurement at a frequency specified in 4.4.3.1 and A.4, a usable test frequency as close as possible to that specified frequency shall be chosen.

The rationale for a deviation from a specified frequency shall be recorded in the validation report (see 4.8).

4.4.4 SIL measurements

4.4.4.1 General

Subclause 4.4.4 describes the three measurements, designated as Measurement 1, Measurement 2, and Measurement 3, needed to determine the measured SIL, A_{im} (see 4.4.3.1 for acceptance criteria), at the specified frequencies. The SIL being considered is between the feed terminals of the transmit antenna (A and B in Figure 3 and Figure 4) and the terminals of the receive antenna (C and D in Figure 3 and Figure 4).

Where a full set of balun S -parameters is available (as described in 4.3.2 f), they should be incorporated in the computation of the theoretical SIL (see C.2.4); this approach enables lower uncertainties to be obtained. In this case, the measured SIL is derived using a cable connection between the two cable/balun interfaces (schematic shown in Figure 3).

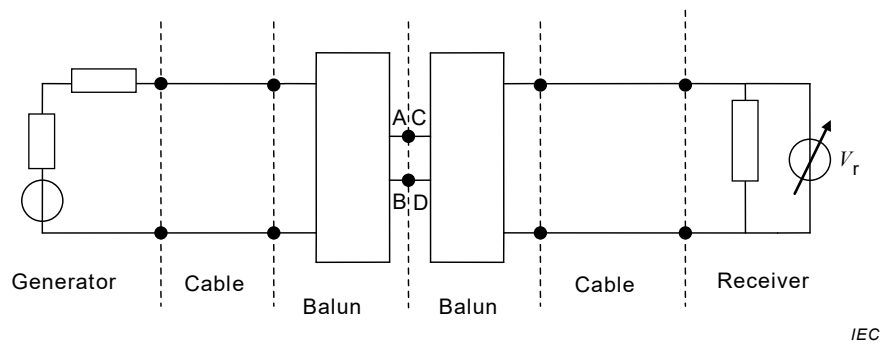


Figure 3 – Determination of $V_{r1}(f)$ or $V_{r2}(f)$

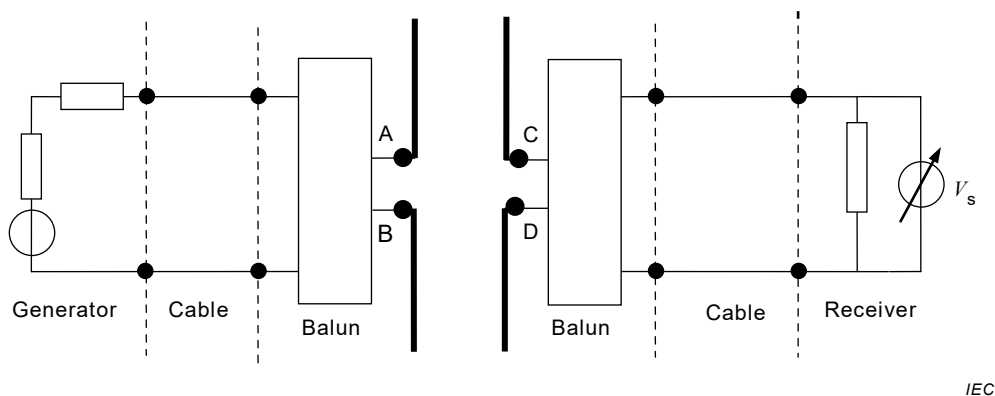


Figure 4 – Determination of $V_s(f)$ with the wire antennas in their specified positions

4.4.4.2 Measurements 1, 2, 3 for determining SIL

4.4.4.2.1 Measurement 1

4.4.4.2.1.1 At a specified frequency f , the reference voltage $V_{r1}(f)$ is determined.

This voltage is used to account for the attenuation of the signal between the RF signal generator output port and the feed terminals of the transmit wire antenna and, similarly, between the feed terminals of the receive wire antenna and the receiver input port.

4.4.4.2.1.2 $V_{r1}(f)$ is determined as follows.

The wire elements of the test antennas are disconnected from their balun, and the two baluns are connected head-to-head with a short connection whose insertion loss shall be accounted for – see Figure 3.

4.4.4.2.1.3 The level of the RF signal generator is set to give a receiver reading at least 60 dB above the noise level of the receiver. The receiver reading is recorded as $V_{r1}(f)$. All readings are in decibels.

The noise level of the receiver may be reduced by reducing the receiver bandwidth. However, if the RF signal generator and RF measuring receiver are not frequency-locked, as in the case of a tracking generator and spectrum analyzer, the receiver bandwidth should be sufficiently wide that a possible drift of the frequency of the RF signal generator signal does not influence the measurement results.

NOTE A signal in Measurement 1 of at least 34 dB above receiver noise yields an acceptable uncertainty; see also 6.2.3 of CISPR 16-1-6:2014. In Table C.1 the SIL at 1 000 MHz is 42,71 dB, so the attenuation including cables and attenuators is likely to be at least 60 dB; if this signal is less than 34 dB above receiver noise, the antenna separation can be reduced to a minimum of 22 and/or the uncertainty due to noise can be increased.

4.4.4.2.1.4 If the S -parameter method indicated in 4.4.4.1 is followed, the complete test antennas are disconnected, and the two antenna cables are interconnected, when determining $V_{r1}(f)$ and $V_{r2}(f)$ in 4.4.4.2.3.

4.4.4.2.1.5 The amplitude setting of the RF signal generator used in 4.4.4.2.1 at a particular frequency remains unchanged throughout the measurements associated with 4.4.4.2.2 and 4.4.4.2.3.

4.4.4.2.2 Measurement 2

The baluns are disconnected from each other, and the wire elements are connected to their baluns (see Figure 4). The elements of the specified length $L_a(f)$ are selected. The test antennas are brought into position, as specified in 4.4.2 and 4.4.3. All other conditions in the test set-up are the same as in 4.4.4.2.1.

NOTE Fixed length elements of constant diameter are preferred. Telescopic elements have varying diameter and will lead to larger uncertainties in the calculation of A_i [see 4.3.2 b) NOTE 2].

At the specified test frequency f , and with the antennas in their specified position, the receiver reading is recorded as $V_s(f)$. Care should be taken to assure that the emitted field does not exceed levels permitted by local regulatory jurisdictions.

4.4.4.2.3 Measurement 3

4.4.4.2.3.1 For Measurement 3, the reference voltage measurement per 4.4.4.2.1 is repeated at the same specified test frequency; the result is recorded as $V_{r2}(f)$.

4.4.4.2.3.2 If $V_{r1}(f)$ and $V_{r2}(f)$ differ by more than 0,2 dB, the stability of the test set-up shall be improved and the preceding Measurements 1, 2 and 3 shall be repeated.

4.4.4.2.3.3 A cause of instability can also be the temperature dependence of the coaxial cable attenuation, especially under direct sunlight exposure. The minimum time between the measurements of $V_{r1}(f)$ and $V_s(f)$, and of $V_{r2}(f)$, shall be used.

4.4.4.3 Determining SIL results

4.4.4.3.1 From the results of Measurements 1, 2, and 3, the measured SIL, $A_{im}(f)$, is given by the Equation (1).

$$A_{im}(f) = V_{ra}(f) - V_s(f) \quad (\text{dB}) \quad (1)$$

where $V_{ra}(f)$ is the average of $V_{r1}(f)$ and $V_{r2}(f)$.

4.4.4.3.2 Where the dynamic range of the RF measuring receiver does not comply with 4.4.2.9, the following substitution method may be used, provided that the full set of balun S -parameters is available, and the balun properties are incorporated in the calculation of the theoretical SIL.

- Determine and record the receiver reading $V_s(f)$, as described in 4.4.4.2.2 (Measurement 2).
- Replace the test antennas by a calibrated precision attenuator, and connect both antenna cables to this attenuator. Adjust the insertion loss caused by the attenuator to a level $A_{im1}(f)$ such that the same receiver reading $V_s(f)$ as determined under step a) is found. Record $A_{im1}(f)$ and its associated measurement uncertainty $\Delta A_{im1}(f)$.
- To demonstrate the stability of the test set-up (as mentioned in 4.4.2.8), repeat step b) to determine $A_{im2}(f)$ after a period of time approximating the total time between the reading of $V_s(f)$ in step a) and $A_{im1}(f)$ in step b). If $A_{im2}(f)$ differs by more than 0,2 dB from $A_{im1}(f)$, the stability of the test set-up shall be improved, and steps a), b) and c) repeated.
- If the test set-up is sufficiently stable, the measured site insertion loss $A_{im}(f)$ is given by

$$A_{im}(f) = A_{im,a}(f) \quad (\text{dB}) \quad (2)$$

where $A_{im,a}(f)$ is the average value of $A_{im1}(f)$ and $A_{im2}(f)$.

4.4.4.3.3 If no provisions have been taken to avoid droop of the wire elements of both test antennas, the site insertion loss A_{im} shall be corrected (see 4.4.2.2).

4.4.5 Swept frequency SIL measurements

4.4.5.1 General

Validation of a calibration site on which antennas will be calibrated at smaller frequency intervals than listed in Table 3 (e.g. swept frequency) shall be performed by swept-frequency measurements using a pair of calculable dipole antennas. Table A.1 gives an example of four dipoles used to cover 30 MHz to 1 000 MHz. The maximum frequency intervals shall be as shown in Table 4. Alternatively the validation may be performed by the RSM of CISPR 16-1-4, for which the reference site shall have a $T_{SIL}(f) < 0,7$ dB for use in Equation (5) (see 4.5.3), when measured according to the procedure used with Table 3. Swept-frequency validations can better reveal reflections from structures such as antenna supports and cables, and any nearby scatterers, such as buildings.

Table 4 – RSM frequency steps

Frequency range MHz	Maximum step size MHz
30 to 100	1
100 to 500	5
500 to 1 000	10

For swept-frequency SIL measurements, the SIL between two calculable dipole antennas is measured using a separation distance of 10 m. The antennas are horizontally polarized and placed at heights given in Table 5. The terms Antenna 1 and Antenna 2 in the column headings signify a pair of near-identical antenna elements suitable for the frequency range given in each row of Table 5. As the frequency is swept, the relative phase of the direct signal between the antennas and the ground reflected signal changes, leading to signal nulls (defined in 3.1.3.2). The accuracy of a site validation result is reduced in a null, but there is sufficient accuracy down to a level of 10 dB below the received signal maximum that is closest in frequency to the frequency of the null. An example plot of normalized SIL (NSIL) is shown in Figure 5 [based on the equation for the field strength parameter $e_0(i,j|H)$ in 7.4.1.2.1 of CISPR 16-1-6:2014], with both horizontally polarized Hertzian dipoles at a height of 2 m.

NOTE Normalized site insertion loss (NSIL) is SIL minus the AFs of the two antennas.

The frequency ranges in Table 5 are based on the set of four dipoles listed in Table A.1. For other dipole designs with different subdivisions of 30 MHz to 1 000 MHz, other heights may be optimal, i.e. with signal levels at the ends of the band close to the level of the maximum. For this reason, in Table 5 the 600 MHz to 1 000 MHz range is shown also subdivided into two ranges, rows 5, 6, as an alternative to the single range of row 4. Using a lowest height of 1 m is avoided in an attempt to move further away from the base of the mast where there is a lot more material; it is preferable to not have a motor at the base of the mast. The NSIL for rows 1, 2, 3, 5, and 6 of Table 5 is plotted in Figure 6, demonstrating avoidance of nulls.