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INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

AMENDMENT 1
AMENDEMENT 1

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

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 – Matériels auxiliaires – Perturbations rayonnées

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FOREWORD

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

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

FDIS	Report on voting
CISPR/A/750/FDIS	CISPR/A/760/RVD

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

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

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- withdrawn,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

INTRODUCTION

In this amendment, the use of a balanced dipole antenna (the CISPR tuned dipole) as a physical reference for radiated emission measurements in the frequency range between 30 MHz and 300 MHz is deleted. It is replaced by the requirement that in this frequency range the quantity to be measured is the electric field strength that can be determined using different types of antennas, provided that the antenna factor and the associated uncertainty are known.

This fundamental change of measurand in the frequency range between 30 MHz and 300 MHz was subject to thorough investigations and discussion within CISPR A, and brings it into line with the measurand that already applies in the rest of the frequency range 9 kHz to 1 GHz, and indeed above 1 GHz. The decision for this change has been supported by the results of a questionnaire. More details on the rationale for the decision to introduce the 'electric field' measurand instead of the CISPR reference dipoles can be found in the CISPR Maintenance Cycle Report CISPR/A/541/MCR.

CISPR/A/541/MCR explains that the need for a CISPR reference dipole no longer exists, due to improvements in the calibration of antennas used for EMC compliance testing and the increased implementation of quality systems in test and calibration laboratories in accordance with ISO 17025. Moreover, Clause 4 of CISPR 16-1-4 covers the frequency range 9 kHz to 1 GHz, yet a reference antenna is only specified in the range 30 MHz to 300 MHz, which seems to make this frequency range an exception to the general rule.

In other words, most measurements of physical quantities are made with an instrument that is traceable to national standards. There is no need for measurement of electric field strength in the frequency range 30 MHz to 300 MHz to deviate from this, especially when application of such a physical reference antenna may give a greater uncertainty to the intended measurand than a regular calibrated broadband antenna. Moreover, these days, the CISPR reference dipole is rarely used in practice because it is impractical from a operational point of view (time consuming). The new measurand is the field strength as defined by the limit level in dBµV/m and as required by the method of measurement. If various operators follow the same measurement method, involving calibrated antennas, a high degree of reproducibility is ensured.

A consequence of using the tuned dipole antenna as a reference is that the antenna uncertainties in CISPR 16-4-2 require the field strength measured by a broadband antenna to be referred to the field strength that would have been measured had a tuned dipole been used. The ramifications would be dependent on the difference in radiation patterns and mutual coupling of a dipole compared to a broadband antenna (including height dependence of antenna factor). This practice can actually result in larger EMC measurement uncertainties than if the field strength were derived from the traceably calibrated broadband antenna. The relating of the behaviour of the commonly used broadband antenna to the extremely rarely used tuned dipole in the notes to the uncertainty budget in CISPR 16-4-2, requires specialist knowledge to understand.

Page 3

CONTENTS

Add, on page 5, to the list of tables the titles of the new figures as follows:

Page 15

3 Terms and definitions

3.5
antenna

Replace the existing Note 2 by the following new note:

NOTE 2 This term covers various devices such as the wire antenna, free-space-resonant dipole and hybrid antenna.

3.8
site attenuation

Replace, on page 17, the existing text with the following:

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

3.9
test antenna

Delete the existing definition 3.9, and replace it with the following new definition of site insertion loss:

3.9
site insertion loss
the loss between a pair of antennas placed at specified positions on a test site, when a direct electrical connection between the generator output and receiver input is replaced by transmitting and receiving antennas placed at the specified positions

3.12
quasi-free space test-site

Replace the existing wording of this definition with the following:

facility for radiated emission measurements, or antenna calibration, that is intended to achieve free-space conditions. Unwanted reflections from the surroundings are kept to a minimum in order to satisfy the site acceptance criterion applicable to the radiated emission measurement or antenna calibration procedure being considered

Add, after definition 3.13, the following new definitions:

3.14
cross-polar response
measure of the rejection by the antenna of the cross-polarised field, when the antenna is rotated in a uniform electromagnetic field

3.15
hybrid antenna
conventional wire-element log-periodic dipole array (LPDA) antenna with boom lengthened at the open-circuit end to add one broadband dipole (e.g., biconical or bow-tie), such that the infinite balun (boom) of the LPDA serves as a voltage source for the broadband dipole. Typically a common-mode choke is used at this end of the boom to minimize parasitic (unintended) RF currents on the outer conductor of the coaxial cable flowing into the receiver

3.16
low uncertainty antenna
good quality robust biconical or LPDA antenna, whose antenna factor is reproducible to better than ±0,5 dB, used for the measurement of E-field strength at a defined point in space

NOTE It is further described in A.2.2.

3.17
semi-anechoic chamber
SAC

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

3.18
common mode absorption device
CMAD
a device that may be applied on cables leaving the test volume in radiated emission measurements to reduce the compliance uncertainty

3.19
insertion loss
the 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. It is equal to the inverse of the transmission *S*-parameter, $|1/S_{21}|$

3.20
reflection coefficient
the ratio of a common quantity to both the reflected and incident travelling waves. 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}

3.21
short-open-load-through (SOLT) or through-open-short-match (TOSM) calibration method
calibration method for a vector network analyser using three known impedance standards – short, open, and match/load, and a single transmission standard – through. 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, which requires twelve reference measurements to perform the calibration

3.22
scattering parameters (S-parameters)
a set of four parameters used to describe the properties of a two-port network inserted into a transmission line

3.23
through-reflect-line (TRL) calibration
calibration method for a vector network analyser using three known impedance standards "Through", "Reflect" and "Line" for the internal or external calibration of the VNA. Four reference measurements are needed for this calibration

3.24
vector network analyser
VNA
a network analyser capable of measuring complex values of the four *S*-parameters S_{11}, S_{12}, S_{21}, S_{22}

Page 17

4 Antennas for measurement of radiated radio disturbance

Add the following sentence to the beginning of the first paragraph

Antennas of the type that are used for radiated emissions measurements, having been calibrated, shall be used to measure the field strength, taking into account their radiation patterns and mutual coupling with their surroundings.

In the second paragraph, replace the first sentence "The antenna shall be substantially plane polarised." *by* "The antenna shall be linearly polarised."

In the third sentence of the second paragraph, after "above ground" *add* "or above the absorber in a FAR".

4.1 Accuracy of field-strength measurements

Replace the existing title with the following new title.

4.1 Physical parameter for radiated emissions measurements

Add the following paragraph to the beginning of the subclause:

The physical parameter for radiated emission measurements made against an emission limit expressed in volts per metre is E-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.

4.2.1 Magnetic antenna

Delete the last sentence of the first paragraph of the Note, i.e.: "This assumption is justified.... H level in dB(μA/m)."

Delete also the second paragraph of the Note: "It should be clearly understood that the above fixed E and H ratio applies only under far-field conditions".

4.2.2 Balance of antenna

Replace the existing title and text of this subclause with the following:

4.2.2 Shielding of loop antenna

Inadequate shielding of a loop antenna can result in E-field response. The E-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 E-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.

4.3.1 Electric antenna

Delete, in the second paragraph, the words "1 m length" *and add the following sentence:* "Annex B states that the antenna factor derived by the Equivalent Capacitor Substitution Method (ECSM) has greater uncertainties for monopole lengths greater than one-eighth of a wavelength".

Delete the third paragraph i.e. "Where the distance.....10% of the distance".

4.3.3 Balance of antenna

Replace the existing title with the following new title.

4.3.3 Cross-polar response of antenna

Modify the text as follows:

If a balanced electric field antenna is used, it shall comply with the requirement of 4.4.3. If a balanced magnetic field antenna is used, it shall comply with the requirement of 4.2.2."

4.4 Frequency range 30 MHz to 300 MHz

Replace the existing title with the following new title.

4.4 Frequency range 30 MHz to 1 000 MHz

After the title of 4.4, add the following text:

In this frequency range the measurements are of the electric field, so magnetic field antennas are not included. The antenna shall be a dipole-like antenna designed to measure the electric field. This includes tuned dipole antennas, whose element pairs are either straight rods or conical in shape, and dipole arrays such as the log-periodic dipole array (LPDA) antenna, comprising a series of staggered sets of straight rod elements, and hybrid antennas.

4.4.1 Electric antenna

Delete the entire subclause, including 4.4.1, 4.4.1.1, 4.4.1.2 and 4.4.1.3:

Add a new subclause 4.4.1 as follows:

4.4.1 Low-uncertainty antenna for use if there is an alleged non-compliance to the E-field limit

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

NOTE 1 Improved uncertainties are achieved by using the biconical antenna over the frequency range 30 MHz to 250 MHz and the 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 and must be included in the reported radiated emissions measurement uncertainty budget.

NOTE 2 The measurement uncertainty of radiated emissions from an EUT depends on many different influence factors such as the quality of the site, antenna factor uncertainty, antenna type, and the measurement 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 a comparison of the readings of the two antennas at the selected change-over frequency, which should give the same value of E-field strength within a margin of ± 1 dB.

Add the following new subclause 4.4.2:

4.4.2 Antenna characteristics

Since, at the frequencies in the range 300 MHz to 1 000 MHz, the sensitivity of the simple dipole antenna is low, a more complex antenna may be used. Such antenna shall be as follows.

a) The antenna shall be linearly polarized, which shall be evaluated by applying the cross-polarization test procedure of 4.4.4.

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 4.4.3. This also applies to hybrid antennas below 200 MHz.

c) A test site with a conducting ground plane is assumed. 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 mainlobe 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 emission: the ensuing uncertainty tolerance is based on the beamwidth, 2φ, see Figure 20.

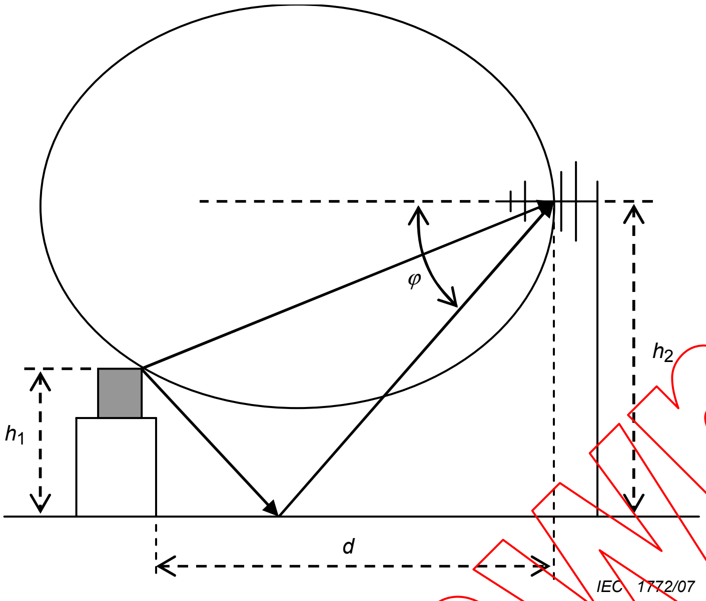

Figure 20 – Schematic of radiation from EUT reaching an LPDA antenna directly and via ground reflections on a 3 m site, showing the half beamwidth, *φ*, at the reflected ray

Conditions for ensuring that this error is no larger than +1dB are given below in 1) for a 10 m site and 2) for a 3 m site. Alternatively a condition based on antenna gain is given in 3) in order to bypass the laborious radiation pattern conditions.

Emission measurements are performed with the antenna horizontally and vertically polarised. If it is chosen to measure the radiation patterns in only one plane, the narrower patterns shall be used, as follows: the pattern of the antenna shall be verified in the horizontal plane while orienting it for horizontal polarisation.

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 emission 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:

$$\varphi > \tan^{-1}[(h_1 + h_2)/d]$$

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:

$$2\varphi > \tan^{-1}[(h_1 + h_2)/d] - \tan^{-1}[(h_1 - h_2)/d]$$

where:

h_1 is the height of the equipment under test;

h_2 is the measurement antenna height;

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

If antenna down tilting that would reduce the associated uncertainties is not employed, the reduction in received signal shall be calculated, see Note, from the radiation patterns and applied as corrections or as directivity uncertainties. Example uncertainties budgets are given in CISPR 16-4-2.

NOTE 1 Assuming an E-field radiation pattern normalised to unity on boresight (= peak of mainlobe) read the E-field at the angles of declination from the antenna for the direct, E_D, and reflected rays, E_R. The error, compared to an E-field of unity magnitude for each of the direct and reflected rays, is given in decibels by: 20log (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 polarisation, the uncertainty in emitted signal strength can be reduced accordingly.

3) For broad beamwidth antenna types used for radiated emission testing, such as biconical, LPDA and hybrid antennas, the beamwidth is inversely related to antenna directivity. An alternative to the criterion based on beamwidths in 1) and 2) above, is to specify the maximum gain of an antenna and to refer to generic uncertainty tolerances for the directivity component in the uncertainty budget for an emission test. The generic uncertainties, based on the narrowest beamwidths in the frequency range used for a given antenna, are given in CISPR 16-4-2. The maximum isotropic antenna gain for biconical antennas shall be 2 dB, and shall be 8 dB for log-periodic dipole array (LPDA) and hybrid antennas. For V-type LPDA antennas, whose H-plane beamwidth is equalised to the E-plane beamwidth, the maximum permissible isotropic gain shall be 9 dB.

NOTE 3 The directivity uncertainties given in CISPR 16-4-2 (2004) can be used for a 10 m separation, but revised uncertainties are needed for a 3 m separation.

d) The return loss of the antenna with the antenna feeder connected shall not be less than 10 dB. A matching attenuator may be part of the feeder cable for antennas if needed to meet this requirement.

e) A calibration factor shall be given making it possible to fulfil the requirements of 4.1.

Renumber existing subclause 4.4.2 as subclause 4.4.3 and all of its subclauses accordingly.

4.4.2.1 Introduction *(renumbered* **4.4.3.1***))*

Delete the third paragraph: "This subclause considers the balun contribution. Contribution a) is under consideration (see last sentence of Note 1 of 4.4.2.2)."

Renumber existing subclause 4.4.3 as subclause 4.4.4.

In the title of the renumbered subclause 4.4.4, replace the word "**performance**" *with the word* **"response"**

Delete existing subclause 4.5.

Renumber existing subclause 4.6 as subclause 4.5.

4.6 Frequency range 1 GHz to 18 GHz *(renumbered* **4.5***)*

Replace the second sentence of renumbered subclause 4.5 with: "Examples are LPDA antennas, double-ridged guide horns and standard gain horns."

Delete the note.

Renumber subclause 4.7 as subclause 4.6 and subclause 4.7.1 accordingly.

Page 47

5.7.1 Normalized site attenuation for alternative test sites

In the first sentence of the fourth paragraph, replace "… less than 1 m …" *by* "…at least 1 m …".

Page 51

Replace the existing Figures 6a and 6b with the following:

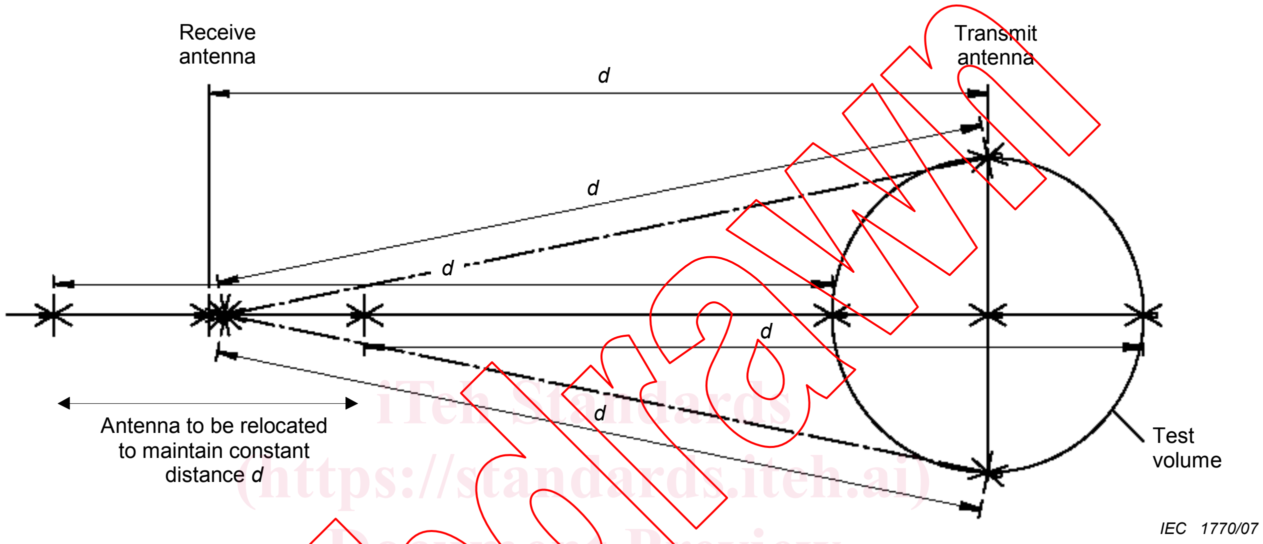

Figure 6a – Typical antenna positions for alternative test site – Vertical polarization NSA measurements

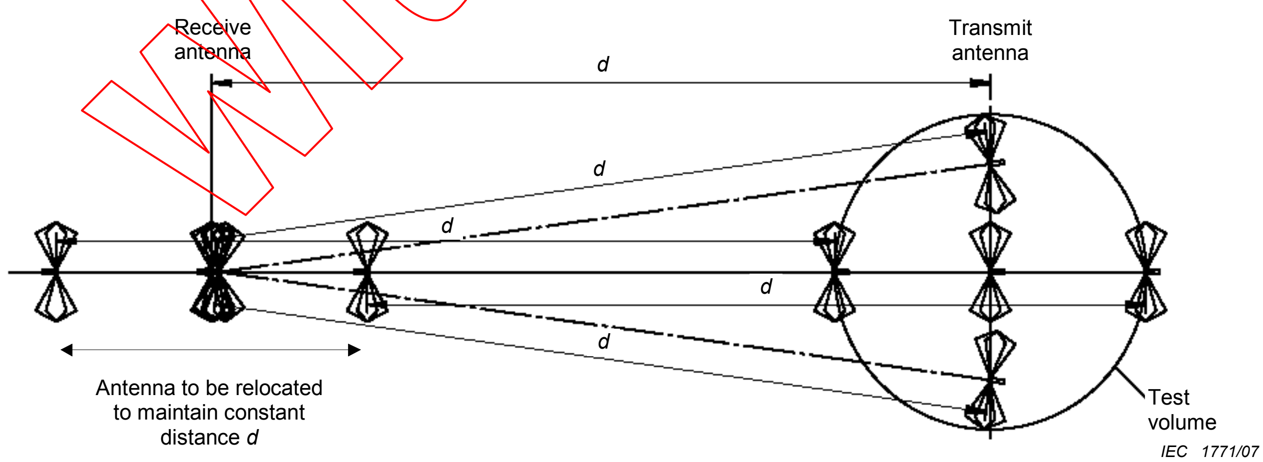

Figure 6b – Typical antenna positions for alternative test site – Horizontal polarization NSA measurements

Page 113

Add a new Clause 9 as follows.

9 Common mode absorption devices

9.1 General

Common mode absorption devices (CMADs) are applied on cables leaving the test volume during a radiated emission measurement. CMADs are used in radiated emission measurements to reduce variations in the measurement results between different test sites, due to possible differing values of common mode impedance and symmetry at the point where cables leave the test site (e.g. turntable centre). The basic characteristics of CMADs can be expressed in terms of *S*-parameters. Derived performance quantities such as insertion loss or reflection coefficient can be determined from these *S*-parameters. This clause specifies the measurement method for the verification of the *S*-parameters of a CMAD.

9.2 CMAD S-parameter measurements

S-parameters measured in a test jig, as described in 9.3, are used to characterise the properties of a CMAD. The values of the complex *S*-parameters are evaluated at the reference planes indicated in Figure 21. The reference method for the measurement of *S*-parameters with the highest possible accuracy uses a vector network analyser (VNA) and the TRL calibration method, as described in 9.4.

9.3 CMAD test jig

A test jig used for measuring the S-parameters of a CMAD under test shall have a cylindrical metal rod above a metal ground plane, as shown in Figure 21. The metal rod between the vertical flanges of the test jig consists of three sections: one section forming a transmission line in the jig between the two reference planes, and two adaptor sections between the reference planes and the adaptor ports.

The effects on the measurement of a CMAD from the adaptor sections and the adaptor ports can be eliminated by using the TRL calibration method described in 9.4, providing a low uncertainty for the final measurements. Any type of adaptor may be used for the measurements of 9.4. Examples of adaptors are shown in Figures 22 to 24.

The diameter *d* of the cylindrical rod shall be 4 mm. The height above the ground plane, *h*, is defined by the dimensions of the CMAD. Typical values are 30 mm, 65 mm, and 90 mm. The measurement shall be performed at the height defined by the construction of the CMAD. The distance between the reference plane and the vertical flange of the jig (adaptor section), L_A, shall be at least 2 *h* (see Figure 21). The distances between the reference planes and the CMAD ends, D_A and D_B, should be as small as possible, but not larger than *h*. The metal ground plane of the test jig shall be greater than (L_{jig} + 4 *h*) in length and greater than 4 *h* in width.

The characteristic impedance, Z_{ref}, is given by the internal diameter of the line, *d*, (defined to be 4 mm), and by the height of the centre of the rod above the ground plane, *h*:

$$Z_{ref} = \frac{Z_0}{2\pi} \cosh^{-1}\left(\frac{2h}{d}\right) \text{ in } \Omega \qquad (17)$$

where

Z_0 is the free-space impedance (120 π) in Ω;

d is the test conductor diameter (defined to be 4 mm);

h is the height of the centre of the test conductor above the ground plane.

EXAMPLE Typical values of Z_{ref} for various heights h are:

h = 30 mm >> Z_{ref} = 204 Ω

h = 65 mm >> Z_{ref} = 248 Ω

h = 90 mm >> Z_{ref} = 270 Ω

9.4 Measurement method using the TRL calibration

The TRL calibration method is recommended for measuring the *S*-parameters of CMADs. Use of this calibration procedure allows selection of the reference plane inside the test jig such that it is in close proximity to the location where the CMAD under test will be placed and hence distances D_A and D_B can be minimized (see Figure 21). The calibration requires a metal rod (termed "line") with the same diameter and height as the transmission line section of the jig. The characteristic impedance and length of the line section have to be known exactly, and are introduced into the calibration data used by the firmware of the VNA or by external correction calculations.

The length of the line section, used for a TRL calibration process, determines the frequency range in which the TRL calibration can be performed. This frequency limitation results from the mathematical procedure used in the TRL calibration method, where at some frequencies a divide-by-zero (or very small values) condition is possible and must be avoided.

If the length of the "line" reference is *L*, the frequency range shall be limited to between low and high frequencies f_L and f_H as follows:

$$f_L = 0{,}05\frac{c}{L} \tag{18}$$

$$f_H = 0{,}45\frac{c}{L} \tag{19}$$

where *c* is 3×10^8 m/s. A "line" length of 0,6 m is appropriate for calibration in the frequency range 30 MHz to 200 MHz. If the measurement has to be extended to higher frequencies, a second "Line" calibration is necessary. A second calibration with a "Line" length of 0,12 m would be appropriate for the frequency range 150 MHz to 1 000 MHz.

Four calibration configurations are necessary for the TRL calibration method:

a) "Reflect" (Port A): Measuring the complex value S_{11} of the adaptor section and adaptor at port 1 without any other connection (simulating an open-circuit condition) [Figure 25 a)]

b) "Reflect" (Port B): Measuring the complex value S_{22} of the adaptor section and adaptor at port 2 without any other connection (simulating an open-circuit condition) [Figure 25 b)]

c) "Through": Measuring the complex values S_{11}, S_{12}, S_{21}, S_{22} with the two adaptor sections directly connected together (without the line section in between) [Figure 25 c)]

d) "Line": Measuring the complex values S_{11}, S_{12}, S_{21}, S_{22} with the line section introduced [Figure 25 d)]

These calibration measurements yield 10 complex numbers for each frequency point. If the VNA includes a firmware for TRL calibration, it will use these reference measurements to calculate the proper corrections for the TRL measurement. If the VNA does not support the TRL calibration, the necessary corrections may be made independent of the VNA according to the procedure described in CISPR 16-3.