IEC 62153-4-16

Edition 1.0 2016-10

INTERNATIONAL STANDARD

colour inside

Metallic communication cable test methods – Part 4-16: Electromagnetic compatibility (EMC) – Extension of the frequency range to higher frequencies for transfer impedance and to lower frequencies for screening attenuation measurements using the triaxial set-up

IEC 62153-4-16:2016-10(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

IEC 62153-4-16

Edition 1.0 2016-10

INTERNATIONAL STANDARD

colour inside

Metallic communication cable test methods – Part 4-16: Electromagnetic compatibility (EMC) – Extension of the frequency range to higher frequencies for transfer impedance and to lower frequencies for screening attenuation measurements using the triaxial set-up

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.120.10

ISBN 978-2-8322-3707-6

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-16: Electromagnetic compatibility (EMC) – Extension of the frequency range to higher frequencies for transfer impedance and to lower frequencies for screening attenuation measurements using the triaxial set-up

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.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62153-4-16 has been prepared by IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories.

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

FDIS	Report on voting
46/615/FDIS	46/622/RVD

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

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

A list of all parts in the IEC 62153 series, published under the general title *Metallic communication cable test methods*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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.

A bilingual version of this publication may be issued at a later date.

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.

METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-16: Electromagnetic compatibility (EMC) – Extension of the frequency range to higher frequencies for transfer impedance and to lower frequencies for screening attenuation measurements using the triaxial set-up

1 Scope

This part of IEC 62153 describes a method to extrapolate the test results of transfer impedance to higher frequencies and the test results of screening attenuation to lower frequencies when measured with the triaxial set-up according to IEC 62153-4-3 (method B) respectively IEC 62153-4-4. A similar approach to extrapolate the test results of transfer impedance to higher frequencies was already described in IEC 61196-1:1995 Subclause 12.2. This method is applicable for homogenous screens, i.e. screens having a transfer impedance directly proportional to length. The transfer impedance may have any frequency behaviour, i.e. it could have a behaviour where it does not increase with 20 dB per decade as observed for screens made of a foil and a braid.

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.

IEC TS 62153-4-1:2014, *Metallic communication cable test methods – Part 4-1: Electromagnetic compatibility (EMC) – Introduction to electromagnetic screening measurements*

IEC 62153-4-3, *Metallic communication cable test methods – Part 4-3: Electromagnetic compatibility (EMC) – Surface transfer impedance – Triaxial method*

IEC 62153-4-4, *Metallic communication cable test methods – Part 4-4: Electromagnetic compatibility (EMC) – Test method for measuring of the screening attenuation as up to and above 3 GHz, triaxial method*

IEC 61156-1:2007, *Multicore and symmetrical pair/quad cables for digital communications – Part 1: Generic specification*
IEC 61156-1:2007/AMD1:2009

IEC TR 62152:2009, *Transmission properties of cascaded two-ports or quadripols – Background of terms and definitions*

3 Acronyms

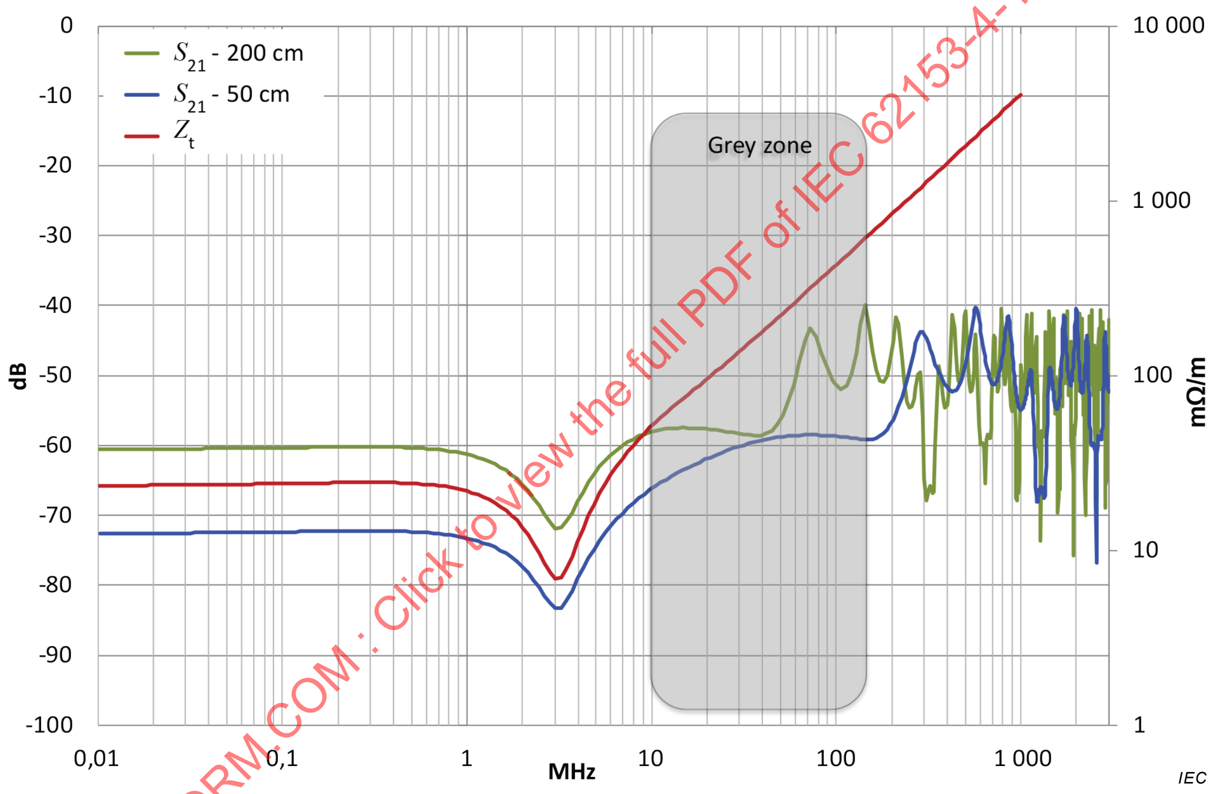
CUT cable under test

DUT device under test

4 Overview

The triaxial set-up can be used to measure both the surface transfer impedance (IEC 62153-4-3) and the screening attenuation (IEC 62153-4-4). The transfer impedance is in general measured with a coupling length of max. 0,5 m resulting in an upper frequency limit of around 100 MHz, whereas the screening attenuation is in general measured with a coupling length of 2 m to 3 m resulting in a upper frequency limit for the transfer impedance of around 10 MHz and a lower frequency limit for the screening attenuation of around 100 MHz (see also IEC TS 62153-4-1:2014 Clause 8 and 9).

Figure 1 shows the grey zone between electrically short (measurement range for the transfer impedance) and electrically long (measurement range for the screening attenuation). In the example, the transfer impedance can be measured up to around 30 MHz using a coupling length of 50 cm and the screening attenuation can be measured starting from 150 MHz using a coupling length of 200 cm.



Simulation using following parameters:

- simulated measurement of S_{21} according IEC 62153-4-3 method B, where the value of the load resistor equals the characteristic impedance of the CUT:
  - – impedance of inner circuit is 50 Ω;
  - – impedance of outer circuit is 150 Ω;
  - – relative dielectric permittivity of inner circuit 2,3;
  - – relative dielectric permittivity of outer circuit 1,1;
  - – coupling length 50 cm and 200 cm.
- transfer impedance calculated according T. KLEY [2][1] for a copper braid design of: diameter under braid 2,95 mm, number of spindles 16, number of wires per spindle 5, wire diameter 0,12 mm, lay length 15 mm.

Figure 1 – Simulation of the scattering parameter S_{21} (left hand scale) and the transfer impedance (right hand scale) for a single braid screen

[1] Figures in square brackets refer to the Bibliography.

The present document describes how to extrapolate the test results of transfer impedance to higher frequencies and the test results of screening attenuation to lower frequencies when measured with the triaxial set-up according to IEC 62153-4-3 (method B), respectively IEC 62153-4-4.

5 Frequency behaviour of the triaxial set-up

Knowing the frequency behaviour of the triaxial set-up one may convert a screening attenuation measurement to transfer impedance and vice versa. And on the other hand, one may extend the results of the measured transfer impedance to higher frequencies.

The general equations for the coupling between the inner and outer circuit for any load conditions are described in [2] and [3].

In the following, the capacitive coupling through the screen and the attenuation of the inner and outer circuit are neglected and the CUT is considered to be matched at the near and far end. In this case, the frequency behaviour of the triaxial set-up is obtained from the coupling equations given in IEC TS 62153-4-1:2014, 9.2.2:

$$F = -\frac{1}{N}\frac{1}{1-n^2}\frac{j}{x}\left\{[\cos x - \cos nx] - j[n\sin nx - \sin x]\right\} \tag{1}$$

$$N = \{\cos x + j\sin x\} \times \{\cos nx + jv\sin nx\} \tag{2}$$

$$x = \beta_1 L = 2\pi\frac{L}{\lambda_1} = 2\pi f L\frac{\sqrt{\varepsilon_{r1}}}{c_0} \tag{3}$$

$$n = \frac{\beta_2}{\beta_1} = \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{\varepsilon_{r2}}{\varepsilon_{r1}}} \tag{4}$$

$$v = \frac{Z_2}{R_{2f}} \tag{5}$$

where

F is the function describing the frequency behaviour of the triaxial set-up, where the capacitive coupling through the screen and the attenuation of the inner and outer circuit are neglected and the CUT is matched at the far end;

N is the auxiliary function;

x is the product of phase constant and coupling length;

L is the coupling length;

$\lambda_{1,2}$ is the wave length in the inner circuit (cable), respectively outer circuit (tube);

$\beta_{1,2}$ is the phase constant in the inner circuit (cable), respectively outer circuit (tube);

f is the frequency;

$\varepsilon_{r1,2}$ is the relative dielectric permittivity of the inner circuit (cable), respectively outer circuit (tube);

c_0 is the velocity of light in free space;

n is the ratio of the velocity in the outer circuit (tube) and inner circuit (cable);

v is the ratio of the impedance in the outer circuit and the load resistance in the outer circuit (tube);

Z_2 is the characteristic impedance of the outer circuit (tube);

R_{2f} is the load resistance at the far end of the outer circuit (tube).

A different way to describe the frequency behaviour is obtained from the equations given in IEC TS 62153-4-1:2014, 10.3:

$$F = -\frac{j}{\omega L} \times \left[\frac{1-e^{-j\varphi_1}}{\sqrt{\varepsilon_{r1}}-\sqrt{\varepsilon_{r2}}} + \frac{1-e^{-j\varphi_2}}{\sqrt{\varepsilon_{r1}}+\sqrt{\varepsilon_{r2}}} \right] \cdot \left[\frac{c_0}{2+\left(Z_2/R_{2f} - 1 \right) \cdot \left(1-e^{-j\varphi_3} \right)} \right] \cdot e^{-j\varphi_3/2} \tag{6}$$

$$\varphi_1 = 2\pi \left(\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}} \right) \frac{L}{\lambda_0} = 2\pi f \left(\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}} \right) \frac{L}{c_0} \tag{7}$$

$$\varphi_2 = 2\pi \left(\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}} \right) \frac{L}{\lambda_0} = 2\pi f \left(\sqrt{\varepsilon_{r1}} + \sqrt{\varepsilon_{r2}} \right) \frac{L}{c_0} \tag{8}$$

$$\varphi_3 = \varphi_2 - \varphi_1 = 4\pi \sqrt{\varepsilon_{r2}}\, \frac{L}{\lambda_0} = 4\pi f \sqrt{\varepsilon_{r2}}\, \frac{L}{c_0} \tag{9}$$

where

F is the function describing the frequency behaviour of the triaxial set-up, where the capacitive coupling through the screen and the attenuation of the inner and outer circuit are neglected and the CUT is matched at the far end;

L is the coupling length;

λ_0 is the wave length in free space;

c_0 is the velocity of light in free space;

$\varphi_{1,2,3}$ are the auxiliary functions describing the periodic variations of the frequency behaviour F;

ω is the circular frequency ($2\pi f$);

$\varepsilon_{r1,2}$ is the relative dielectric permittivity of the inner circuit (cable), respectively outer circuit (tube);

Z_2 is the characteristic impedance of the outer circuit (tube);

R_{2f} is the load resistance at the far end the outer circuit (tube).

Figure 2 and Figure 3 show an example of the frequency behaviour (F) in linear and logarithmic frequency scale for a coupling length of 0,5 m, respectively 2 m and a relative dielectric permittivity of 2,3 and 1,1 for the inner, respectively outer circuit.

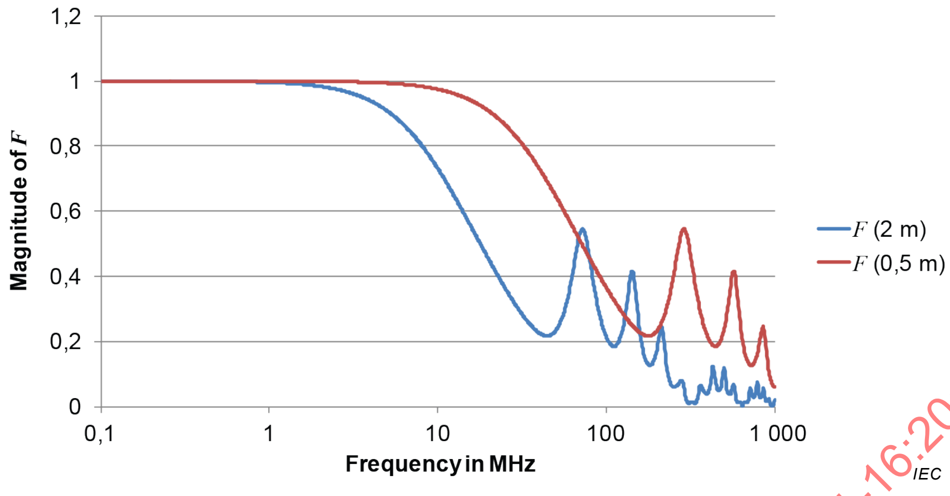


Figure 2 – Magnitude of the frequency behaviour (F) in logarithmic frequency scale for a coupling length of 0,5 m, respectively 2 m and relative dielectric permittivity of 2,3 and 1,1 for the inner, respectively outer circuit

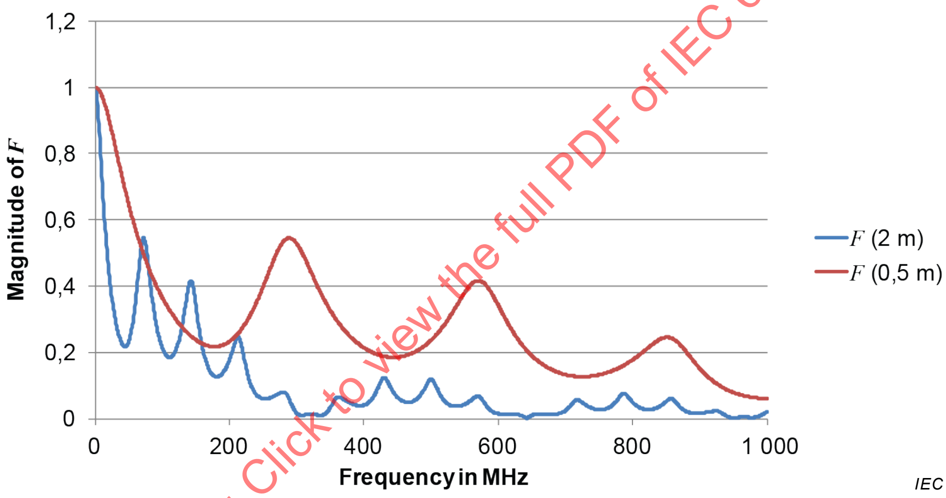


Figure 3 – Magnitude of the frequency behaviour (F) in linear frequency scale for a coupling length of 0,5 m, respectively 2 m and relative dielectric permittivity of 2,3 and 1,1 for the inner, respectively outer circuit

6 Extrapolation of measurement results

The test results of the transfer impedance shall be extrapolated to higher frequencies by using the function F according to formula (1) or (6):

$$\left|Z_{\mathrm{T,ex}}\right| = \frac{\left|Z_{\mathrm{T,meas}}\right|}{\left|F\right|} \tag{10}$$

where

$Z_{\mathrm{T,ex}}$ is the extrapolated transfer impedance;

$Z_{\mathrm{T,meas}}$ is the measured transfer impedance;

F is the frequency behaviour of the triaxial set-up, see formulae (1) and (6), where the capacitive coupling through the screen and the attenuation of the inner and outer circuit are neglected and the CUT is matched at the far end.

Figure 4 shows an example for the extrapolation of the measured transfer impedance of a RG59 type cable. The measurement was done with a coupling length of 2 m. For the extrapolation, a relative dielectric permittivity of 2,3 and 1,1 was assumed for the inner respectively outer circuit. The blue dotted line is the measurement result obtained with a coupling length of 2 m. The green dotted line is the measurement obtained with a coupling length of 0,5 m. The red solid line is the extrapolation of the measurement with a coupling length of 2 m.

Good concordance is observed between the from 2 m extrapolated results and the 0,5 m measured results. The extrapolation works well up to 100 MHz. The spikes observed above 100 MHz are due to slight differences between the real and assumed dielectric permittivities.

This example shows that it is possible by the use of formula (10) to measure the transfer impedance and screening attenuation with one and the same triaxial set-up with a coupling length of 2 m instead of doing two measurements, one with a short coupling length for the transfer impedance and one with a long coupling length for the screening attenuation.

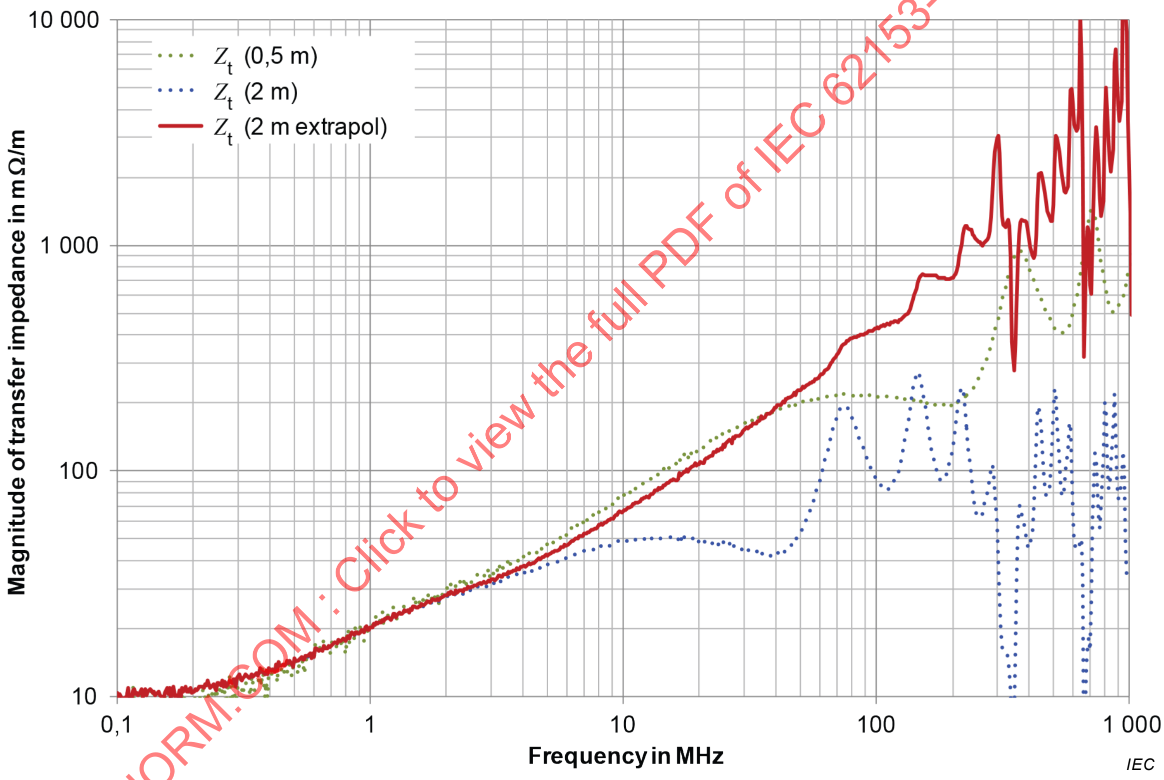


Figure 4 – Example for the extrapolation of the transfer impedance of a RG59 type cable measured with a coupling length of 2 m and assuming relative dielectric permittivity of 2,3 and 1,1 for the inner, respectively outer circuit

The test results of the screening attenuation, respectively the measured (forward transmission) scattering parameter S_{21} shall be extrapolated to lower frequencies, or in other words extrapolated from a short to a long length by using the function F according formula (1) or (6):

$$S_{21}(L_2) = S_{21}(L_1)\frac{F(L_2)}{F(L_1)}\frac{L_2}{L_1} \tag{11}$$

where

$S_{21}(L_2)$ is the scattering parameter S_{21} for the extrapolated coupling length;

$S_{21}(L_1)$ is the scattering parameter S_{21} for the measured coupling length;

$F(L_2)$ is the frequency behaviour of the triaxial set-up, see formulae (1) and (6), for the extrapolated coupling length, where the capacitive coupling through the screen and the attenuation of the inner and outer circuit are neglected and the CUT is matched at the far end;

$F(L_1)$ is the frequency behaviour of the triaxial set-up, see formulae (1) and (6), for the measured coupling length, where the capacitive coupling through the screen and the attenuation of the inner and outer circuit are neglected and the CUT is matched at the far end;

L_2 is the extrapolated coupling length;

L_1 is the measured coupling length.

Figure 5 and Figure 6 show an example for the extrapolation of the measured scattering parameter S_{21} of a RG59 type cable.

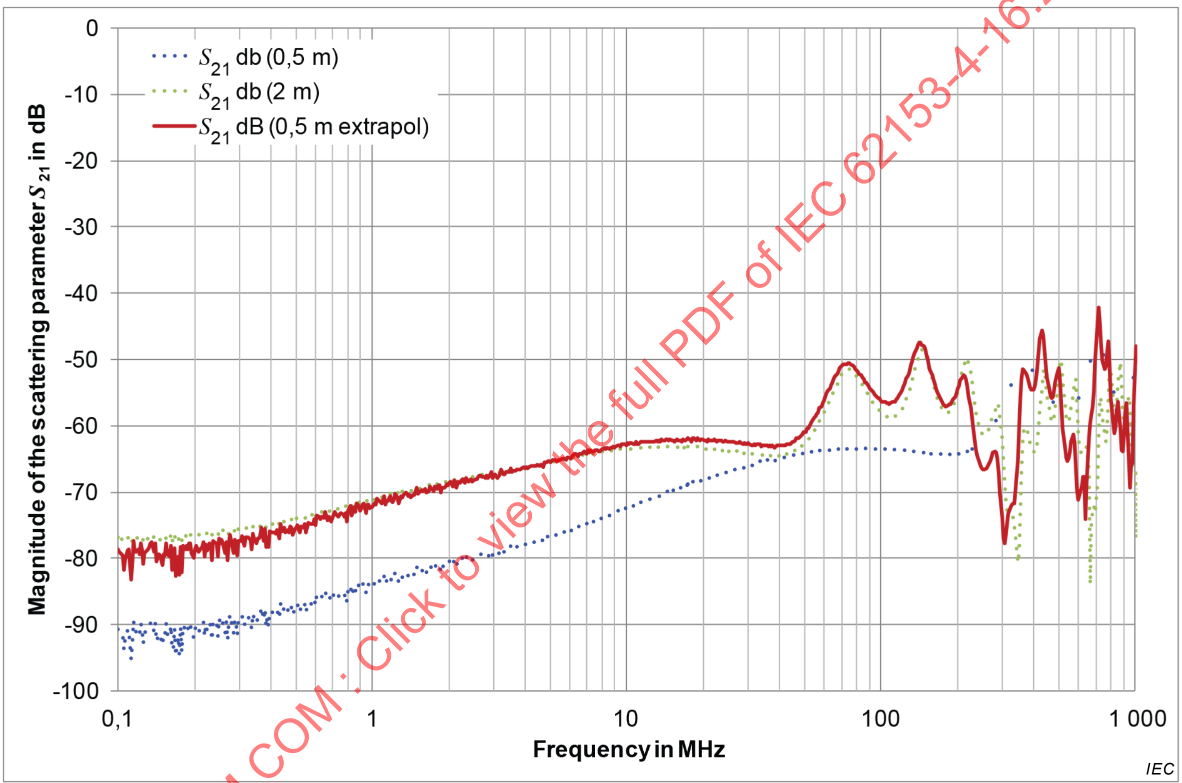


Figure 5 – Example for the extrapolation of the scattering parameter S_{21} in logarithmic frequency scale of a RG59 type cable measured with a coupling length of 0,5 m and assuming dielectric permittivities of 2,3 and 1,1 for the inner, respectively outer circuit

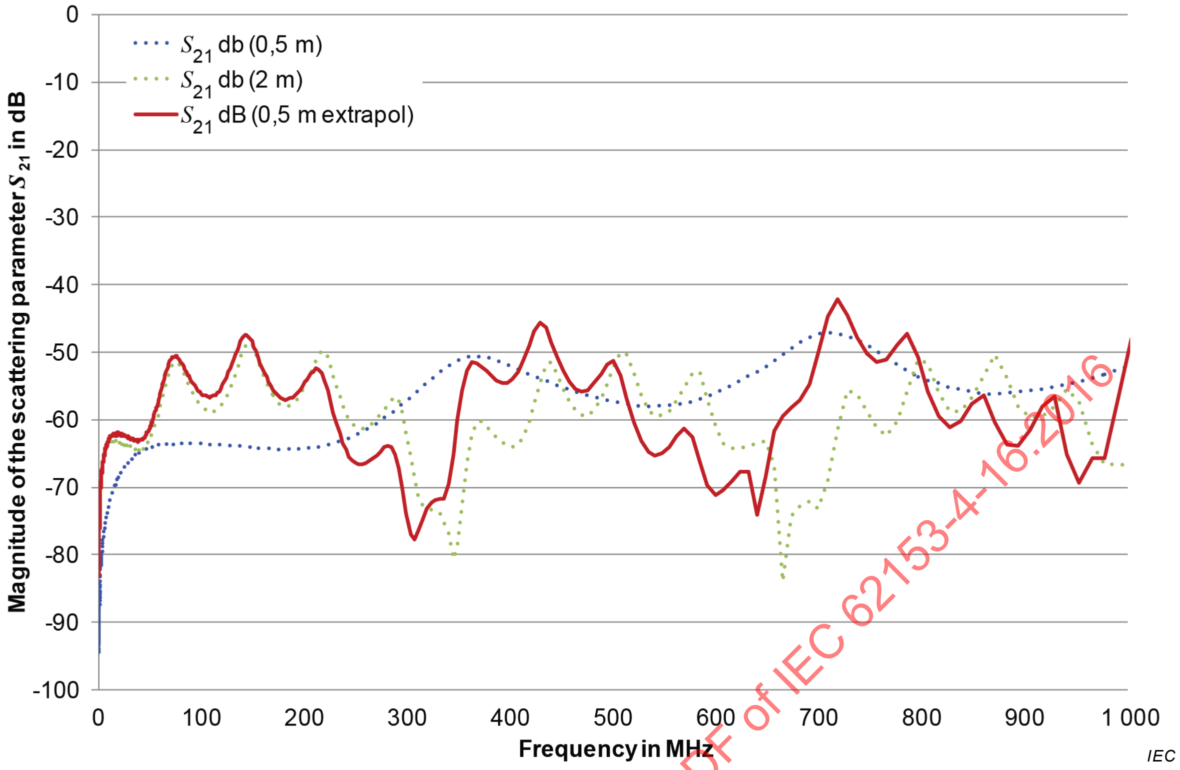


Figure 6 – Example for the extrapolation of the scattering parameter S_{21} in linear frequency scale of a RG59 type cable measured with a coupling length of 0,5 m and assuming dielectric permittivities of 2,3 and 1,1 for the inner, respectively outer circuit

The measurement was done with a coupling length of 0,5 m. For the extrapolation, a dielectric, permittivity of 2,3 and 1,1 was assumed for the inner, respectively outer circuit. The blue dotted line is the measurement result obtained with a coupling length of 0,5 m. The green dotted line is the measurement obtained with a coupling length of 2 m. The red solid line is the extrapolation of the measurement with a coupling length of 0,5 m.

A good concordance is observed between the from 0,5 m extrapolated results and the 2 m measured results. The extrapolation works well up 300 MHz. The deviations observed above 300 MHz are due to slight differences between the real and assumed dielectric permittivities.

7 Determination of the relative dielectric permittivity and impedance

7.1 General

For the calculation of the frequency behaviour of the triaxial set-up, the exact dielectric permittivities and impedance of the inner and outer circuit are needed (see formulae (1) through (11) and the examples given in Figure 3 to Figure 6). The relative dielectric permittivity and impedance of the inner circuit (CUT) is in general known or may be obtained from an open/short measurement (see IEC 61156-1:2007/AMD1:2009 6.3.10, IEC TR 62152:2009 Clause A.6) or a TDR measurement.

For the determination of the impedance and relative dielectric permittivity of the outer circuit (tube), one can use a TDR measurement (rise-time max. 20 ps) or use the theory of the transformation characteristics of a line. The input impedance of a line is expressed by the following equation (neglecting the attenuation):

$$Z_{\text{in}} = Z_{\text{c}} \frac{\frac{Z_{\text{load}}}{Z_{\text{c}}} + j\tan\left(2\pi\frac{L}{\lambda}\right)}{1 + \frac{Z_{\text{load}}}{Z_{\text{c}}}\, j\tan\left(2\pi\frac{L}{\lambda}\right)} \tag{12}$$

where

Z_{in} is the input impedance of the transmission line;

Z_{load} is the load impedance of the transmission line;

Z_{c} is the characteristic impedance of the transmission line;

λ is the wave length of transmission line;

L is the length of the transmission line.

For even multiples of the half wavelength ($\lambda/2$), the input impedance is equal to the load impedance and for odd multiples of the quarter wavelength ($\lambda/4$), the transmission line acts as a dual transformer.

With the short circuit in the outer circuit of the triaxial set-up, one gets:

$Z_{\text{in}} = 0$ or $S_{11} = -1$ when $L = n\,\lambda/2$

$Z_{\text{in}} = \infty$ or $S_{11} = +1$ when $L = (2n+1)\,\lambda/4$

So by measuring the scattering parameter S_{11} and observing two successive resonances where the real part Re(S_{11})=–1 (and Im(S_{11})=0), or two successive resonances where the real part Re(S_{11})=+1 (and Im(S_{11})=0), one can obtain the relative dielectric permittivity:

When Re(S_{11})=–1 or Re(S_{11})=+1

$$\varepsilon_r = \left[\frac{c_0}{2L\Delta f}\right]^2 \tag{13}$$

where

ε_{r} is the relative dielectric permittivity;

c_0 is the speed of light in free space;

L is the length of the transmission line;

Δf is the frequency spacing between two successive resonances where the real part Re(S_{11})=–1 (and Im(S_{11})=0), or two successive resonances where the real part Re(S_{11})=+1 (and Im(S_{11})=0).

The observation of two successive resonances also allows determining the characteristic impedance in the outer circuit. From formula (12), the input impedance for a short circuited transmission line is obtained:

$$Z_{\text{in}}^{Z_{load}=0} = Z_{\text{c}}\, j\tan(\beta L) \tag{14}$$

Hence:

$Z_{\text{in}} = jZ_{\text{c}}$ for $\tan\beta L = 1$, $\beta L = (n\pi + \pi/4)$, $f = (4n+1)/4\ \Delta f$

or

$Z_{in} = -jZ_c$ for $\tan\beta L = -1$, $\beta L = (n\pi - \pi/4)$, $f = (4n-1)/4\ \Delta f$

where

Z_{in} is the input impedance of the transmission line;

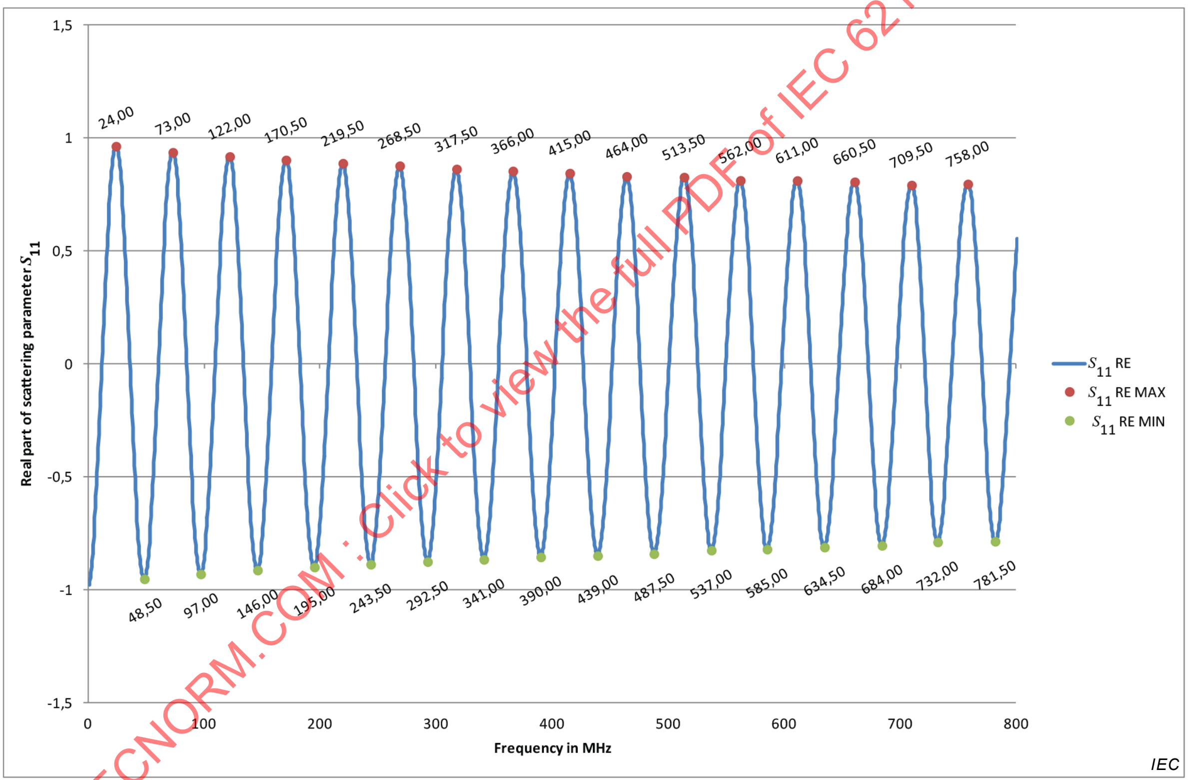
Z_c is the characteristic impedance of the transmission line;

L is the length of the transmission line;

β is the phase constant of transmission line.

The principle of this method is shown in Figure 7,which shows the test results of a short circuited RG58 cable having a length of 203 cm. Subclause 7.2 describes how to apply this method to determine the relative dielectric permittivity and impedance of the outer circuit.

It is recommended to take the average frequency spacing of at least 5 successive resonances as shown in Figure 7. The average frequency spacing of two successive resonances is 48,90 MHz. Formulae (13) and (14) result in a relative dielectric permittivity of 2,28 and a characteristic impedance of 49,5 Ω which correspond to the typical values of such kind of cable.



Test results of the real part of the scattering parameter S_{11} of a RG58 type cable (with solid PE insulation) having a length of 203 cm and a short circuit at the far end. Where the average distance between two successive maxima is 48,93 MHz and between two successive minima is 48,87 MHz, i.e. the global average distance is 48,90 MHz.

Figure 7 – Measurement of S_{11} of the outer circuit (tube) having a length of 50 cm

The characteristic impedance in the outer circuit can also be obtained if the dimensions of the cable and the tube and the relative dielectric permittivity in the outer circuit are known:

$$Z_2 = \frac{60}{\sqrt{\varepsilon_{r2}}} \ln\left(\frac{D}{d}\right) \tag{15}$$

where

Z_2 is the characteristic impedance of the outer circuit in Ohm;

ε_{r2} relative dielectric permittivity of the outer circuit;

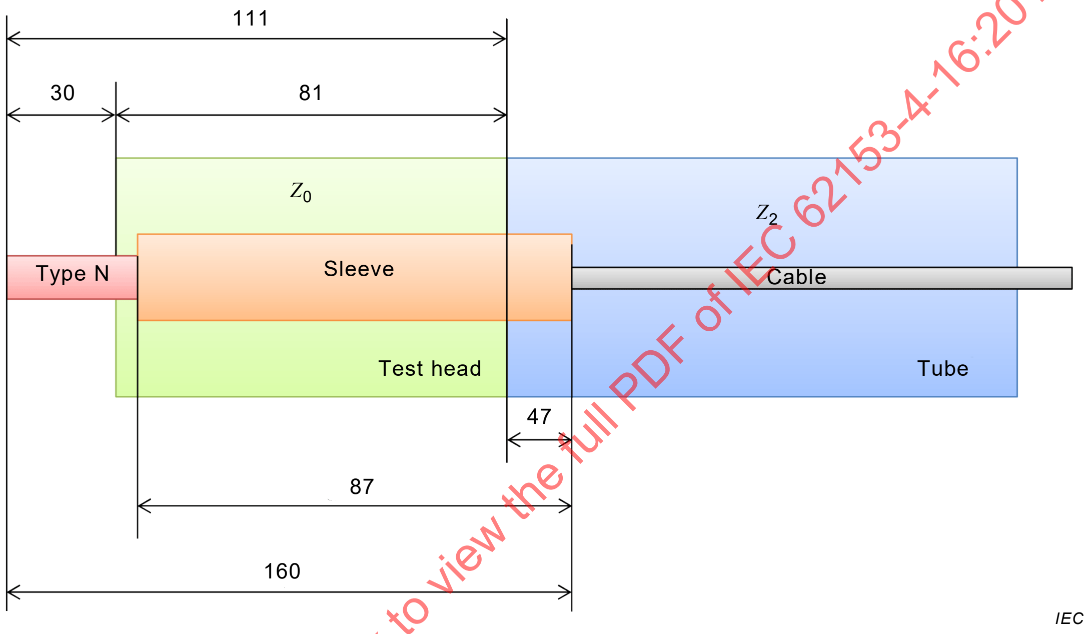
D is the inner diameter of the tube in mm;

d is the outer diameter of the cable screen in mm.

7.2 Influence of the test head

To obtain the relative dielectric permittivity and impedance in the outer circuit from the measurement of the scattering parameter S_{11}, the configuration of the triaxial tube shall be taken into account. The well-known COMET set-up has a test head which is attached to the measuring tube, see Figure 8.

Dimensions in millimetres



Key

Z_2 characteristic impedance in the outer circuit (tube)

Z_0 characteristic impedance of the test head

Figure 8 – Example of test head (COMET set-up)

This test head is built to have a characteristic impedance of 50 Ω to match with the test receiver. As the characteristic impedance in the outer circuit, Z_2 is different from the impedance of the test head, the test head will act as a line transformer and the S_{11} measurement shall be corrected.

$$S_{11}^{\text{cor}} = S_{11}^{\text{meas}} \times e^{j2\beta_{\text{H}} L_{\text{H}}^{\text{mech}}} = S_{11}^{\text{meas}} \times e^{j4\pi \cdot L_{\text{H}}^{\text{elec}} \cdot f / c_0} \tag{16}$$

$$L_{\text{H}}^{\text{elec}} = L_{\text{H}}^{\text{mech}} \sqrt{\varepsilon_{\text{r,H}}} \tag{17}$$

where

S_{11}^{cor} is the corrected scattering parameter S_{11};

S_{11}^{meas} is the measured scattering parameter S_{11};

$L_{\text{H}}^{\text{mech}}$ is the mechanical length of the test head;

$L_{\text{H}}^{\text{elec}}$ is the electrical length of the test head;