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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)

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CONTENTS

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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

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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- withdrawn,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.

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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

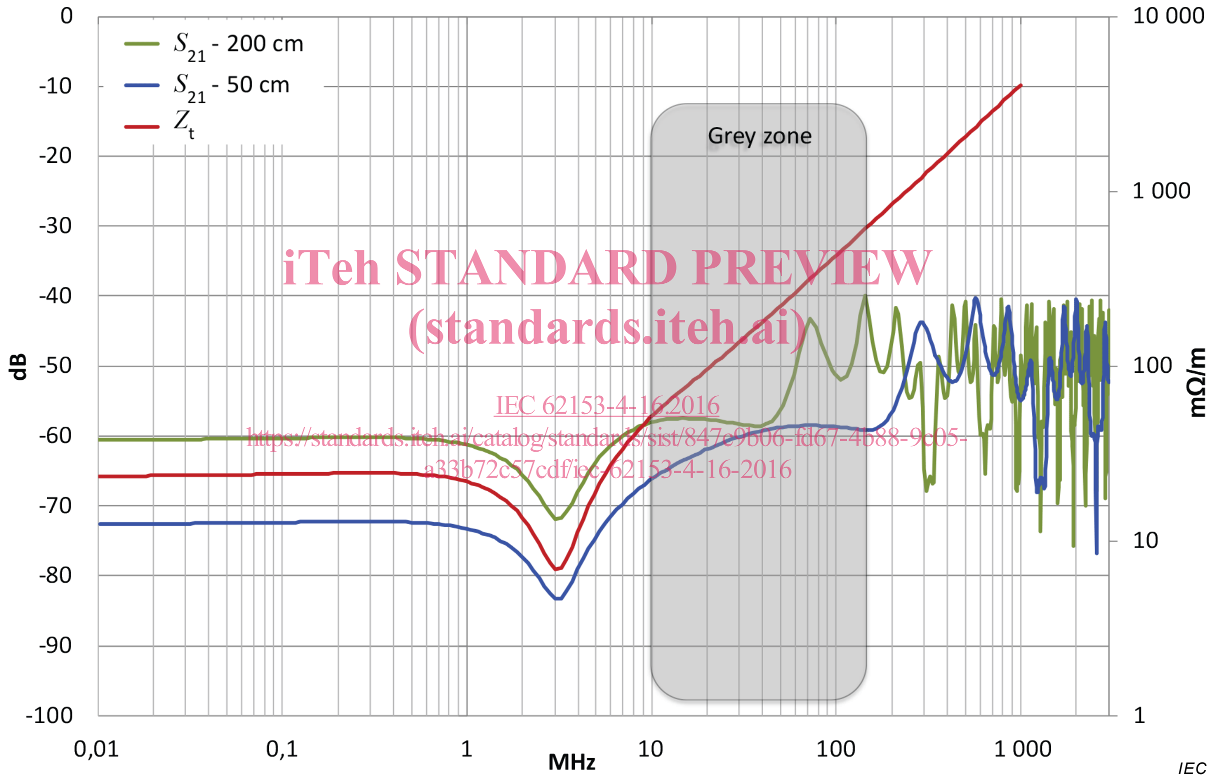
CUT cable under test

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:

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

$$N = \{\cos x + j \sin x\} \times \{\cos nx + jv \sin nx\} \quad (2)$$

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

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

$$v = \frac{Z_2}{R_{2f}} \quad (5)$$

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.

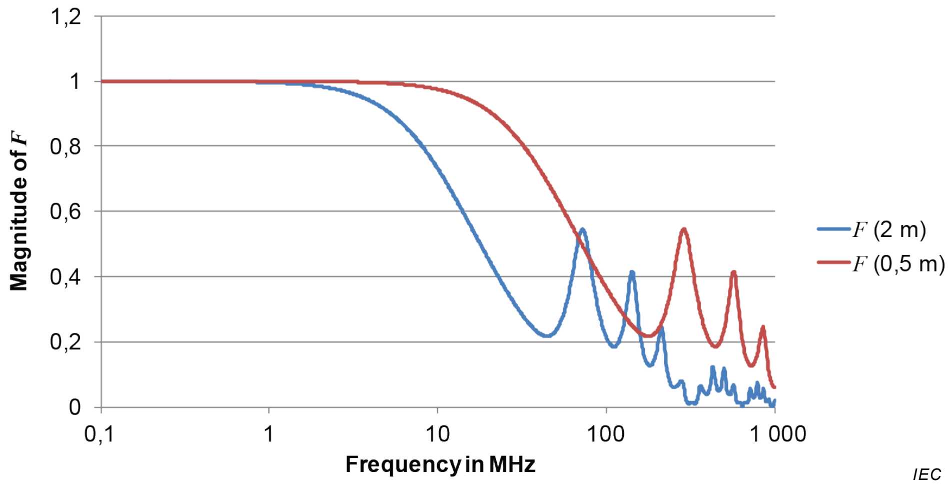


Figure 2 – Magnitude of the frequency behaviour (F) in logarithmic frequency scale for a coupling length of 0,5 m, respectively 2 m and relative dielectric permittivity of 2,3 and 1,1 for the inner, respectively outer circuit

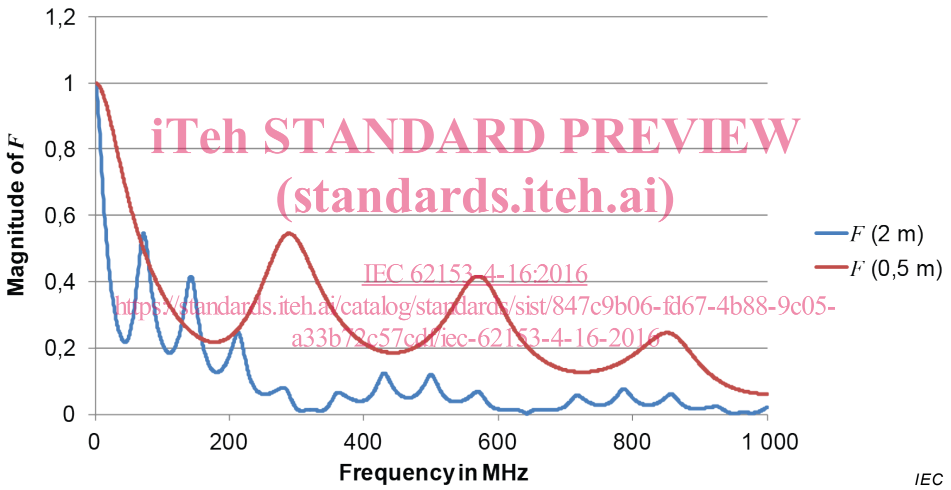


Figure 3 – Magnitude of the frequency behaviour (F) in linear frequency scale for a coupling length of 0,5 m, respectively 2 m and relative dielectric permittivity of 2,3 and 1,1 for the inner, respectively outer circuit

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):

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

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.