# IEC 62153-4-16

Edition 2.0 2021-08

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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inside

## Metallic cables and other passive components 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

## Méthodes d'essai des câbles métalliques et autres composants passifs – Partie 4-16: Compatibilité électromagnétique (CEM) – Extension de la plage de fréquences à des fréquences supérieures pour l'impédance de transfert et à des fréquences inférieures pour mesurer l'affaiblissement d'écran à l'aide d'un montage triaxial

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

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

- Replacement of the conversion formula which was limited to a matched DUT by a new conversion formula suitable for any load conditions.

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

| FDIS | Report on voting |
|---|---|
| 46/817/FDIS | 46/826/RVD |

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

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

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

A list of all parts in the IEC 62153 series, published under the general title *Metallic cables and other passive components test methods*, can be found on the IEC website.

Future documents in this series will carry the new general title as cited above. Titles of existing documents in this series will be updated at the time of the next edition.

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# METALLIC CABLES AND OTHER PASSIVE COMPONENTS 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 specifies 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 in accordance with IEC 62153-4-3, IEC 62153-4-4 [1][1] and IEC 62153-4-15. This method is applicable for homogenous screens, i.e. screens having a transfer impedance directly proportional to length. The transfer impedance can 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 62153-4-3:2013, *Metallic communication cable test methods – Part 4-3: Electromagnetic compatibility (EMC) – Surface transfer impedance – Triaxial method*

IEC 62153-4-15, *Metallic communication cable test methods – Part 4-15: Electromagnetic compatibility (EMC) – Test method for measuring transfer impedance and screening attenuation – or coupling attenuation with triaxial cell*

## 3 Terms, definitions and abbreviated terms

### 3.1 Terms and definitions

No terms and definitions are listed in this document.

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

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

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[1] Numbers in square brackets refer to the bibliography.

### 3.2 Abbreviated terms

| | |
|---|---|
| CUT | cable under test |
| DUT | device under test |
| TDR | time domain reflectometer |
| VNA | vector network analyser |

## 4 Overview

The triaxial set-up can be used to measure both the surface transfer impedance (IEC 62153-4-3, IEC 62153-4-15) and the screening attenuation (IEC 62153-4-4, IEC 62153-4-15). The transfer impedance is in general measured with a coupling length of maximum 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 an 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, Clauses 8 and 9 [2]).

Figure 1 shows the grey zone between electrically short (measurement range for the transfer impedance) and electrically long (measurement range for the screening attenuation). The parameters used in the simulation are:

- forward transfer scattering parameter $S_{21}$ in accordance with 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 to T. KLEY [3] 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.

In the example shown in Figure 1, 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.

This 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 in accordance with IEC 62153-4-3, IEC 62153-4-4 and IEC 62153-4-15.

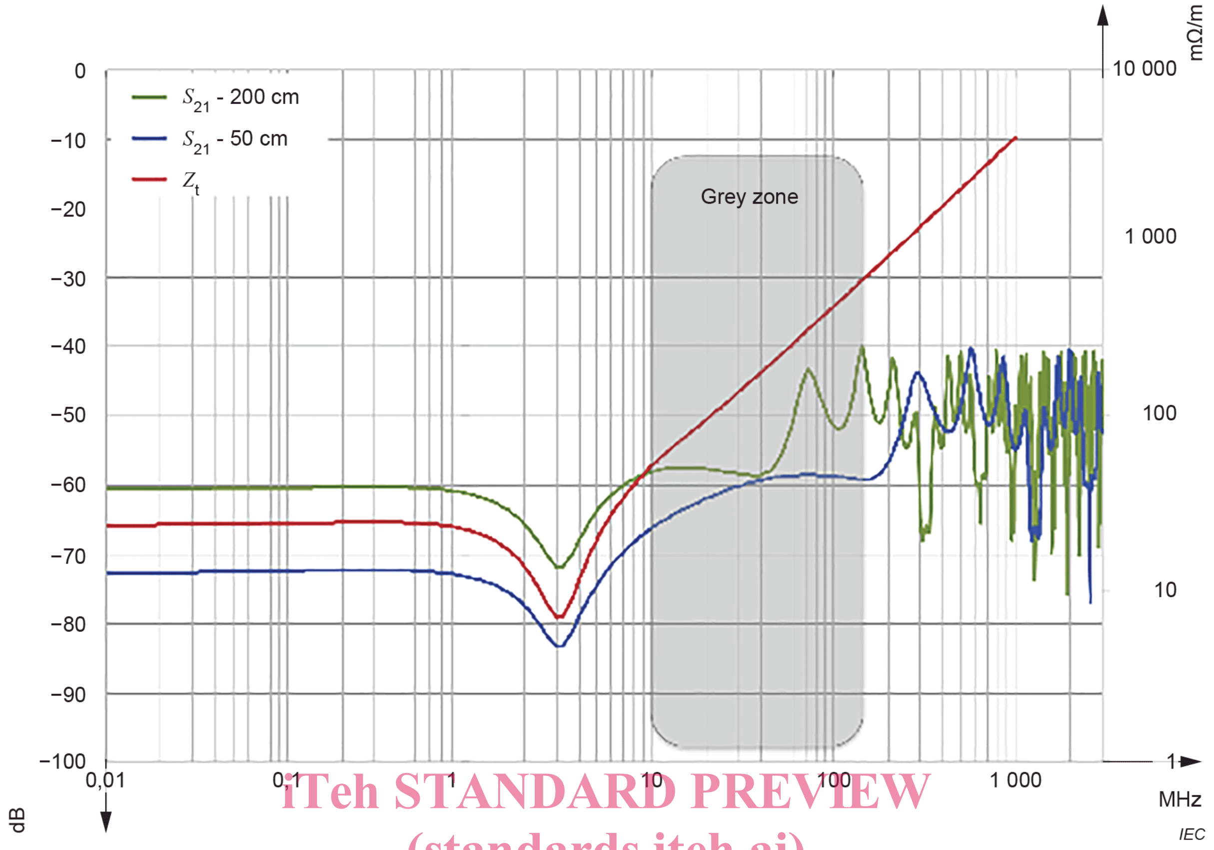


**Figure 1 – Simulation of the scattering parameter $S_{21}$ (left hand scale) and the transfer impedance (right hand scale) for a single braid screen**

## 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 [3] and [4].

The relation between the measured forward transfer scattering parameter and the transfer impedance respective screening attenuation is described in [4].

In Formula (1) the capacitive coupling through the screen is neglected. In this case the transfer impedance $Z_\mathrm{T}$ is obtained from the measured forward transfer scattering parameter $S_\mathrm{M}$ by:

$$Z_\mathrm{T}\Big|_{Z_\mathrm{F}=0} = S_\mathrm{M}\frac{2\sqrt{Z_1 Z_2}}{\sqrt{1-r_{1\mathrm{n}}^2}\sqrt{1-r_{2\mathrm{f}}^2}}\times \frac{\left[1+r_{1\mathrm{n}}r_{1\mathrm{f}}e^{-2\gamma_1 L}+r_{2\mathrm{f}}e^{-2\gamma_2 L}+r_{1\mathrm{n}}r_{1\mathrm{f}}r_{2\mathrm{f}}e^{-2(\gamma_1+\gamma_2)L}\right]}{e^{-\gamma_2 L}\left[\frac{1-e^{-(\gamma_1-\gamma_2)L}}{\gamma_1-\gamma_2}\left(1-r_{1\mathrm{f}}e^{-(\gamma_1+\gamma_2)L}\right)+\frac{1-e^{-(\gamma_1+\gamma_2)L}}{\gamma_1+\gamma_2}\left(1-r_{1\mathrm{f}}e^{-(\gamma_1-\gamma_2)L}\right)\right]} \tag{1}$$

For low frequencies ($\gamma L$<<1) Formula (1) becomes

$$Z_\mathrm{T} = S_\mathrm{M} \frac{Z_\mathrm{2f}\left(Z_\mathrm{1n} + Z_\mathrm{1f}\right)}{2L\sqrt{Z_\mathrm{1n} Z_\mathrm{2f}}} \tag{2}$$

where

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

$Z_\mathrm{F}$ is the capacitive coupling impedance ($Z_\mathrm{F}$ = 0);

$S_\mathrm{M}$ is the measured forward transfer scattering parameter;

$L$ is the coupling length;

$Z_1$, $Z_2$ are the characteristic impedances of the inner circuit (cable) and outer circuit (tube), respectively;

$\gamma_1, \gamma_2$ are the wave propagation factors in the inner circuit (cable) and outer circuit (tube), respectively;

$r_\mathrm{1n}, r_\mathrm{1f}$ are the reflection coefficients in the inner circuit (cable) at the near end and far end, respectively;

$r_\mathrm{2f}$ is the reflection coefficient in the outer circuit (tube) at the far end.

Formula (2) is the basis for the conversion formulae given in IEC 62153-4-3 and IEC 62153-4-15.

Figure 2 shows the comparison between the results of transfer impedance obtained from Formula (1) and the commonly used conversion formula between the measured forward transfer scattering parameter and transfer impedance as described in IEC 62153-4-3. The configuration is detailed in Table 1. The inner circuit is mismatched having a short circuit at the far end. (i.e. method C of IEC 62153-4-3)

**Table 1 – Parameters for simulation of triaxial set-up**

| Parameter | Values |
|---|---|
| Reference impedance of VNA, $Z_0$ | 50 Ω |
| Coupling length, $L$ | 0,5 m |
| Impedance of inner circuit (CUT), $Z_1$ | 75 Ω |
| Load at the near end of the inner circuit, $Z_\mathrm{1n}$ | 50 Ω |
| Load at the far end of the inner circuit, $Z_\mathrm{1f}$ | 0 Ω |
| Dielectric permittivity of the inner circuit, $\varepsilon_\mathrm{r1}$ | 2,25 |
| Attenuation of the inner circuit, $\alpha_1$ | 0 dB/m |
| Impedance of outer circuit (tube), $Z_2$ | 150 Ω |
| Load at the near end of the outer circuit, $Z_\mathrm{2n}$ | 0 Ω |
| Load at the far end of the outer circuit, $Z_\mathrm{2f}$ | 50 Ω |
| Dielectric permittivity of the outer circuit, $\varepsilon_\mathrm{r2}$ | 1,0 |
| Attenuation of the outer circuit, $\alpha_2$ | 0 dB/m |
| DC resistance of the screen, $R_\mathrm{T}$ | 13,6 mΩ/m |
| Coupling inductance of the screen, $M_\mathrm{T}$ | 0,93 nH/m |
| Coupling capacitance of the screen, $C_\mathrm{T}$ | 0 pF/m |

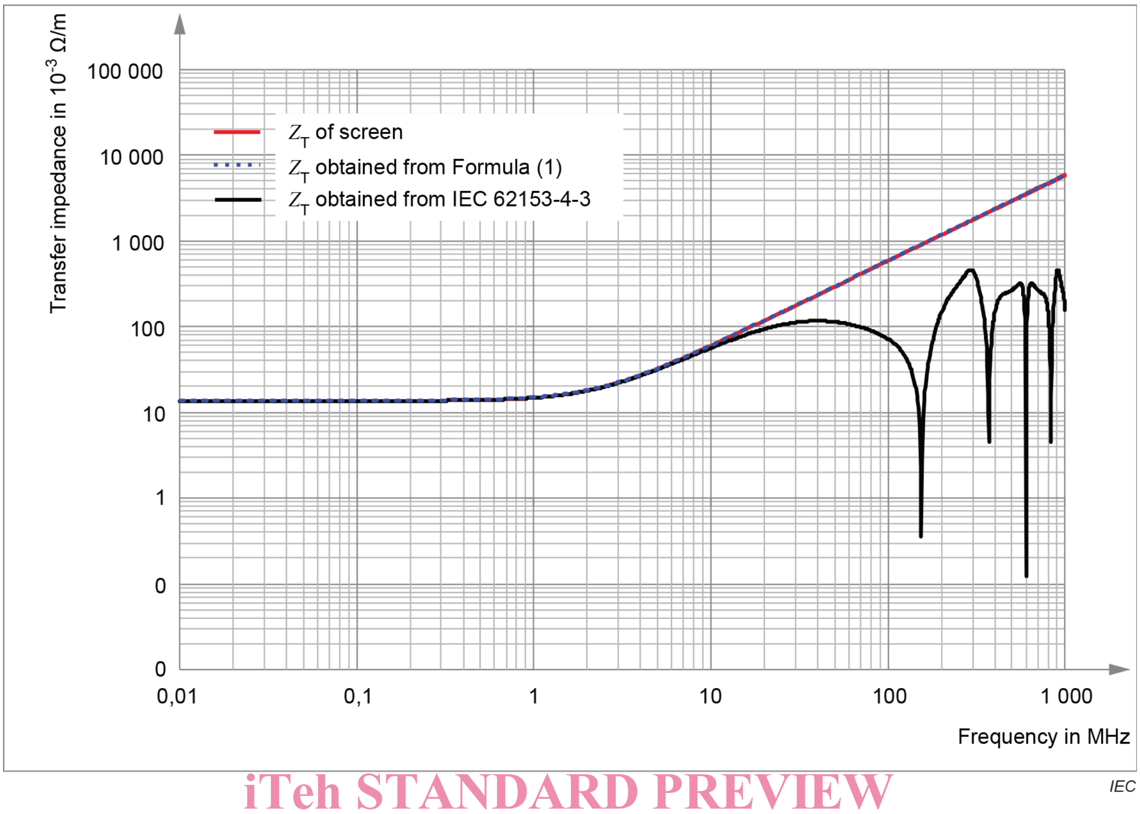


**Figure 2 – Comparison of formulae for conversion between forward transfer scattering parameter and transfer impedance**

The transfer impedance obtained from Formula (1) corresponds, as expected, to the transfer impedance obtained from the screen parameter ($R_T$, $M_T$, and $C_T$). But using Formula (12) described in IEC 62153-4-3:2013 to convert the measured forward transfer scattering parameter to transfer impedance limits the upper frequency for the transfer impedance to about 30 MHz.

## 6 Extrapolation of transfer impedance measurement results

### 6.1 General

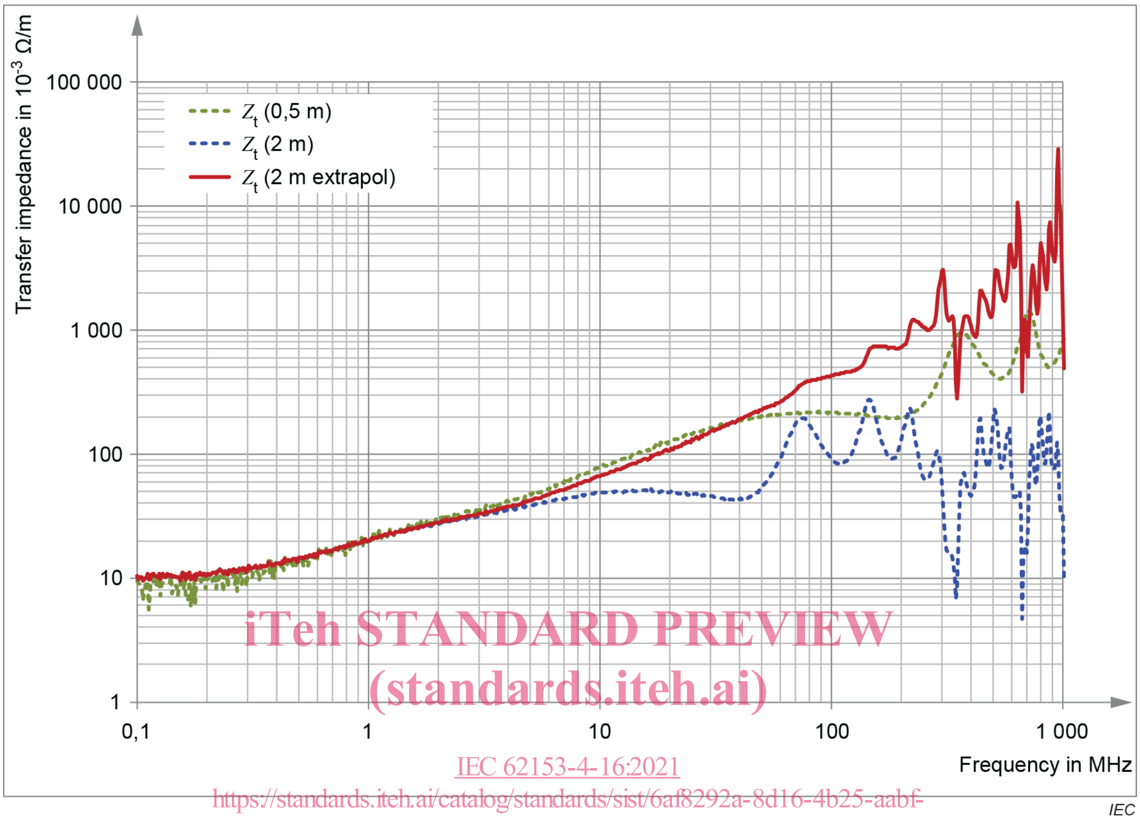
The test results of the transfer impedance shall be extrapolated to higher frequencies by using Formula (1) instead of the formulae detailed in IEC 62153-4-3 and IEC 62153-4-15 to convert the measured forward transfer scattering parameter $S_M$ to the transfer impedance.

### 6.2 Example of a measurement according to IEC 62153-4-3, Method B

Figure 3 shows an example of the extrapolation of the measured transfer impedance of an RG59 type cable. The measurement was done in accordance with IEC 62153-4-3, Method B (matched inner circuit) 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 circuit and outer circuit, respectively. The blue dotted line is the measurement result obtained with a coupling length of 2 m. The green dotted line is the measurement result 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 (1) 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.



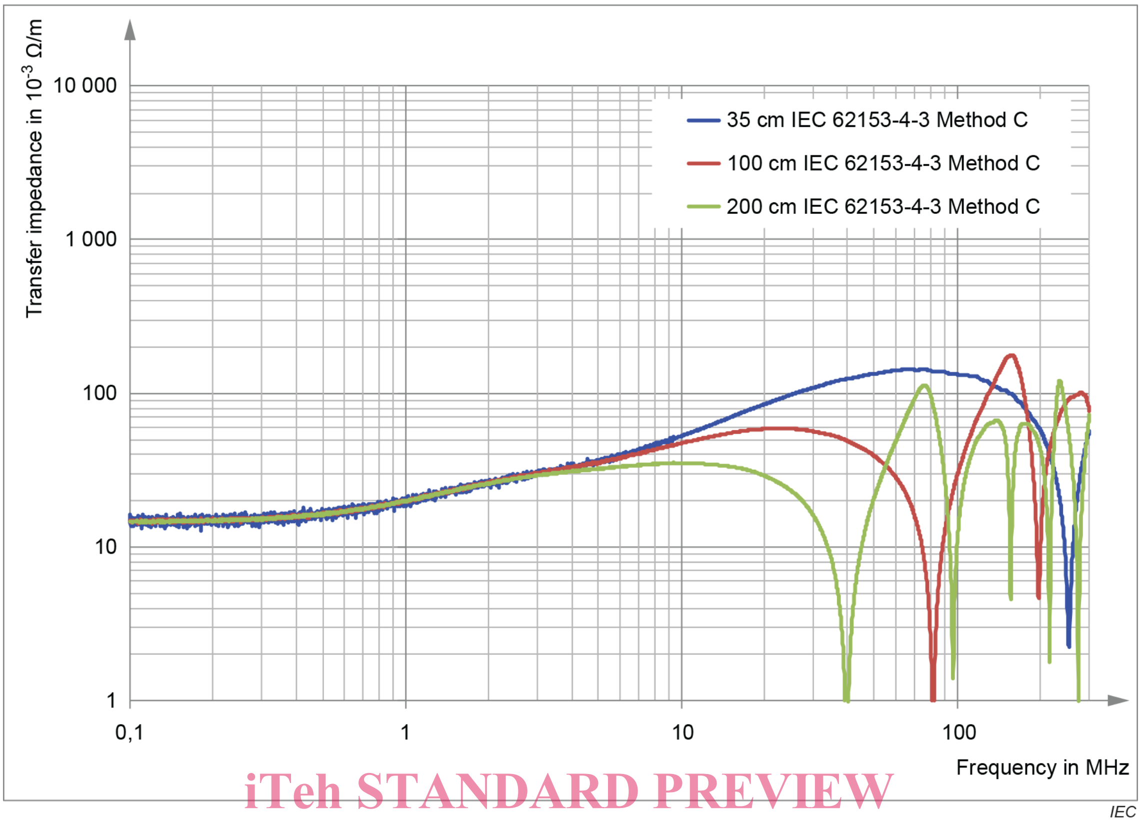
Cable measured with a coupling length of 2 m and assuming relative dielectric permittivity of 2,3 and 1,1 for the inner circuit and outer circuit, respectively.

**Figure 3 – Example of the extrapolation of the transfer impedance of an RG59 type cable**

### 6.3 Example of a measurement according to IEC 62153-4-3, Method C

Figure 4 shows the test results of transfer impedance measurement (IEC 62153-4-3, Method C) for a single braided coaxial cable with a 50 Ω impedance. The DUT is short circuited at the far end ($Z_{1f} = 0$). The results are shown for three different coupling lengths 35 cm, 100 cm and 200 cm. The cut-off frequency for the transfer impedance measurement decreases as the length increases, from 60 MHz for 35 cm to 10 MHz for 200 cm.

Figure 5 shows the conversion of the measured scattering parameter $S_M$ to the transfer impedance using Formula (1) instead of Formula (12) given in IEC 62153-4-3:2013. The conversion was done using a relative dielectric permittivity of the inner circuit (DUT) of 2,3 (PE dielectric) and 1,0 of the outer circuit (cable jacket was removed). The cut-off frequency was increased from 10 MHz for 200 cm and from 20 MHz for 100 cm respectively to 200 MHz. The observed residual peaks at higher frequencies are due to the capacitive coupling impedance $Z_F$ which is not exactly zero and due to uncertainties in the dielectric permittivity used in the conversion formula.



Cable with a 50 Ω impedance; inner circuit short circuit; coupling length 35 cm, 100 cm, 200 cm.

**Figure 4 – Measurement of transfer impedance of a single braided cable**