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Komunikacijski kabli - Specifikacije za preskusne metode - 1-11. del: Električne preskusne metode - Karakteristična impedanca, vhodna impedanca, povratne izgube

Communication cables - Specifications for test methods - Part 1-11: Electrical test methods - Characteristic impedance, input impedance, return loss

Kommunikationskabel - Spezifikationen für Prüfverfahren - Teil 1-11: Elektrische Prüfverfahren - Wellenwiderstand, Eingangsimpedanz, Rückflußdämpfung

Câbles de communication - Spécifications des méthodes d'essai - Partie 1-11: Méthodes d'essais électriques - Impédance caractéristique, impédance d'entrée, affaiblissement de réflexion

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European foreword

This document [EN 50289-1-11:2016] has been prepared by CLC/TC 46X "Communication cables".

The following dates are fixed:

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This document supersedes EN 50289-1-11:2001.

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1 Scope

This part of EN 50289 details the test methods to determine characteristic impedance, input impedance and return loss of cables used in analogue and digital communication systems.

It is to be read in conjunction with EN 50289-1-1, which contains essential provisions for its application.

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.

EN 50289-1-1:2001, *Communication cables - Specifications for test methods - Part 1-1: Electrical test methods - General requirements*

EN 50289-1-5:2001, *Communication cables - Specifications for test methods - Part 1-5: Electrical test methods - Capacitance*

EN 50289-1-7:2001, *Communication cables - Specifications for test methods - Part 1-7: Electrical test methods - Velocity of propagation*

EN 50290-1-2, *Communication cables - Part 1-2: Definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 50290-1-2 and the following apply.

3.1
characteristic impedance
$\boldsymbol{Z_C}$
(wave) impedance at the input of a homogeneous line of infinite length. The characteristic impedance Z_c of a cable is defined as the quotient of a voltage and current wave which are propagating in the same direction, either forwards or backwards.

$$Z_C = \frac{u_f}{i_f} = \frac{u_r}{i_r} \tag{1}$$

where

Z_c	is characteristic impedance;
$u_{f,r}$	is voltage wave propagating in forward respectively reverse direction;
$i_{f,r}$	is current wave propagating in forward respectively reverse direction.

3.2
mean characteristic impedance
Z_{cm}
in practice for real cables which always have structural variations the characteristic impedance is described by the mean characteristic impedance which is derived from the measurement of the velocity of propagation (EN 50289-1-7) and the mutual capacitance (EN 50289-1-5). However, this method is only applicable for frequencies above 1 MHz and non-polar insulation materials (i.e. materials having a dielectric permittivity which doesn't change over frequency). The mean characteristic impedance approaches at sufficiently high frequencies (≈100 MHz) an asymptotic value Z_∞

The characteristic impedance may be expressed as the propagation coefficient divided by the shunt admittance. This relationship holds at any frequency.

$$Z_c = \frac{\alpha + j\beta}{j\omega C(1 - j\tan\delta)} \approx \frac{\beta}{\omega C} - j\frac{\alpha}{\omega C} \quad (2)$$

where

Z_c is complex characteristic impedance (Ω);

α is attenuation coefficient (Np/m) ;

β is phase constant (rad/m);

tanδ is loss factor;

ω is circular frequency (s^{-1});

C is mutual capacitance (F/m).

At high frequencies, where the imaginary component of impedance is small, and the real component and magnitude are substantially the same we get for the mean characteristic impedance

$$Z_{cm} \approx \frac{\beta}{\omega \times C} = \frac{\tau_p}{C} = \frac{1}{v \times C} \quad (3)$$

Where

Z_{cm} is mean characteristic impedance (m);

v is velocity of propagation (m/s);

τ_p is phase delay (s/m);

C is mutual capacitance (F/m).

3.3
terminated input impedance
Z_{in}
impedance measured at the near end (input) when the far end is terminated by a load resistance of value equal to the system nominal impedance Z_R

3.4
open/short input impedance
***Z*OS**
impedance measured at the near end (input) when the far end is terminated with its own impedance. In practice this is the case when the round trip attenuation is greater than 40 dB at any measured frequency. This property takes into account structural variations in the cable. For samples with lower round trip loss it is determined by the open/short circuit method:

$$Z_{\mathrm{os}} = \sqrt{Z_{\mathrm{open}} \times Z_{\mathrm{short}}} \tag{4}$$

where

Z_{os} is input Impedance of the cable obtained from an open/short measurement;

Z_{open} is impedance with an open circuit at the far end of the cable;

Z_{short} is impedance with a short circuit at the far end of the cable.

3.5
fitted characteristic impedance
Z_{fit}
is obtained from a least square error function fitting of the open/short input impedance. The fitting can be applied on the magnitude, real and imaginary part of the input impedance. The fitted characteristic impedance is an alternative to the mean characteristic impedance to describe the characteristic impedance. It is only valid if the variations with frequency of the input impedance around its characteristic impedance are balanced.

3.6
(operational) return loss
RL
(operational) return loss is measured at the near end (input) when the far end is terminated by a load resistance of value equal to the system nominal impedance Z_{R}. It quantifies the reflected signal caused by impedance variations. The (operational) return loss takes into account the structural variations along the cable length and the mismatch between the reference impedance and the (mean) characteristic impedance of the cable (pair). If the (mean) characteristic impedance of the cable (pair) is different from the reference impedance, one gets, especially at lower frequencies (where the round trip attenuation is low), multiple reflections that are overlaid to the structural and junction reflections. Therefore, return loss *RL* is also referenced as operational return loss.

As an example, Figure 1, shows the operational return loss under different conditions. The blue line shows the return loss of a pair having a characteristic impedance equal to the reference impedance but taking into account that the impedance is varying with frequency (see right-hand graph). The red line shows the return loss of a pair having a characteristic impedance that is different from the reference impedance (110 Ω vs. 100 Ω). For both lines, periodic variations – that are caused by multiple reflections between the junctions at the near and far end – are observed. The green line shows a simulation of a pair having a frequency independent characteristic impedance which is equal to the reference impedance.

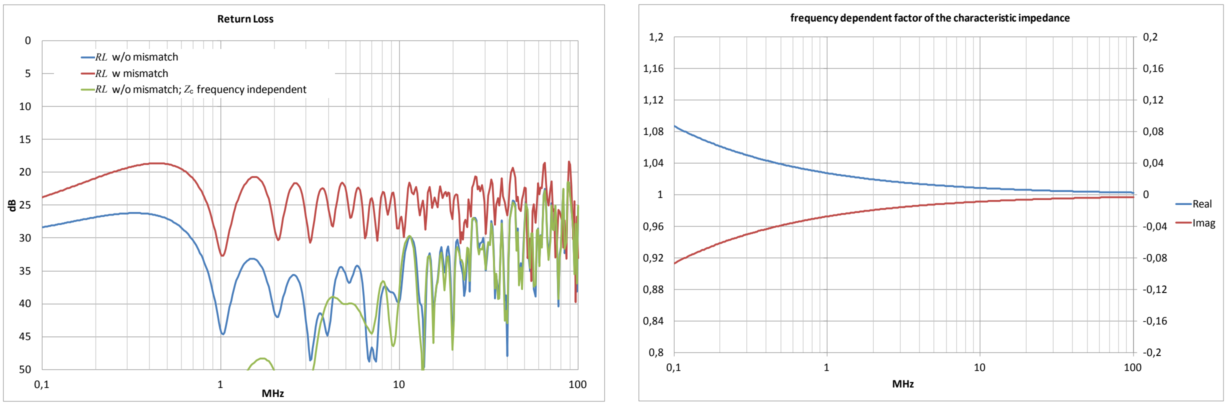

Figure 1 — Return loss with and without junction reflections

3.7
open/short return loss
OSRL

way to avoid in the measurement of return loss multiple reflections due to a mismatch between the characteristic impedance (asymptotic value at high frequencies) of the CUT and the reference impedance is to use a CUT terminated in its nominal impedance and having a very long test length such that the round trip attenuation of the CUT is at least 40 dB at the lowest frequency to be measured. For standard LAN cables, this would result in a CUT length of roughly 1 000 m for the lowest frequency of 1 MHz.

Another way (when long CUT length is not available) is to measure the characteristic impedance (open/short method) and to calculate the return loss. As the characteristic impedance is obtained from the measurement of the open and short circuit impedance, it is proposed to name such obtained return loss open/short return loss.

This open/short return loss includes the effect of structural variations and the mismatch at the near end (including the effect due to a frequency-dependent characteristic impedance), but it does not take into account multiple reflections.

Figure 2 shows the difference between operational return loss and open/short return loss. The left-hand graph shows the results of a pair having a characteristic impedance which is different from the reference impedance (110 Ω vs. 100 Ω). The right-hand graph shows the results of a pair having a characteristic impedance which is equal to the reference impedance (100 Ω). One may recognize that the open/short return loss does not take into account multiple reflections.

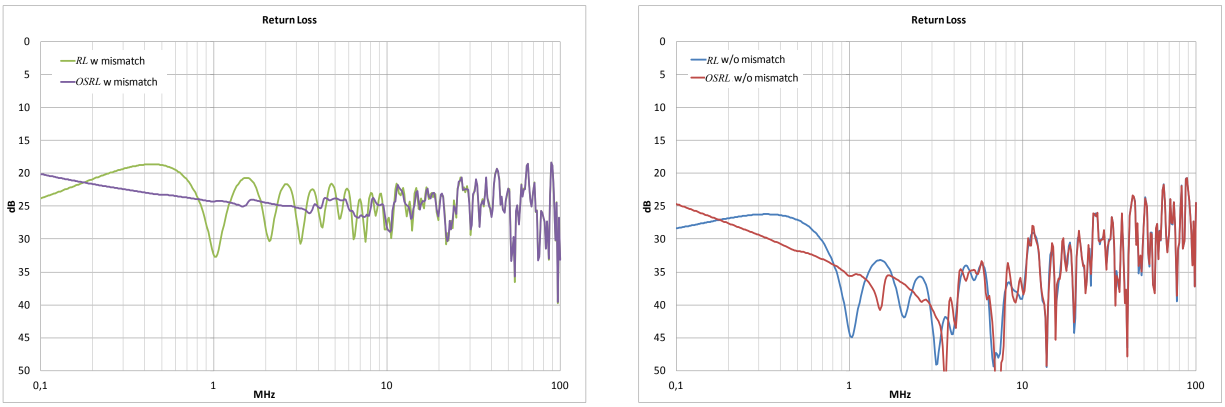

Figure 2 — Return loss and open/short return loss

3.8
structural return loss
SRL
The structural return loss is the return loss where only structural variations along the cable are taken into account. The mismatch effects at the input and output of the transmission line (including the effect due to a frequency-dependent characteristic impedance) have been eliminated. The structural return loss cannot be measured directly but is calculated from the measurement of the characteristic impedance (open/short method).

$$SRL = 20 \times \lg \left| \frac{Z_{\mathrm{os}} - Z_{\mathrm{fit}}}{Z_{\mathrm{os}} + Z_{\mathrm{fit}}} \right| \tag{5}$$

where

Z_{OS} is the (complex) input impedance obtained from the measurement of the open and short circuit impedance;

Z_{fit} is the (complex) characteristic impedance obtained from a curve fitting of the real and imaginary part of ZOS.

The left-hand graph of Figure 3 shows the operational return loss, open/short return loss and structural return loss of a CUT having a characteristic impedance of 110 Ω. A difference between both is observable. The operational return loss takes into account all effects (structural variations, mismatch effects at the input and output). The open/short return loss does not take into account mismatch effects at the output (i.e. no multiple reflections). Whereas the structural return loss only takes into account structural variations along the cable.

The right-hand graph shows the real and imaginary part of the mean characteristic impedance (obtained from the measurement of the open and short circuit impedance) and it's fitting.

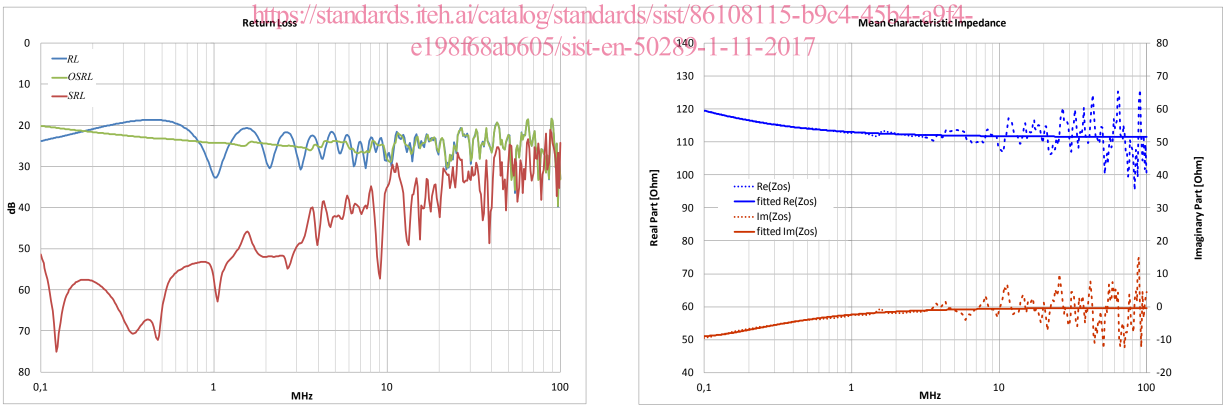

Figure 3 — Return loss, open short return loss and structural return loss

3.9
parasitic inductance corrected return loss
PRL
return loss where the effect a parasitic inductance (due to sample preparation and/or test fixture), which is observed as an increase of the input impedance at high frequencies (above 100 Mhz), has been corrected

3.10
gated return loss
GRL
return loss where the effect of the test fixtures and sample preparation, which is observed as an increase of the input impedance at high frequencies (above 100 MHz), has been corrected by a gating function

3.11
fitted return loss
FRL
return loss where the effect of the test fixtures and sample preparation, which is observed as an increase of the input impedance at high frequencies (above 100 MHz), has been corrected by applying fitting function on the input impedance

4 Test method for mean characteristic impedance (S_{21} type measurement)

4.1 Principle

This method shall only be applied for cables having non-polar insulation materials (e.g. PE, PTFE), i.e. materials having a dielectric permittivity which doesn't change over frequency. Or in other words this method shall only be applied to cables having a mutual capacitance which doesn't change over frequency.

The mean characteristic impedance shall be derived from the measurement of the velocity of propagation, respectively phase delay, according to EN 50289-1-7 and the mutual capacitance according EN 50289-1-5. The measurement shall be carried out at frequencies above 100 MHz where the phase delay approaches an asymptotic value.

4.2 Expression of test results

The mean characteristic impedance Z_{cm} shall be derived from Formula (6):

$$Z_{\mathrm{cm}} = \frac{\tau_p}{C} = \frac{1}{v \times C} \quad (6)$$

where

- Z_{cm} is mean characteristic impedance (Ω);
- v is velocity of propagation (m/s), measured according EN 50289-1-7;
- τ_p is phase delay (s/m), measured according EN 50289-1-7;
- C is mutual capacitance (F/m), measured according EN 50289-1-5.

5 Test method for input impedance and return loss (S_{11} type measurement)

5.1 Method A: measurement of balanced cables using balun setup

5.1.1 Test Equipment

The test equipment consists of a 2-port vector network analyser (VNA) with:

— S-parameter set-up;