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TECHNICAL REPORT

colour inside

Multicore and symmetrical pair/quad cables for digital communications – Part 1-5: Correction procedures for the measurement results of return loss and input impedance

IEC/TR 61156-1-5:2013(E)

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

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MULTICORE AND SYMMETRICAL PAIR/QUAD CABLES FOR DIGITAL COMMUNICATIONS –

Part 1-5: Correction procedures for the measurement results of return loss and input impedance

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IEC/TR 61156-1-5, which is a technical report, has been prepared by subcommittee SC46C: Wires and symmetric cables, of IEC technical committee TC46: Cables, wires, waveguides, R.F. connectors, R.F. and microwave passive components and accessories.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
46C/973/DTR	46C/979/RVC

Full information on the voting for the approval of this technical report 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 61156 series, published under the general title *Multicore and symmetrical pair/quad cables for digital communications*, 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 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- withdrawn,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.

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

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MULTICORE AND SYMMETRICAL PAIR/QUAD CABLES FOR DIGITAL COMMUNICATIONS –

Part 1-5: Correction procedures for the measurement results of return loss and input impedance

1 Scope

This part of IEC 61156 describes correction procedures for the measurement results of return loss and input impedance.

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.

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

IEC/TR 61156-1-2, *Multicore and symmetrical pair/quad cables for digital communications – Part 1-2: Electrical transmission characteristics and test methods of symmetrical pair/quad cables*

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

IEC 62153-1-1, *Metallic communication cables test methods – Part 1-1: Electrical – Measurement of the pulse/step return loss in the frequency domain using the Inverse Discrete Fourier Transformation*

ASTM D4566:1998, *Standard Test Methods for Electrical Performance Properties of Insulations and Jackets for Telecommunications Wire and Cable*

3 Acronyms

CUT cable under test

FRL fitted return loss

GRL gated return loss

IFDT Inverse discrete Fourier transformation

OSRL open short return loss

PRL parasitic inductance corrected return loss

RL return loss

SRL structural return loss

4 Return loss measurements

4.1 General

The return loss of a transmission line (cable) can be obtained by different test methods, each having certain advantages and/or disadvantages and therefore giving not exactly the same results. At higher frequencies, the measured return loss is strongly influenced by the cable end preparation (stray inductances and capacitances play an important role) leading to an underestimated cable performance. Under laboratory conditions, one might be able to minimize this negative effect; however under general industrial conditions using automated test systems, one might need mathematical procedures to eliminate the effect of the cable end preparation.

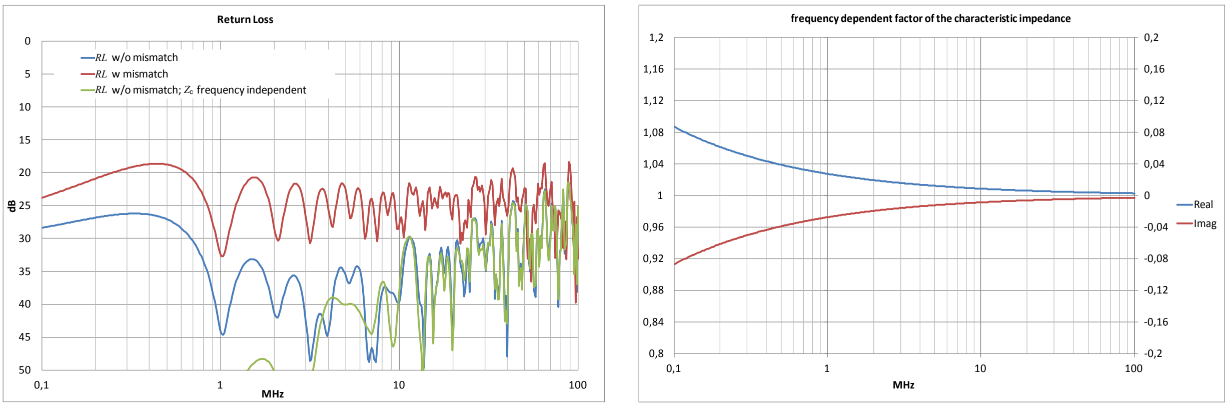
The results of return loss measurements may also depend on the sample length. Therefore, for balanced cables according to IEC 61156 series, the specified sample length is at least 100 m (if not specified otherwise).

4.2 Return loss (*RL*)

The return loss is obtained by measuring the scattering parameter $S11$ using a test apparatus of which the test port has the same reference impedance than the cable under test, and where the far end of the cable is terminated with its reference impedance (See IEC/TR 62152, IEC 61156-1). The return loss takes into account the structural variations along the cable and the mismatch between the reference impedance and the (mean) characteristic impedance of the pair. If the (mean) characteristic impedance of the 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.

NOTE The impedance of a homogenous transmission line is a complex quantity where the real part is decreasing with frequency and tending to an asymptotic value, the so called characteristic impedance and the imaginary part is also decreasing from negative values to zero. This "normal" behaviour of a transmission line will also generate multiple reflections.

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, we observe periodic variations that are caused by multiple reflections between the junctions at the near and far end. The green line shows a simulation of a pair having a frequency independent characteristic impedance which is equal to the reference impedance.



IEC 1612/13

Figure 1 – Return loss with and without junction reflections

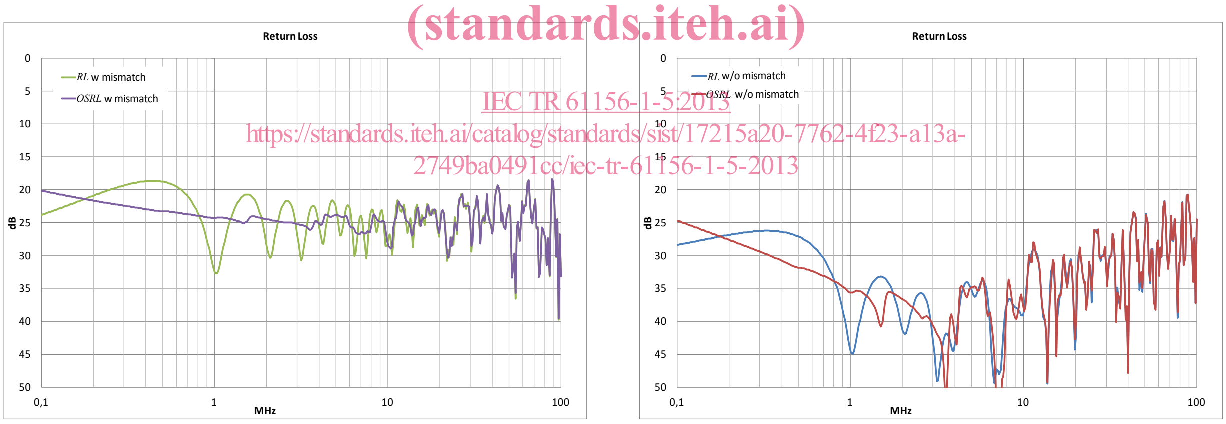
4.3 Open/short return loss (*OSRL*)

A 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, see IEC/TR 62152) 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). We recognize that the open/short return loss does not take into account multiple reflections.



IEC 1613/13

Figure 2 – Return loss and open/short return loss

4.4 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 (see IEC/TR 62152). The structural return loss cannot be measured directly but is calculated from the measurement of the characteristic impedance (open/short method).

$$SRL = 20 \cdot \log_{10} \left| \frac{Z_{CM} - Z_C}{Z_{CM} + Z_C} \right| \quad (1)$$

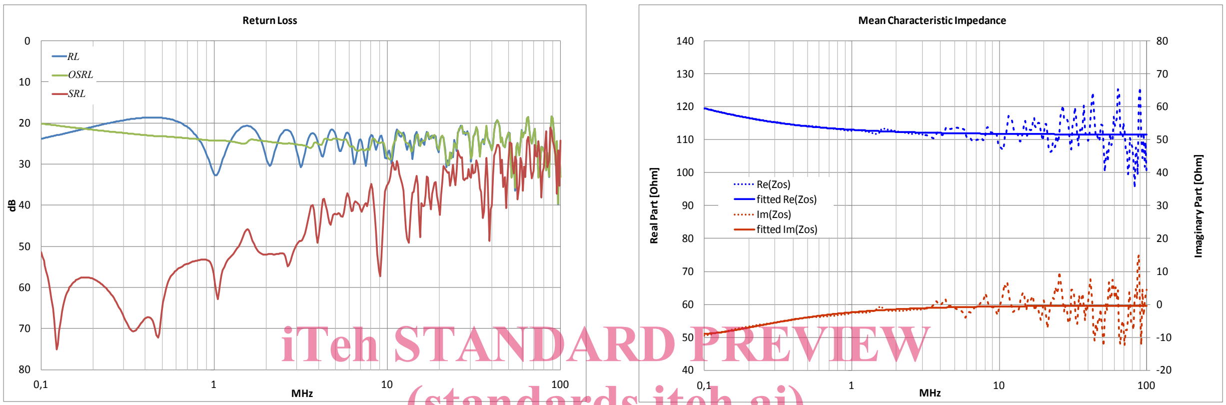
where

Z_{CM} is the (complex) mean characteristic impedance obtained from the measurement of the open and short circuit impedance;

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

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. We clearly see the differences between them. 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.



IEC 1614/13

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

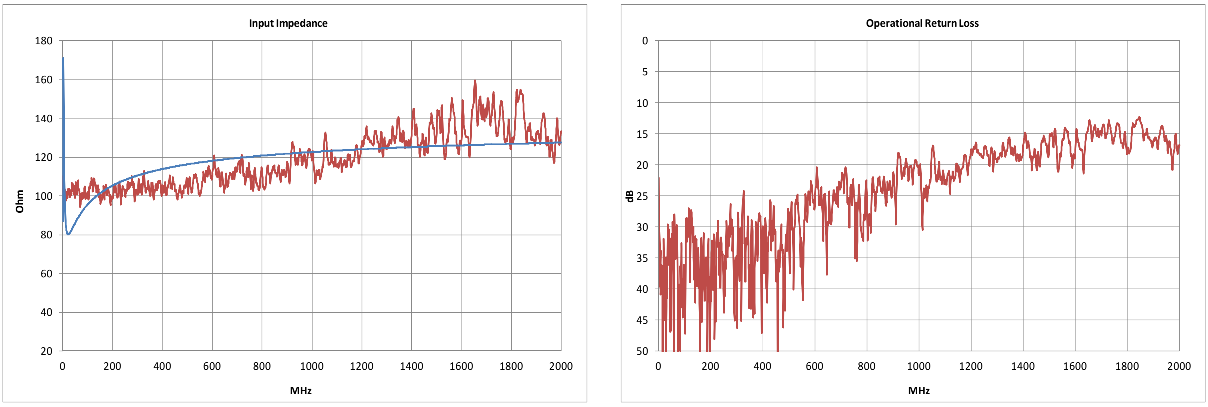
5 Correction procedures

5.1 General

From the transmission line theory we know that the characteristic impedance is decreasing with frequency and approaching an asymptotic value (assuming dielectrics having an almost frequency-independent dielectric constant). Therefore an asymptotic value is assumed in the described correction procedures.

However measurements at higher frequencies often show an increase of the characteristic impedance. This is due to the cable end preparation and related stray inductances and capacitances. In fact we can consider the CUT as a cascade of 3 transmission lines, the two cable ends and the cable, or even 5 lines taking into account the test fixtures.

Figure 4 shows the results of an S/FTP cable obtained with an automated test system. On the left-hand side we see the input impedance (magnitude) and its fitting and on the right-hand side the operational return loss. One can recognize the above-described effect of increasing impedance and related decreasing return loss. Thus correction procedures are needed.

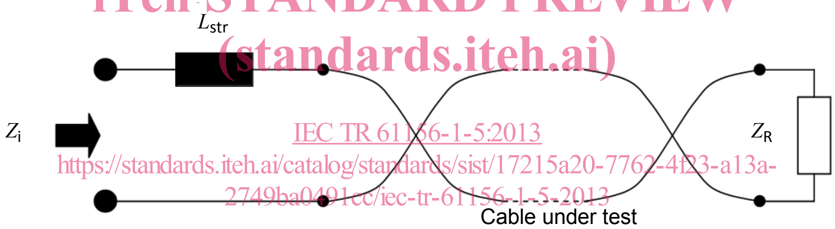


IEC 1615/13

Figure 4 – Input impedance (magnitude) and operational return loss up to 2 GHz

5.2 Parasitic inductance corrected return loss (*PRL*)

The characteristic impedance of an ideal cable is at high frequencies constant and only has a real part. Measuring the input impedance Z_i of a cable in contrast often shows a steady increase with frequency. The same effect can be seen measuring the return loss. This is mainly due to a parasitic inductance L_{str} in the zone of the connection to the measurement equipment. The correction procedure is based on the equivalent circuit shown in Figure 5.



IEC 1616/13

Figure 5 – Equivalent circuit for the corrective calculation

The stray inductance L_{str} is calculated from the imaginary part of the complex input impedance Z_i at specific frequencies. The input impedance is then corrected using the stray inductance. From the corrected input impedance, a corrected return loss can be calculated.

The calculation of the corrected input impedance and the return loss data is done in the following steps:

For frequencies higher than 30 MHz up to the half of the maximum measurement frequency f_{max}, the value of stray inductance is calculated for every measurement frequency point:

$$L_{str} = \frac{\mathrm{Im}(Z_i)}{2\pi f} \tag{2}$$

where

f is the frequency, in Hz, and 30 MHz $\leq f \leq f_{max}/2$;

L_{str} is the stray inductance;

Z_i is the measured input impedance.

Then the mean value $L_{str,m}$ and the standard deviation L_{stad} of the stray inductance are calculated: