IEC/PAS 62260

Edition 1.0
2001-08

Pulse/Step Return Loss from measurement in the frequency domain using the Inverse Discrete Fourier Transformation (IDFT)

PUBLICLY AVAILABLE SPECIFICATION

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FOREWORD

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IEC-PAS 62260 has been processed by IEC subcommittee 46C: Coaxial cables, of IEC technical committee 46: Cables, wires, waveguides, r.f. connectors and accessories for communication and signalling.

The text of this PAS is based on the following document: | This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:

Draft PAS	Report on voting
46A/415/PAS	46A/440/RVD

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PULSE/STEP RETURN LOSS FROM MEASUREMENT IN THE FREQUENCY DOMAIN USING THE INVERSE DISCRETE FOURIER TRANSFORMATION (IDFT)

1 General

The test determines the regularity of impedance of RF-cables by measuring the return loss in the frequency domain using a vector network analyser equipped with a reflection test set (bridge) and transfer them into the time domain by using the Inverse Discrete Fourier Transformation (IDFT). The Pulse/Step Return Loss is displayed against time to show the magnitude and the local distribution of irregularities of the characteristic impedance of the cable under test. Depending on the number of points of the network analyser cable length up to and above 5km may be measured.

2 Principle

The test determines the return loss of coaxial RF-cables in the time domain by measuring the return loss in the frequency domain, and transforming the results into the time domain by using the Inverse Discrete Fourier Transformation (IDFT).

The network analyser measures the magnitude and phase of the CUT's return loss (S11) in the frequency domain at discrete frequencies specified by the harmonic portions contained in an equivalent time domain pulse of predetermined shape. After processing a complete sweep over these frequencies the network analyser has collected the spectral representation of the cable's pulse answer into memory. The pulse answer in time domain representation can be calculated now by applying a mathematical algorithm called Inverse Discrete Fourier Transformation (IDFT) to the stored data. Because from the mathematically point of view the pulse is the derivative of the step, the response to a step function can be computed easily by integrating the pulse response data over time.

The Discrete Fourier Transformation calculates the complex factors H_n of the sine and cosine waves contained in an arbitrary waveform. The Inverse Discrete Fourier Transformation synthesises a complex arbitrary waveform by calculating the sum of the sine and cosine functions multiplied with the complex Fourier transforms H_n. The transformation does not depend on any dimensional parameter such as a time scale or frequency.

Because the actual measurements are made in the frequency domain, the calibration of the network analyser has to be done in the frequency domain as well using a full one port calibration for reflection measurements.

3 Equations

The performance of a RF-cable depends on its mechanical homogeneity. Deviations in its mechanical dimensions will cause reflections of the RF-signal which is travelling through the cable. The complex reflection factor $\underline{r}_{rx}$ of such a reflection is given by:

$$\underline{r}_{rx} = \frac{Z_0 - \underline{Z}_x}{Z_0 + \underline{Z}_x} \qquad (1)$$

where
Z_0 is the nominal impedance of the cable
$\underline{Z}_x$ is the actual impedance of the cable on a given point x.

The transformation of one single reflection to the cables input with attention to the attenuation and propagation is given by:

$$\underline{r}_x = \underline{r}_i \cdot e^{-2\cdot\gamma\cdot l} \qquad (2)$$

where γ is the propagation constant

$$\gamma = \alpha + j\beta \qquad (3)$$

where
l is the distance of the single reflection from the input of the cable
α is the attenuation constant
β is the phase constant

Using the velocity ratio v_r of the CUT, the distance d_{rx} towards the location of the fault can be calculated by:

$$d_{rx} = \frac{t_{rx} \cdot c_0 \cdot v_r}{2} \qquad (4)$$

where

t_{rx}	is the time between the stimulating pulse and detection of the pulse answer in s.
c_0	is the propagation velocity in free space in m/s.
v_r	is the velocity ratio of the CUT.

The maximum resolution in the time axis depends on the shape and width of the stimulating pulse as stated in IEC 61196-1 sub clause 11.16.4. It is inversely proportional to the highest frequency portion contained in the pulse.

The pulse return loss a_p is defined as:

$$a_p = 20 \cdot \log(r_{rx}) + a_{win} \quad \text{in dB} \qquad (5)$$

where

$r_{r.x}$	is the reflection coefficient of an irregularity at a distance x from the cable end and measured at the input end of the cable.
a_{win}	is the constant factor added for the correction of the different windowing functions. For the square window this factor can be set to 0 dB.

The width of the virtual impulse t_p is inversely proportional to the measurement span:

$$t_p = \frac{b_{win}}{f_{stop} - f_{start}} \quad \text{in s} \qquad (6)$$

where

b_{win}	is the constant factor representing the bandwidth correction of the windowing function. For the square window this factor can be set to 1.
f_{start}	is the start frequency of the sweep in the frequency domain in Hz.
f_{stop}	is the stop frequency of the sweep in the frequency domain in Hz. The stop frequency has to meet the requirement $f_{stop} = n \cdot f_{start}$ where n is the number of measured points to fulfill the harmonic relation between the frequencies needed for the IDFT.

NOTE To fulfil the requirements of the IDFT the frequency points in the frequency domain have to be chosen in a harmonic relation. The first frequency in the sweep defines the fundamental f_g, the second frequency in the sweep gives the first harmonic $2 \cdot f_g$, the third frequency gives the second harmonic at $3 \cdot f_g$ etc. until the highest frequency is reached.

The rise time t_r of the virtual impulse is half the width of the virtual impulse:

$$t_r = \frac{t_p}{2} \quad \text{in s} \qquad (7)$$

The minimum time interval Δt_{min} between two points can be calculated by:

$$\Delta t_{\min} = \frac{2}{f_{stop} - f_{start}} \quad \text{in s} \qquad (8)$$

where

f_{start}	is the start frequency of the sweep in the frequency domain in Hz.
f_{stop}	is the stop frequency of the sweep in the frequency domain in Hz. The stop frequency has to meet the requirement $f_{stop} = n \cdot f_{start}$ where n is the number of measured points to fulfil the harmonic relation between the frequencies needed for the IDFT.

The minimum resolution Δx_{min} can be calculated by:

$$\Delta x_{min} = \Delta t_{min} \cdot c_0 \cdot v_c \qquad \text{in m} \qquad (9)$$

where

Δt_{min}	is the minimum time intervall in s.
c_0	is the propagation velocity in free space in m/s.
v_c	is the velocity ratio for the CUT.

The maximum time t_{max} contained in the result can be calculated by:

$$t_{max} = \frac{\Delta t_{min} \cdot n}{2} \qquad \text{in s} \qquad (10)$$

where

Δt_{min}	is the minimum time interval in s.
n	is the total number of measured points in the frequency domain.

NOTE Because of the cyclical character of the Inverse Discrete Fourier Transformation the results of interest are contained in the points *0* to *n / 2*. The points *n / 2 + 1* to *n* contain information about the behaviour of the system for negative values on the time axis.

The maximum distance l_{max} covered by the measurement can be calculated by:

$$l_{max} = t_{max} \cdot c_0 \cdot v_c \qquad \text{in m} \qquad (11)$$

where

t_{max}	is the maximum time contained in the result.
c_0	is the propagation velocity in free space in m/s.
v_c	is the velocity ratio for the CUT.

From these values the distance toward the location of interest d_{rx} can be calculated by:

$$d_{rx} = k \cdot \Delta t_{min} \cdot c_0 \cdot v_c \qquad \text{in m} \qquad (12)$$

where

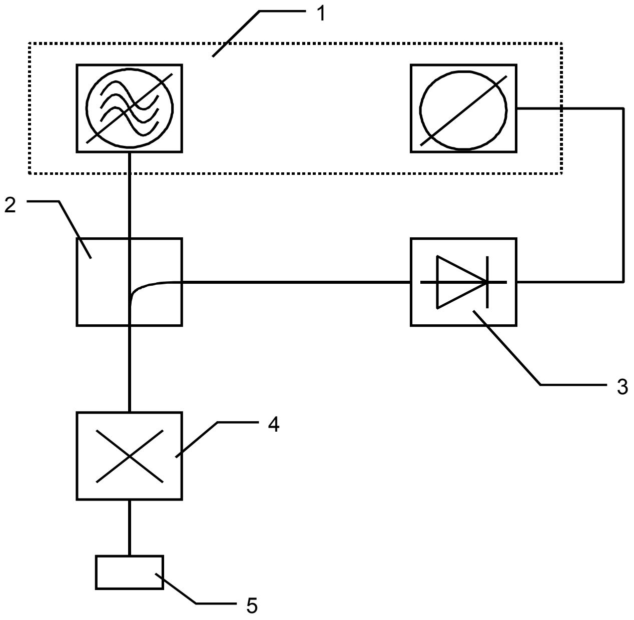
k	is the actual number of the data point containing the complex values of interest ranging from 0 to n - 1.
Δt_{min}	is the minimum time interval in s.
c_0	is the propagation velocity in free space in m/s.
v_c	is the velocity ratio for the CUT.

4 Procedure

4.1 Equipment

The test equipment to measure the return loss in the frequency domain shall be assembled generally in accordance with the circuit arrangements shown in figure 1.

The minimum number of points to measure should be set in accordance with 11.12 of IEC 61196-1.



1 network analyser
2 bridge
3 demodulator
4 cable under test
5 termination load

Figure 1 - Layout for return loss measurement in the frequency domain

4.2 Preparation of test specimen

Unless otherwise specified, the length of the test specimen shall be such that the composite loss at the lowest test frequency is at least 6 dB. If this cannot be achieved the minimum cable length shall be not less than 100m.

Test connectors with small inherent reflections shall be fitted on both ends of the CUT to allow direct connection to the bridge as well as to the terminating load.

4.3 Calibration

The calibration of the test equipment should be done using a full one port calibration (short - open - termination), which removes the residual errors of the bridge and test port, according to the manufacturer of the equipment.

4.4 Attenuation constant

The attenuation constant of the CUT shall be measured in accordance with subclause 11.13 of IEC 61196-1.

5 Expression of results

The pulse return loss a_p loss shall be displayed against cable length.

The magnitude of the curve shall be corrected by using two times the complex attenuation $\underline{\gamma}$ of the cable from the cables input to the reflection point r_x:

$$a_{pcorr} = a_p \cdot e^{2 \cdot \underline{\gamma} \cdot d_{rx}} \quad (13)$$

where

a_p is the uncorrected pulse return loss.
$\underline{\gamma}$ is the complex attenuation constant of the CUT.
d_{rx} is the distance to the location of interest.