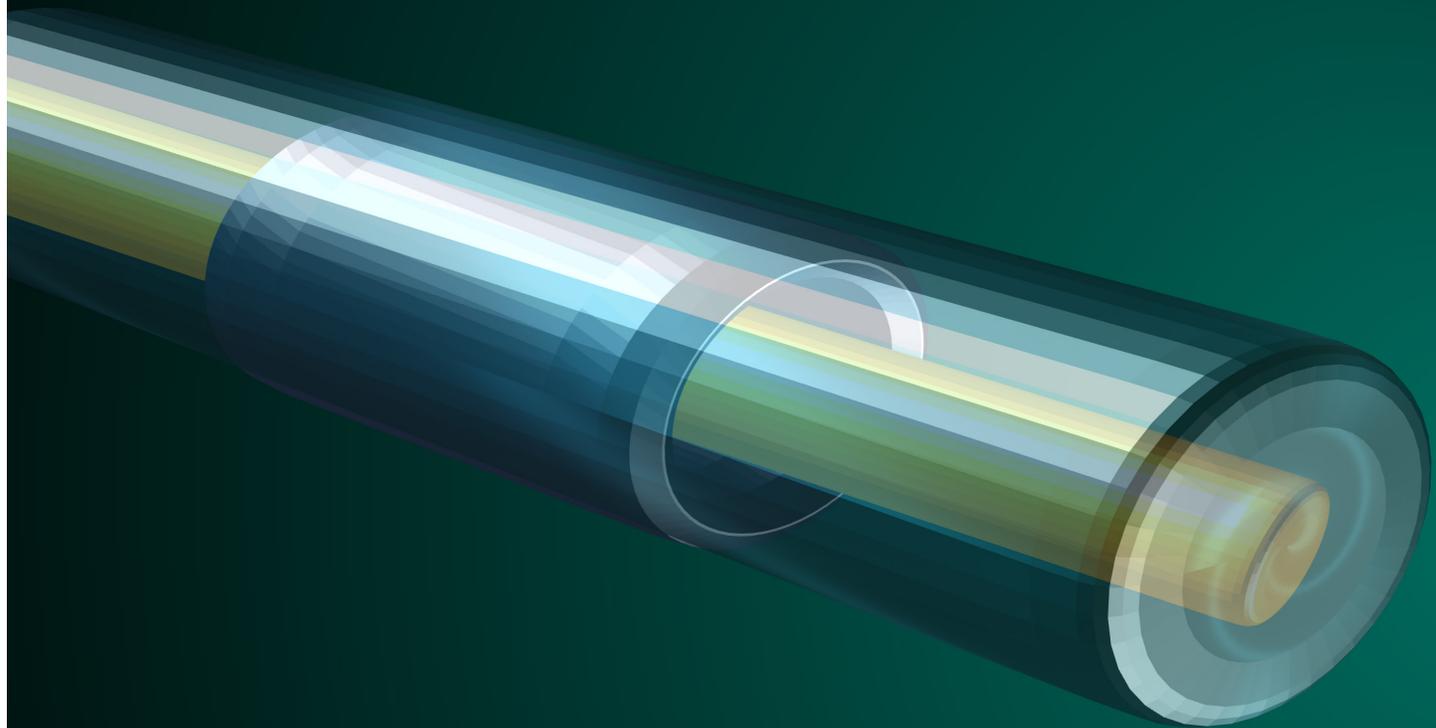


TDR SIMULATION FOR a DISCONTINUOUS COAXIAL CABLE



S-PARAMETERS ALONG WITH TDR SIMULATIONS FOR A DISCONTINUOUS COAXIAL CABLE

Description

A coaxial cable with discontinuities (figure 1) is analyzed using the Time-Domain Reflectometry (TDR) solution of the S-parameter module of HFWorks. This is done by sending a pulse signal through the entry port of the cable, and reviewing the reflection produced by the other end of the cable. The shown cable model has three sections separated by discontinuous transitions. An individual section is treated as a transmission line of 50 Ohms.

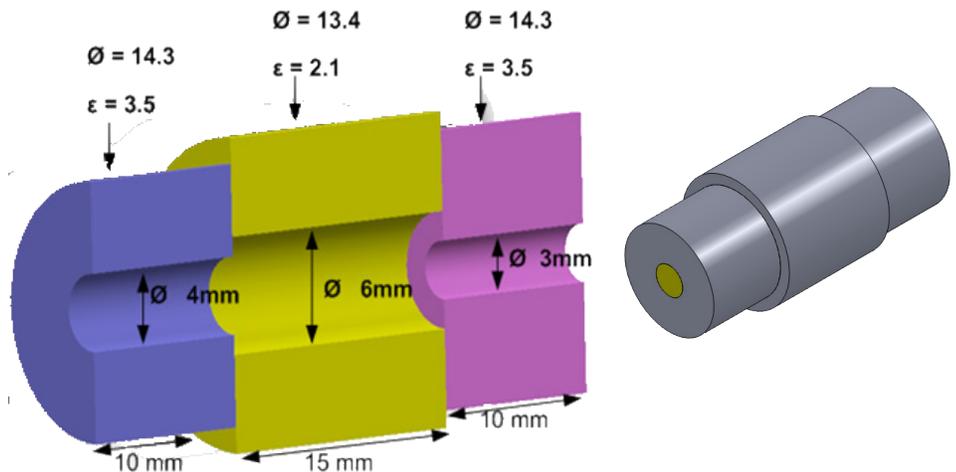


Figure 1: Coaxial cable with discontinuities

The TDR module can determine the impedance through the path of propagation of the pulse from the starting port to the receiving port. The designer can then understand where the reflections occur, and determine what may have caused them.

Simulation

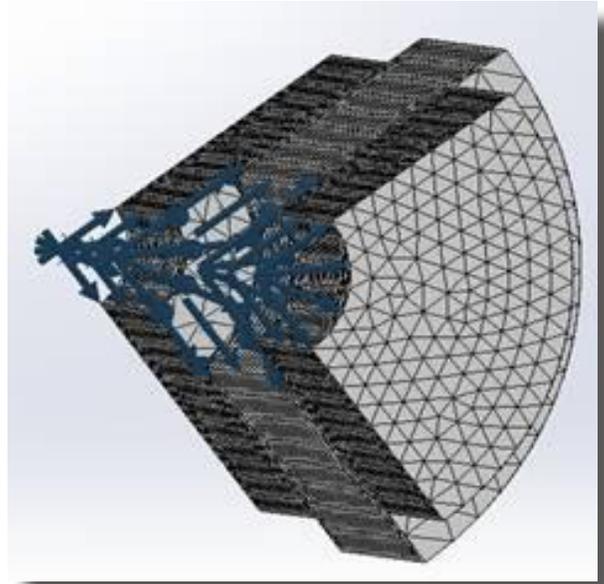
Simulating this discontinuous coaxial cable portion in an S-parameters-study in HFWorks enables us to investigate its behavior in the frequency domain (through its scattering parameters) as well as its reflectometry properties in time domain (through the TDR simulation found below the scattering parameters simulation settings). Switching the signals expressions to time domain from expressions outputted by FEM in the frequency domain

get a clearer idea about the behavior of the structure in the frequency domain. The results of the simulation requires an IFFT on a number of samples of frequencies (at least two frequencies); Thus, a TDR simulation is not allowed for a single-frequency S- parameters simulation in HFWorks. As a first step, we perform an S-parameter simulation of the structure, in order to

can be seen in Figure 2. The reflection coefficient S11 reaches more than -25 dB at 5 GHz. Then, the results of this frequency domain analysis will serve as the input of an IFFT before running the TDR analysis.

Solids and Materials

FIGURE 1 SHOWS A THREE PARTS ASSEMBLY OR STRUCTURE WITH SIMILAR SHAPES BUT SLIGHTLY DIFFERENT DIMENSIONS AND RELATIVE PERMITTIVITIES. IT IS FROM THESE DIFFERENCES THAT ORIGINATE THE DISCONTINUITIES MENTIONED IN THE TITLE. THE PREDEFINED MATERIAL FOR THESE BLOCKS OR BODIES HAS A RELATIVE PERMITTIVITY OF 2.1 FOR THE PART IN THE MIDDLE AND 3.5 FOR THE LATERAL ONES. WHEN INJECTED INTO THE ALGORITHMS CALCULATIONS, THESE PARAMETERS MAKE THE MODEL HETEROGENEOUS AND THUS DISCONTINUITIES OCCUR IN THE EXPRESSIONS OF THE ELECTRICAL PARAMETERS (VOLTAGE, CURRENT, IMPEDANCE, EXCITATION). THE PLOTS OF THESE EXPRESSIONS ARE THE KEY FEATURES FOR THE INVESTIGATION OF ANY TRANSMISSION MODEL'S INTERNAL STRUCTURE.



The materials have all isotropic permittivity type. Thus, the permittivity parameter is a scalar (For orthotropic material, the permittivity is a 3 by 3 matrix).

Boundary Conditions

In this example, we suppose that we have a Pure TEM propagation; so the check-box "Pure TEM" in the first port is active. Maxwell's equations state that in order to get TEM propagation in a hollow waveguide (single conductor), we must have a second conductor (signal boundary condition); otherwise, we would have the trivial solution (zero electric field) for Maxwell's equation. Therefore, we assign a signal boundary condition besides the TEM ports. Using boundary conditions along with symmetry (PECS or PMCS) reduces the time of calculations and makes it easier for the simulator to give more realistic results since the contribution of the symmetric portions of the model are automatically taken into account. Considering the electric field direction regarding a face or a plane, we can tell whether we need a magnetic or electric boundary.

Meshing

Accurate meshing has to be applied to the most important surfaces such as the carrier of the RF signal or the pads of signal injection, which means the port in the middle of the structure. The mesher of HFWorks calculates the average mesh element size based on the applied mesh controls specified by the user; Then, volume meshing is performed. The mesh elements have smaller size when we approach the surfaces to which the mesh controls are applied; in our case the inner wire of the coaxial cable.

Results

As mentioned within the beginning of this report, HFWorks uses the FEM solver which runs the calculations of the Maxwell's equation solution in the frequency domain. Thus, to get the reflected waves' expressions calculated, an IFFT has to be applied to the different fields frequency-domain expressions. These expressions will be the means of calculating impedance, voltage and current measured at the considered port. The following figure illustrates the S11 plot in the frequency range 0.625 GHz to 40 GHz. This frequency window should be large enough to compute the IFFT of the different signals.

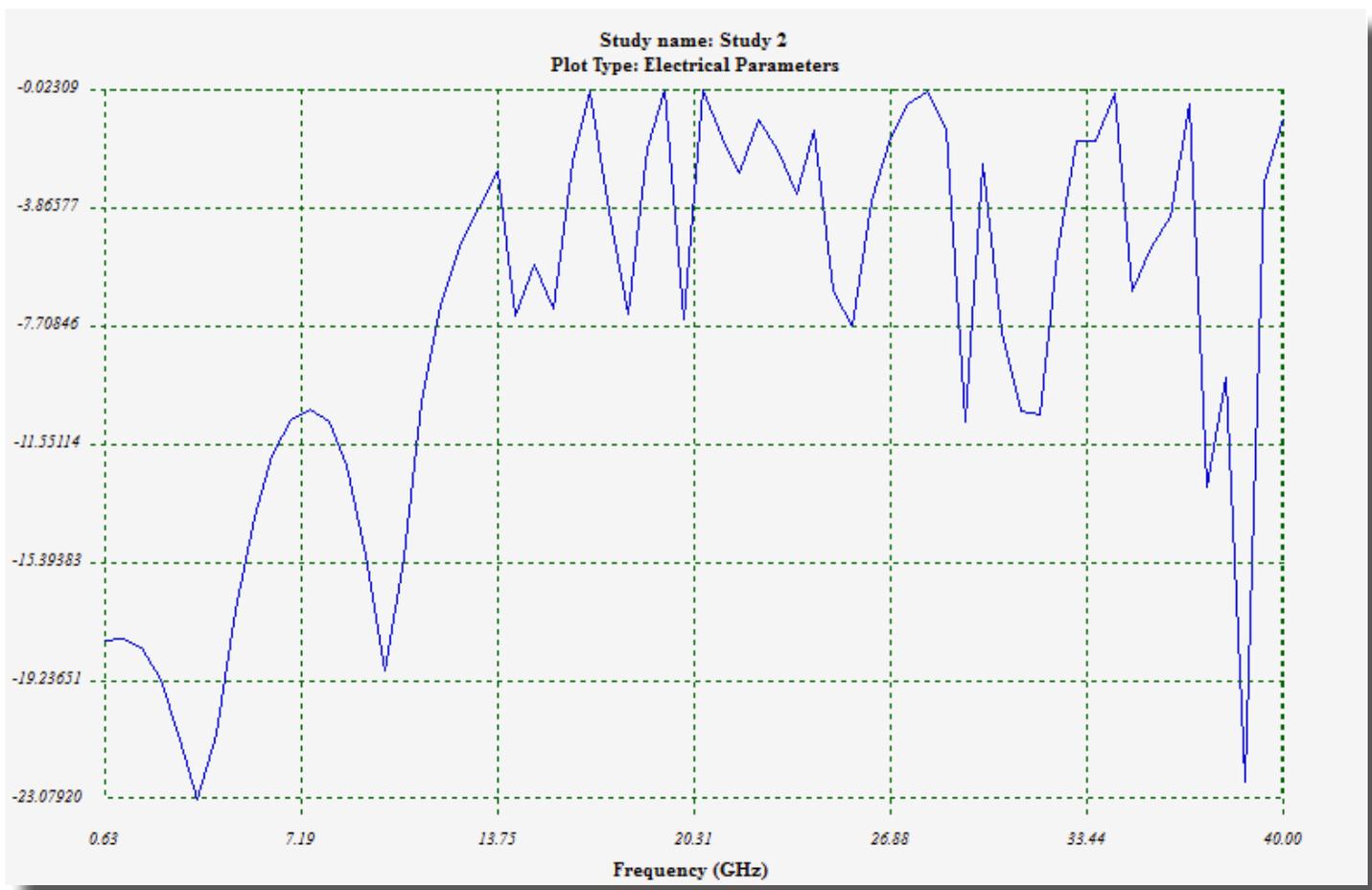


Figure 3: Reflection coefficient at port 1

The results of the simulations require some knowledge about TDR theory in order to get convenient interpretations. The following figure shows a recapitulation of TDR displays:

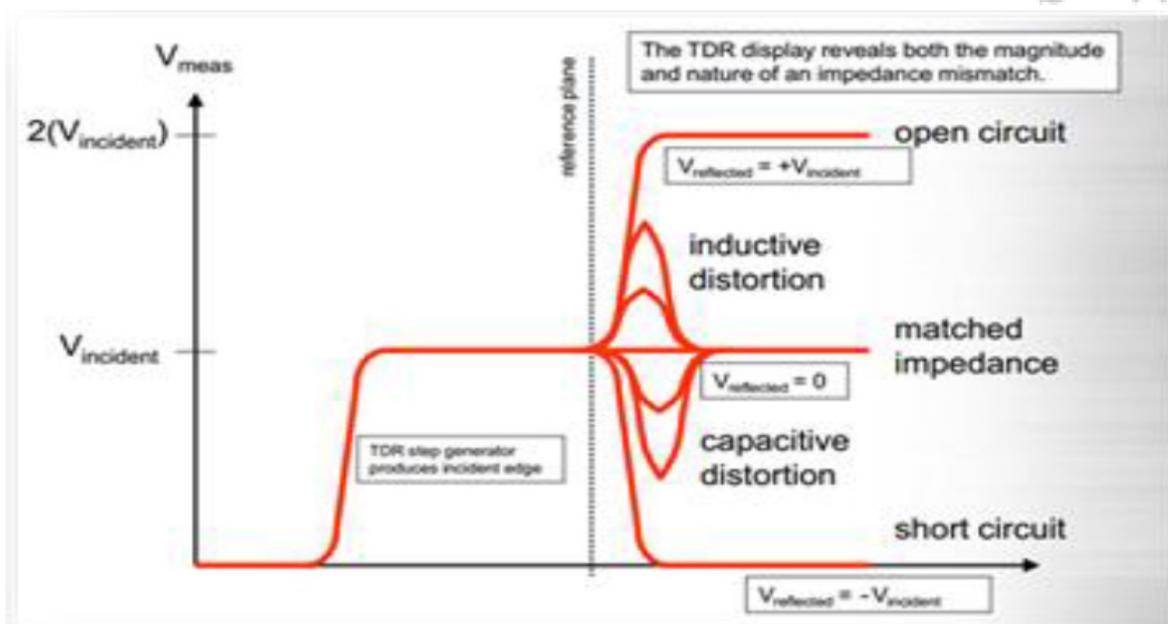


Figure 4: Distance To Fault with impedance infor-



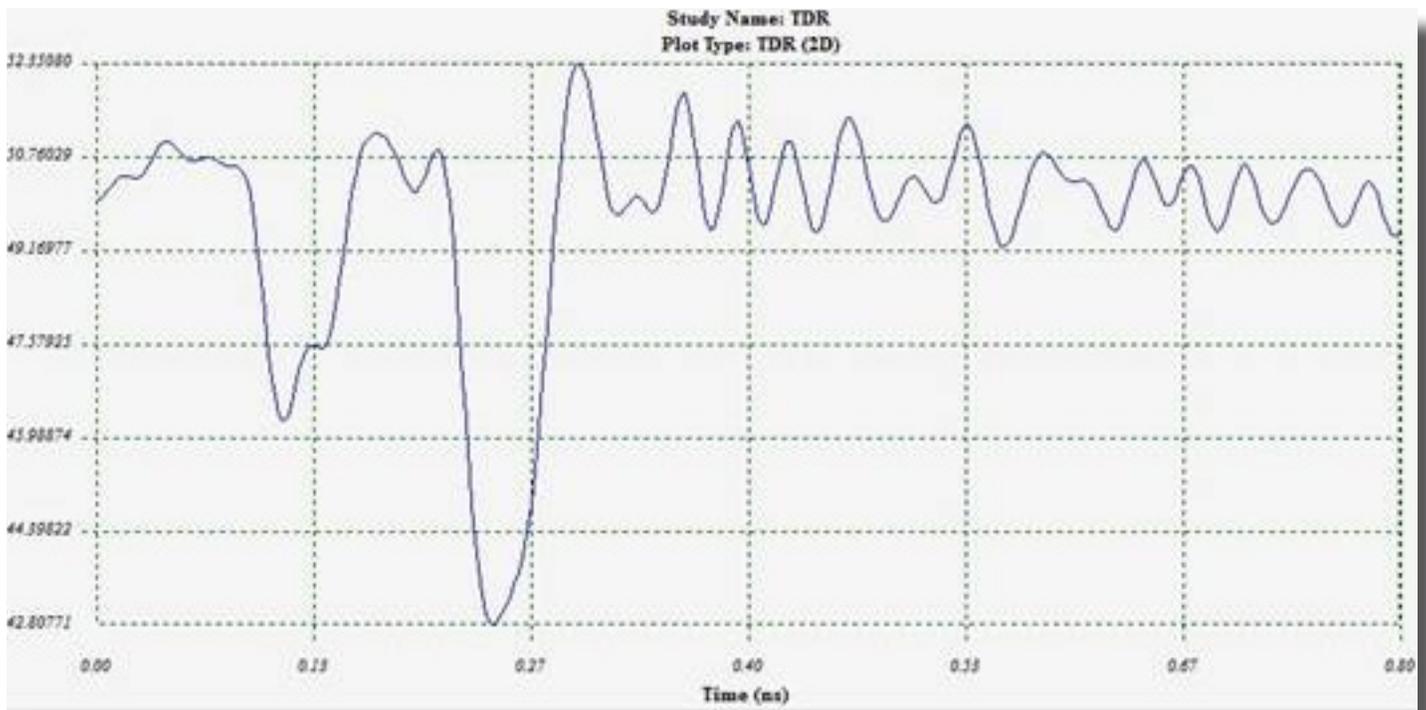
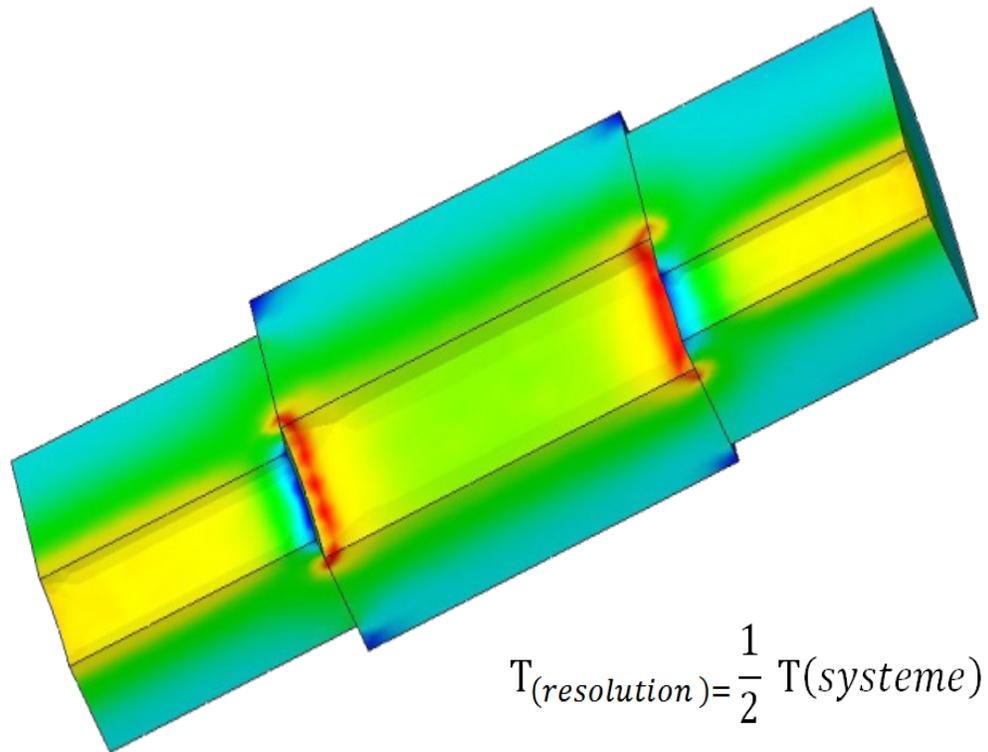


Figure 5: Impedance seen from Port 1

Before viewing the TDR results, a user must specify the type of the excitation signal which is step in our case in our case. Several parameters are related to the choice of the pulse signal. The rise time of the signal is related its bandwidth and to the resolution of the system as well. Indeed, Two neighboring discontinuities may be indistinguishable to the measurement instrument if the distance between them amounts to less than half the system rise time. The equation [2] below summarizes this concept



$$T_{(resolution)} = \frac{1}{2} T_{(systeme)}$$

The plot above shows the measured impedance within the TDR simulation. The curve has sharp variations that warn about the discontinuities in the structure. Using curvature analogy between this plot and plots of figure 1, we can tell what kind of discontinuity we have.

Locating Mismatches

In order to calculate the distance between the mismatch and the monitoring point, we should know in advance the velocity of propagation: The velocity of propagation

approaches the speed of light, U_{cl} For transmission lines with air dielectric. For the general case, where ϵ_r is the dielectric constant:
$$v_p = \frac{v_c}{\sqrt{\epsilon_r}}$$

The reflected wave is readily identified since it is separated in time from the incident wave. This time is also valuable in determining the length of the transmission system from the monitoring point to the mismatch. Letting D denote this length:where

$$D = v \cdot \frac{T}{2} = \frac{(v_p T)}{2}$$

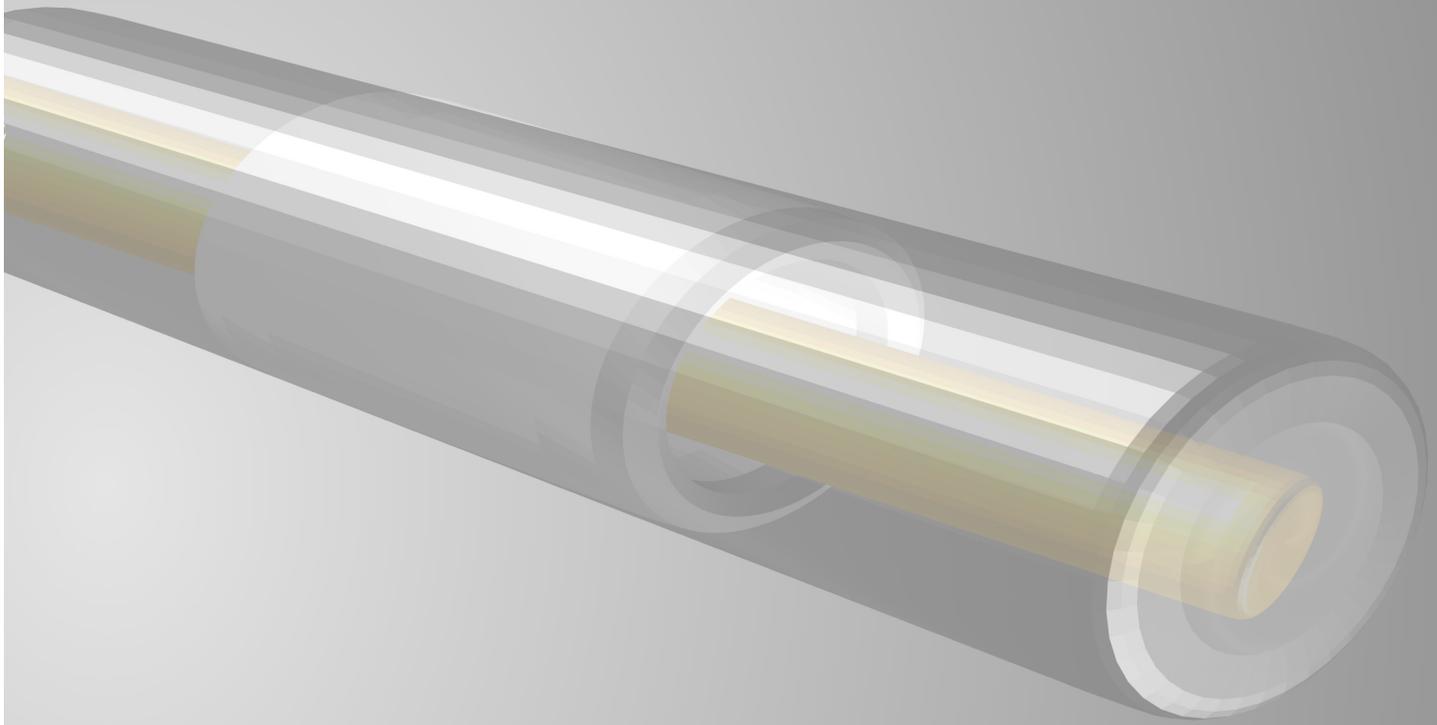
where v_p = velocity of propagation ; T = transit time from monitoring point to the mismatch and back again.

References

Time Domain Reflectometry (TDR) and S-parameters-Advanced Measurements ...not only Signal Integrity - July2009

Tektronix, enabling innovation : TDR Impedance Measurements: Foundation for Signal Integrity

Time Domain Reflectometry Theory Application Note 1304-2- Agilent Technologies



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