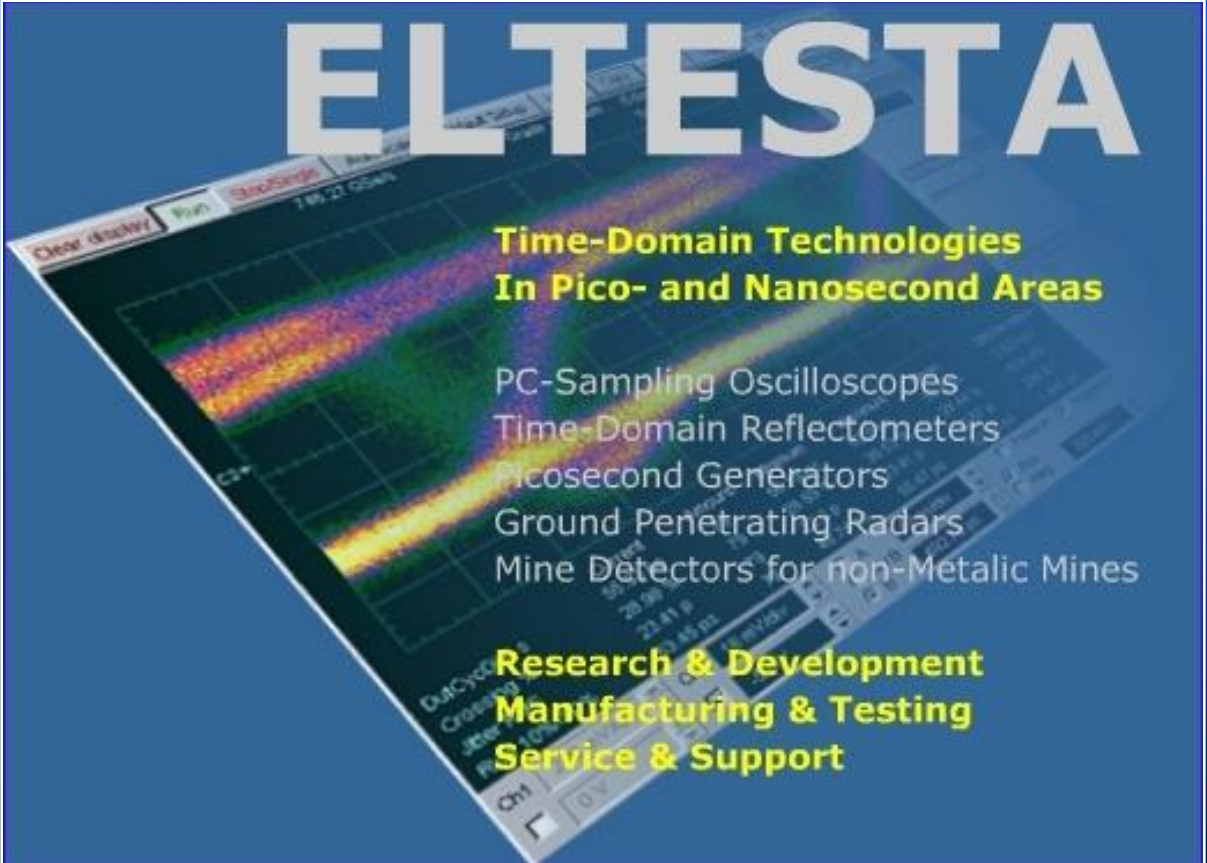


# Low-cost High-resolution TDR Measurements with the PicoScope 9211 USB-Sampling Oscilloscope



**ELTESTA**

**Time-Domain Technologies  
In Pico- and Nanosecond Areas**

- PC-Sampling Oscilloscopes
- Time-Domain Reflectometers
- Picosecond Generators
- Ground Penetrating Radars
- Mine Detectors for non-Metallic Mines

**Research & Development  
Manufacturing & Testing  
Service & Support**

# TDR/TDT Measurements

**Time Domain Reflectometry (TDR)** is a method of characterizing a transmission line or network by sending a signal into one end and monitoring the electrical reflections.



✚ A **TDR** step can also be used to make **Time Domain Transmission (TDT)** measurements. **TDT** is a technique that allows you to measure the response of a system by sending steps through a device and monitoring the output of the device.

✚ The measurements are made on signals transmitted through the device, rather than reflections from the device (as in **TDR**).

An example of **Z-profile** of transmission line. Both markers provide distance and Ohm measurements

# Basics equations

For TDR measurements:

$$V_{refl} = V_{in} (Z - Z_0) / (Z + Z_0)$$

Examples:

$$Z = 25 \text{ Ohm}, V_{refl} = -1/3$$

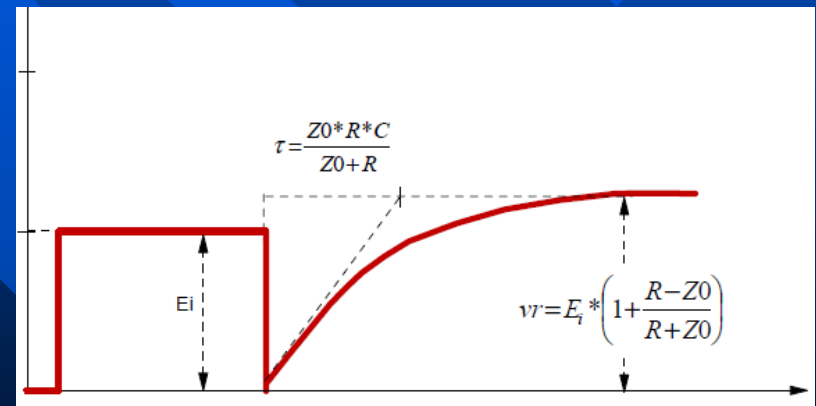
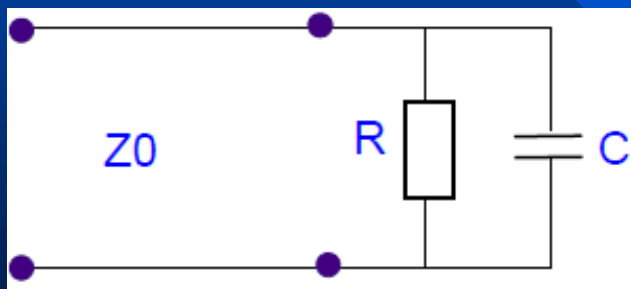
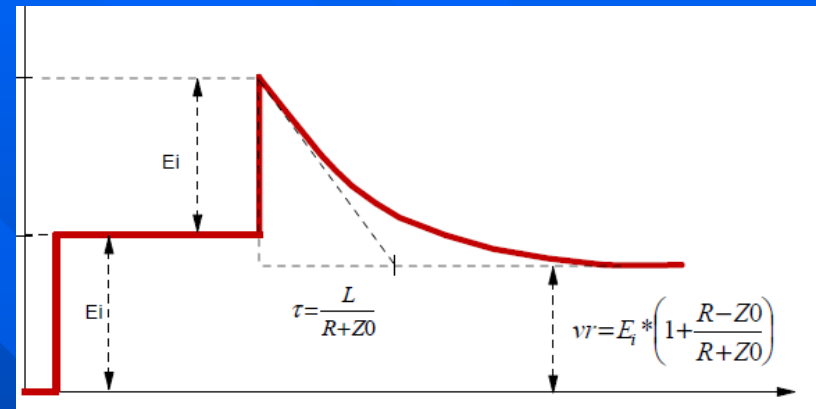
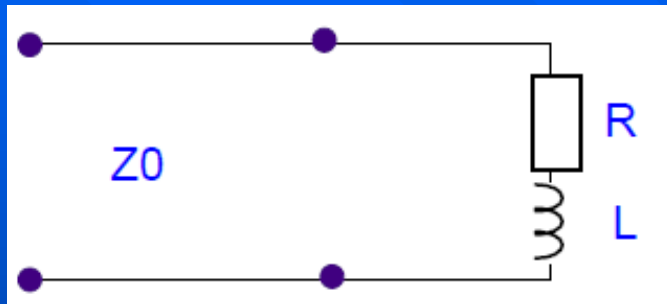
$$Z = 100 \text{ Ohm}, V_{refl} = 1/3$$

For TDT measurements:

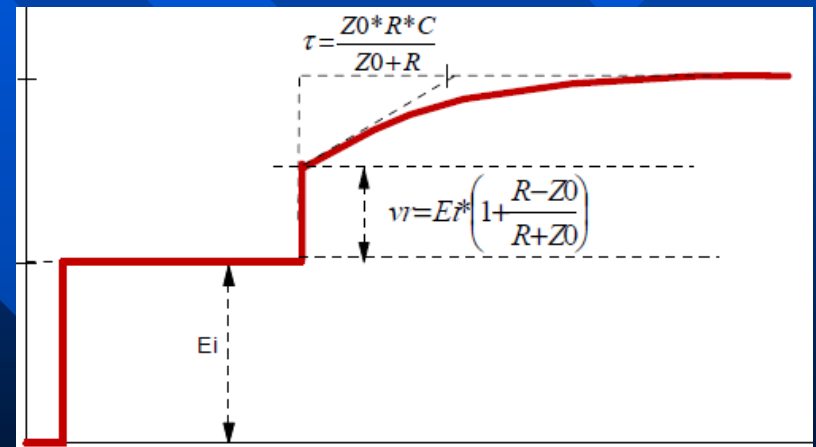
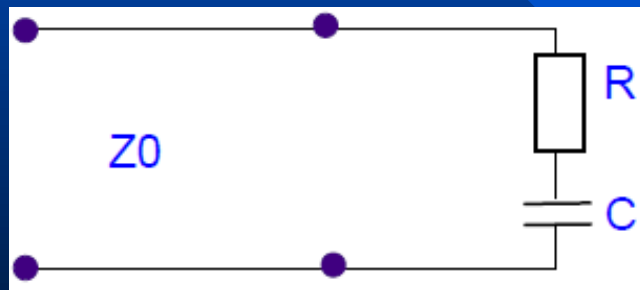
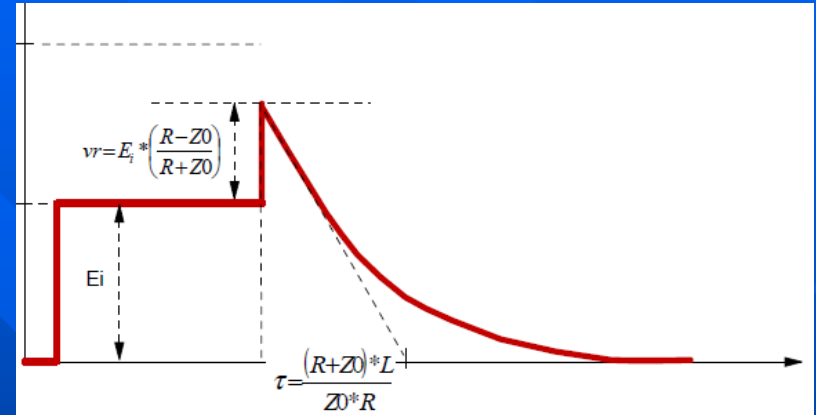
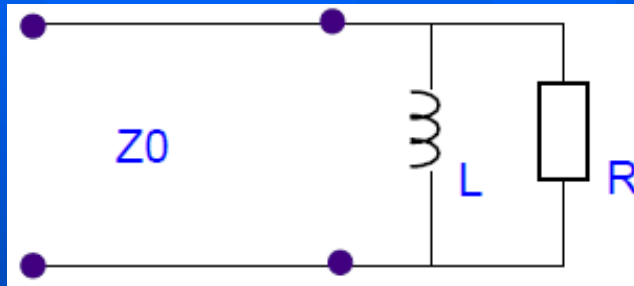
$$V_{thru} = V_{in} * 2Z / (Z + Z_0)$$

**Z - impedance seen in forward direction at the actual location**

# Examples of the Complex Load Out of TDR Plots

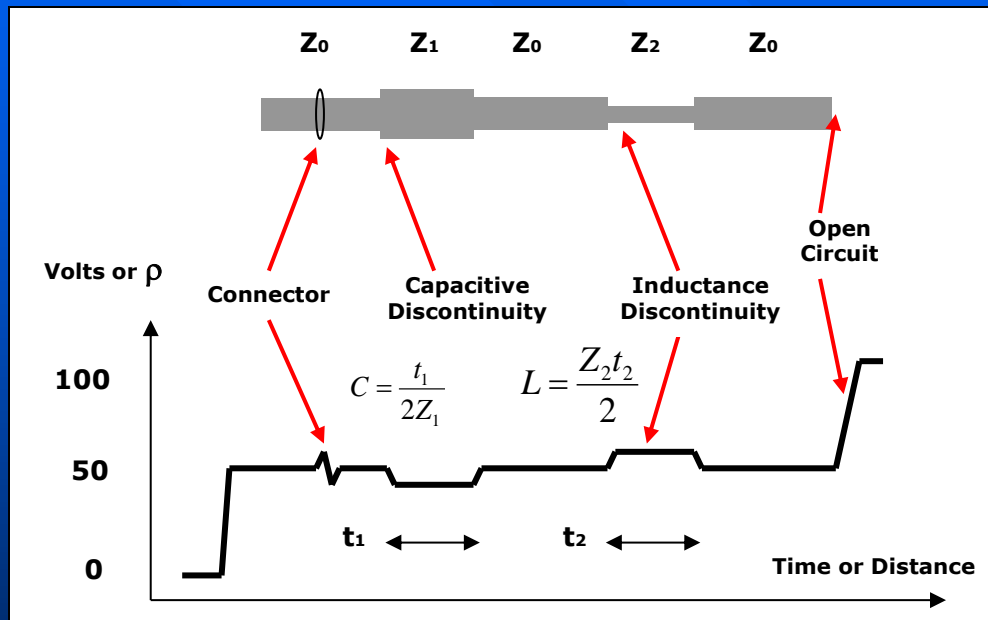


# Examples of the Complex Load Out of TDR Plots (cont.)



# Distributed Discontinuities

**TDR Measurement** are used to characterize the signal transmission properties

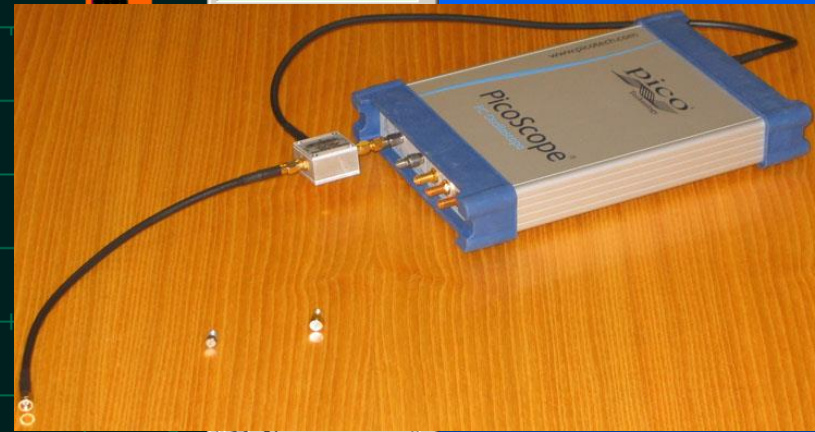
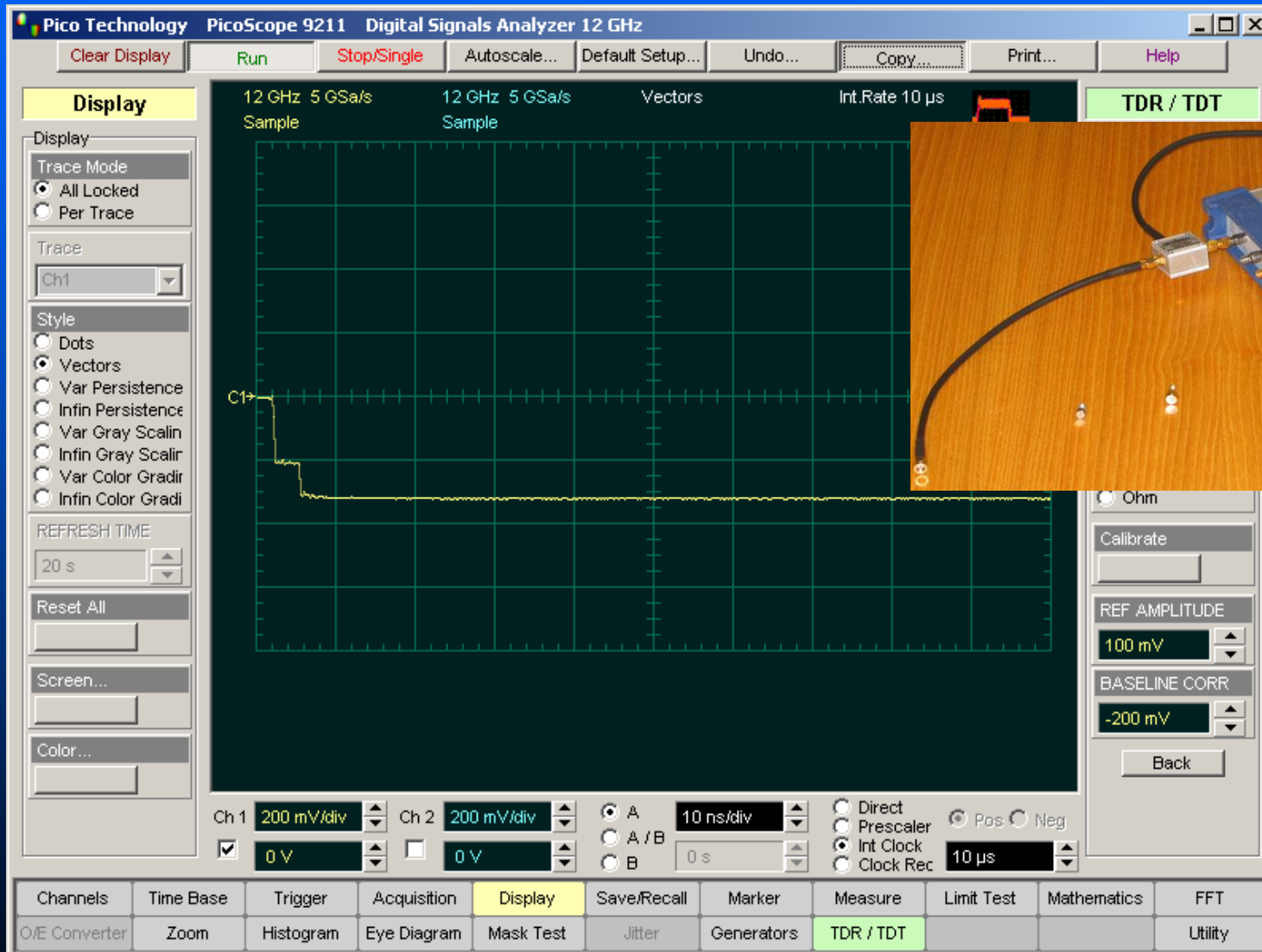


Typical **TDR** Applications:

TDR Measurement are used to characterize the signal transmission properties of:

- ▶ Printed Circuit Boards
- ▶ Connectors
- ▶ IC Packages
- ▶ Cables and Interconnects

# Equipment connections for TDR measurements

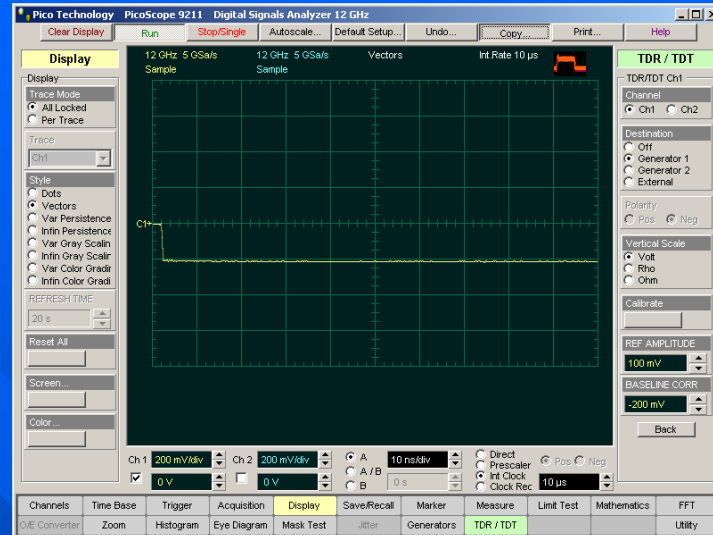


# Main TDR Waveform for Different Loads

Open



50 Ohm



Short



85 Ohm





# Vertical Scaling in TDR/TDT

The three choices for TDR are: Volt, Rho, Ohm

## Rho

Reflection Coefficient is defined as follows:  $Rho = E_r / E_o$

where  $E_r$  is the measured reflected voltage

$E_o$  is the reflected voltage for the opened reference plane.

For open circuit:  $E_r = E_o$  and  $Rho = 1$

For short circuit:  $E_r = -E_o$  and  $Rho = -1$

For 50-ohm circuit:  $E_r = 0$  and  $Rho = 0$

## Ohm

Rho values can be converted to impedance values  $Z$  or back by using the following equations:

$$Z = Z_o * (1 + Rho) / (1 - Rho),$$

$$Rho = (Z - Z_o) / Z + Z_o$$

where  $Z$  is the impedance of the DUT

$Z_o$  is the 50-ohm impedance of the transmission line

For open circuit when  $Rho = 1$ ,  $Z = \infty$ .

For short circuit when  $Rho = -1$ ,  $Z = 0$ .

For a 50-ohm circuit,  $Rho = 0$  and  $Z = 50$  ohm.

In addition to the voltage scale, TDT can also use **Gain** scaling. **Volt, Gain**

## Gain

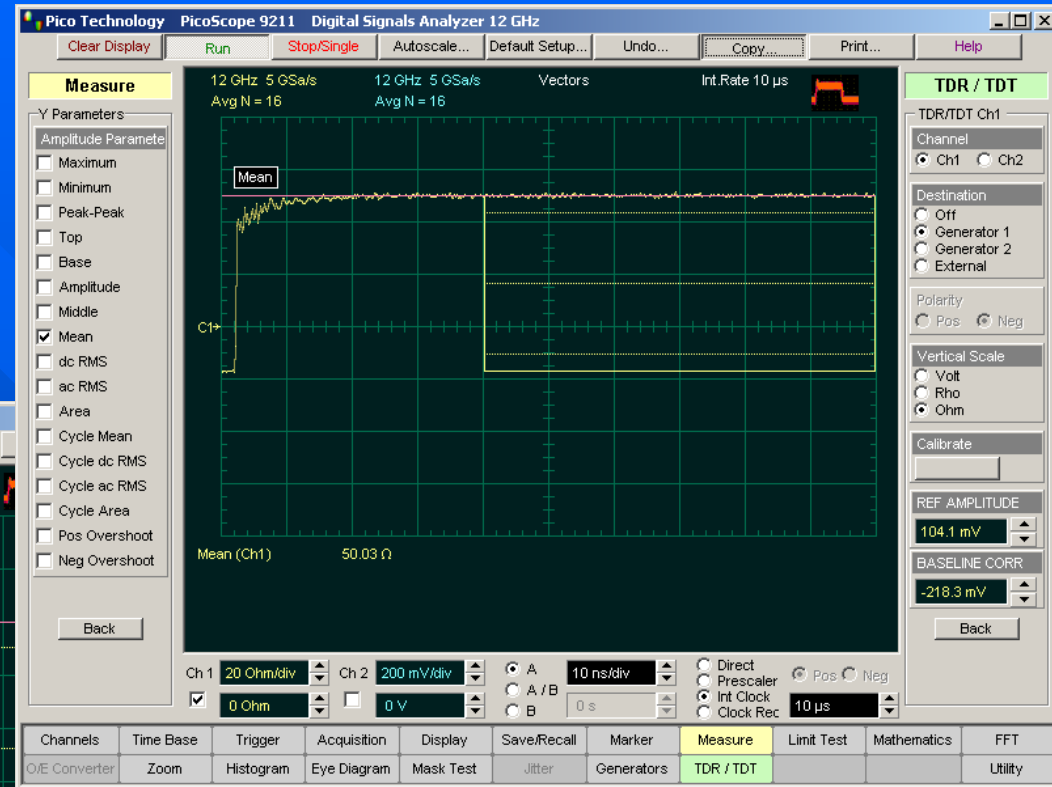
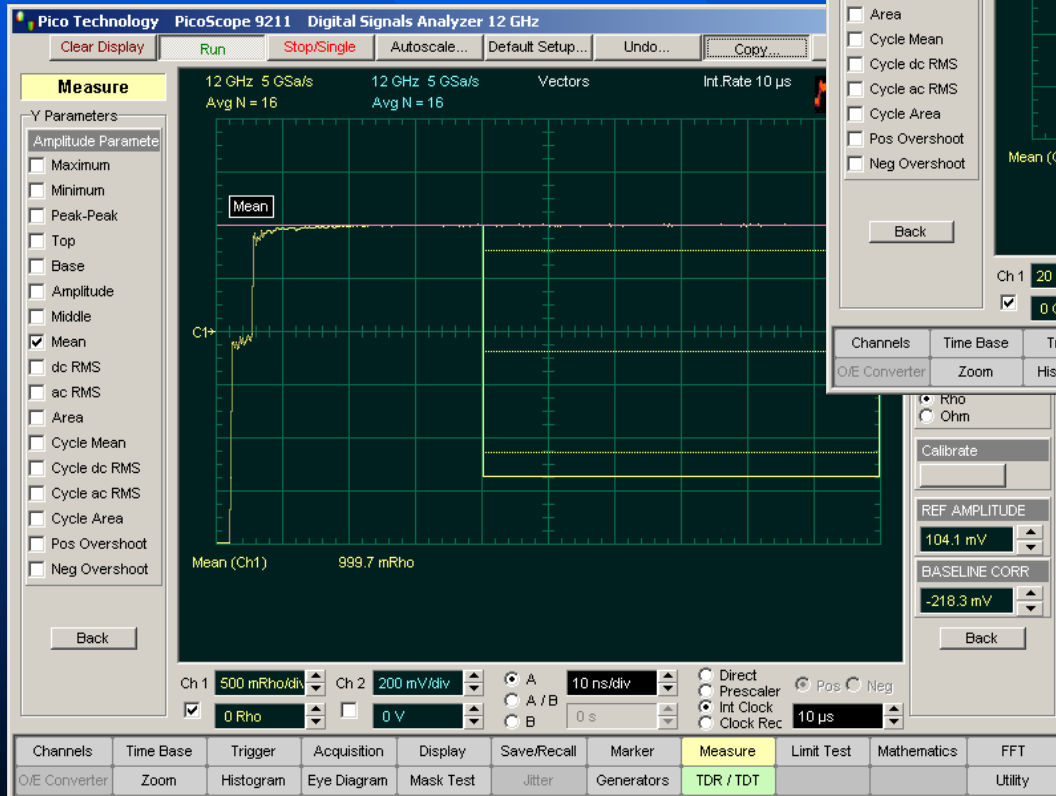
Gain is defined as follows:  $GAIN = E / A$

where:  $E$  is the measured voltage

$A$  is the amplitude of the TDT step.

# Vertical Scaling in TDR/TDT (cont)

TDR Scale in Ohm



TDR Scale in Ohm

# Horizontal Scaling

The selection is: Time, Meter, Foot, Inch

The Propagation VELOCITY or DIELECTRIC CONSTANT controls let you specify the fraction of the speed of light at which the signal passes through your transmission line or network.

PROP VELOCITY and DIELECTRIC CONST apply only to axis units of distance, and do not apply if your horizontal units are seconds.

Propagation velocity is relative to an air-line transmission cable, so a setting of 1.0 indicates that your transmission line or network passes signals at the same speed as an air-insulated cable. The default value of 0.7 applies to most 50-Ohm coaxial cables with plastic dielectric.

You can change the value of propagation velocity from 0.1 to 1 in 0.005 steps, or the value of dielectric constant from 1 to 100 in 0.01 steps.

If you don't know the velocity but you know the dielectric constant of the transmission medium, you can convert its dielectric constant to a velocity using the following equation:

$$Velocity = \frac{1}{\sqrt{Dielectric\ Constant}}$$

# Distance Measurements (cont)

Pico Technology PicoScope 9211 Digital Signals Analyzer 12 GHz

Clear Display Run Stop/Single Autoscale... Default Setup... Undo...

**Marker**

Marker  
Type  
 Off  Y  
 X  XY

M1 Source  
Ch1

M1 POSITION  
550 mm

M2 Source  
Ch1

M2 POSITION  
3.75 m

Motion  
 Independent  
 Paired

Reference  
 On  Off

Set Reference

12 GHz 9.993 GSa/s 12 GHz 9.993 GSa/s Vectors  
Avg N = 16 Avg N = 16

Ch1 = 550 mm XM2 = 3.75 m dXM = 3.2 m  
YM1 = -272.125 mV YM2 = -322.437 mV dYM = -50.3125 mV dYM / dXM = -15.723 mV / m

Ch 1 200 mV/div Ch 2 200 mV/div  
0 V 0 V

500 mm/div  
A/B  
0 m

Direct Prescaler  
Int Clock Clock Rec 10 μs

Channels	Time Base	Trigger	Acquisition	Display	Save/Recall	Marker	Measure	Limit Test	Mathematics	FFT
O/E Converter	Zoom	Histogram	Eye Diagram	Mask Test	Jitter	Generators	TDR / TDT			Utility

Pico Technology PicoScope 9211 Digital Signals Analyzer 12 GHz

Clear Display Run Stop/Single Autoscale... Default Setup... Undo... Copy... Print... Help

**Marker**

Marker  
Type  
 Off  Y  
 X  XY

M1 Source  
Ch1

M1 POSITION  
550 mm

M2 Source  
Ch1

M2 POSITION  
1.48 m

Motion  
 Independent  
 Paired

Reference  
 On  Off

Set Reference

12 GHz 9.993 GSa/s 12 GHz 9.993 GSa/s Vectors  
Avg N = 16 Avg N = 16

Ch1 = 550 mm XM2 = 1.48 m dXM = 930 mm  
YM1 = -217.312 mV YM2 = -239.125 mV dYM = -21.8125 mV dYM / dXM = -23.454 mV / m

Ch 1 200 mV/div Ch 2 200 mV/div  
0 V 0 V

500 mm/div  
A/B  
0 m

Direct Prescaler  
Int Clock Clock Rec 10 μs

**TDR / TDT**

Horizontal  
Horizontal Scale  
 Time  
 Meter  
 Foot  
 Inch

Preset Unit  
 Prop Velocity  
 Dielectric Const

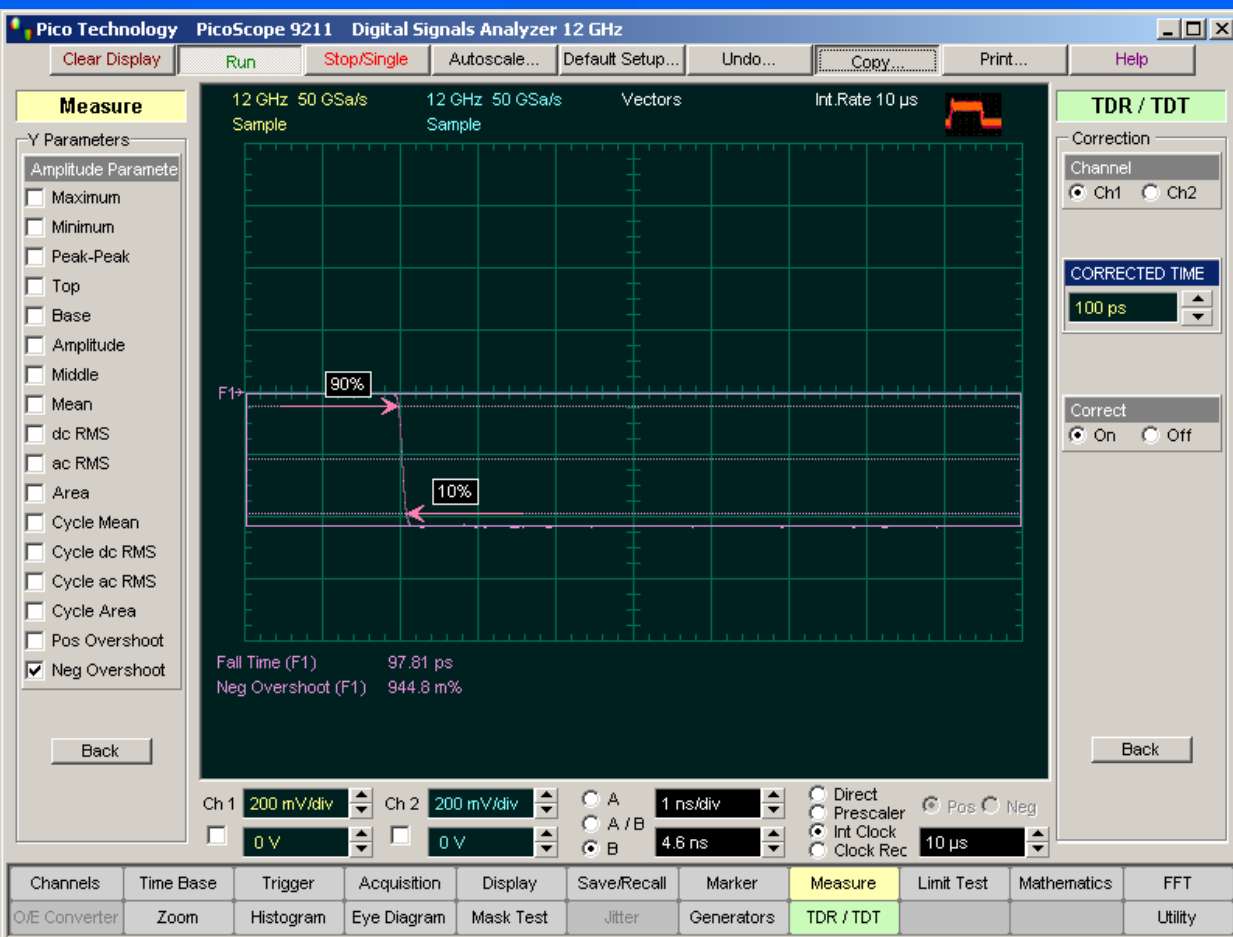
DIELECTRIC CONST  
2.25

Back

Channels	Time Base	Trigger	Acquisition	Display	Save/Recall	Marker	Measure	Limit Test	Mathematics	FFT
O/E Converter	Zoom	Histogram	Eye Diagram	Mask Test	Jitter	Generators	TDR / TDT			Utility

# TDR/TDT Correction

The Correction allows you to change the rise time of the corrected step for TDR or for TDT on each of the channels, and also to turn on or off the display of the normalized TDR or TDT trace (function).



The Correction allows you to change the rise time of the corrected step for TDR or for TDT on each of the channels, and also to turn on or off the display of the normalized TDR or TDT trace (function).

Correction procedure corrects for sources of measurement errors concerned with TDR response. By using correction, the results become more reliable, repeatable, and accurate. In addition, performing a correction allows the instrument to simulate stimulus steps with different effective rise times. This allows you to view the effect of actual signal rise times on the magnitude of reflections from discontinuities.

The measurement results show 97.81 ps corrected fall time and 0.9448% negative overshoot.

# The End

# ELTESTA



**Thank You for Your time**

**Questions?**

**[info@eltesta.com](mailto:info@eltesta.com)**

**Application Notes available @  
[www.eltesta.com](http://www.eltesta.com)**

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Mine Detectors for non-Metallic Mines

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