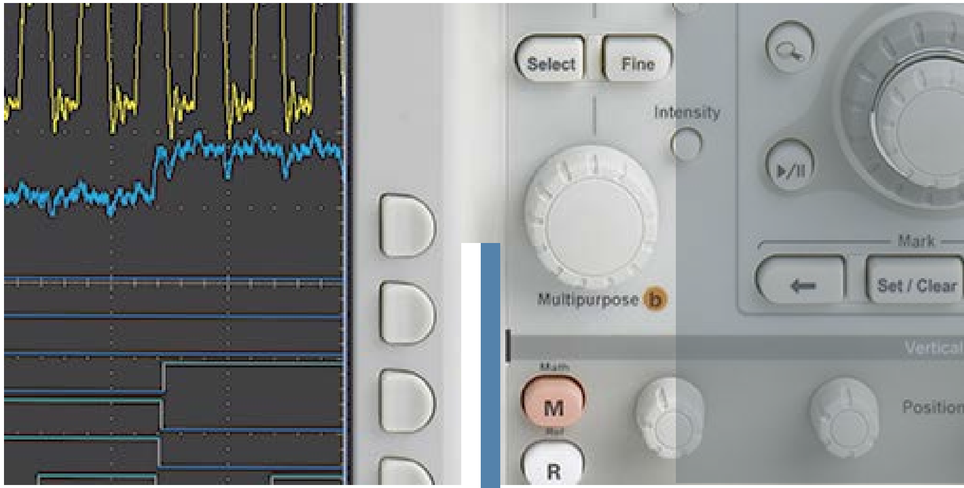
Recommendations for TDR configuration for channel characterization by S-parameters



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IEEE 802.3 100GCU
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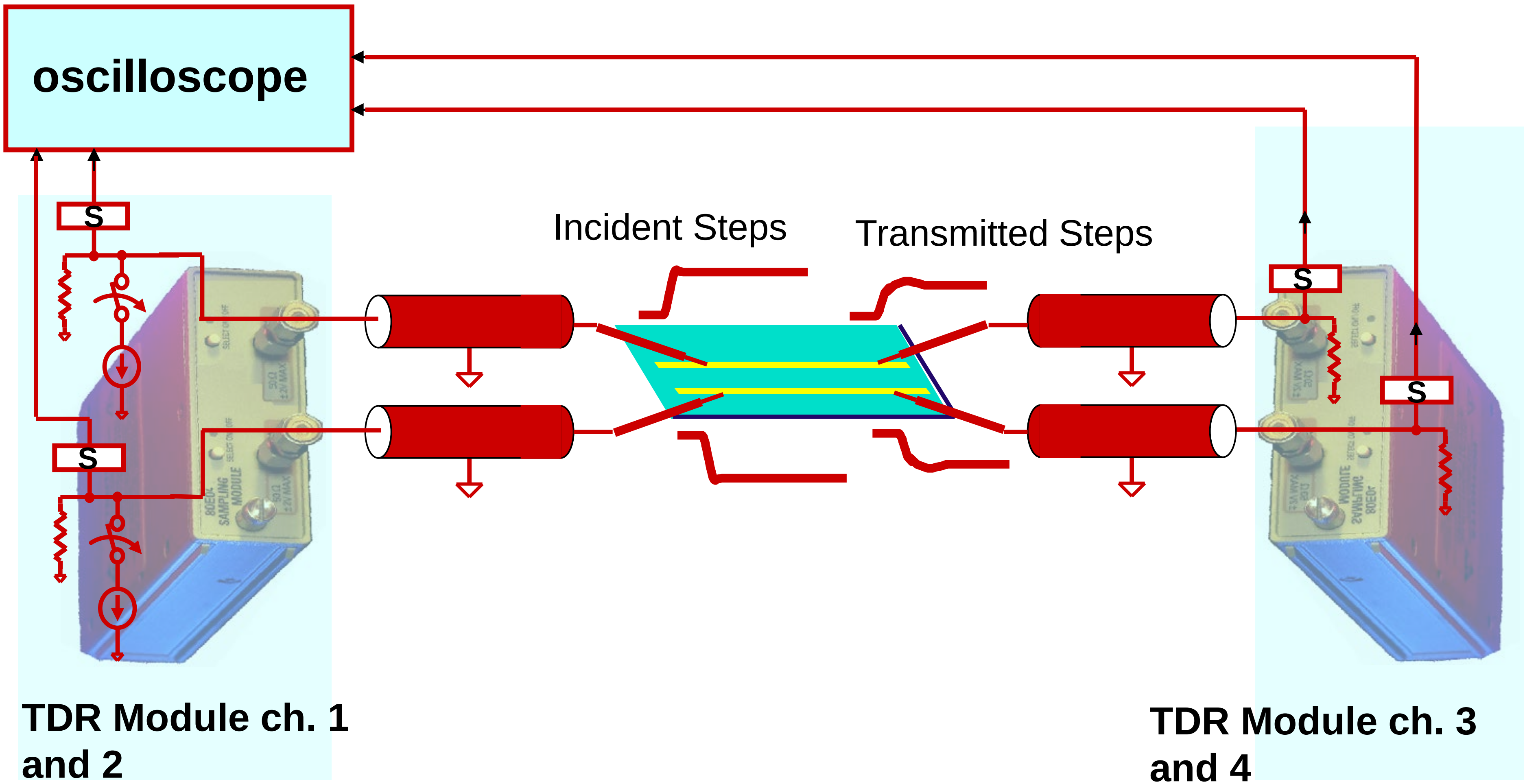
Agenda

- TDR/TDT measurement setup
- TDR/TDT measurement flow
- DUT electrical length vs. timebase setting consideration
- S-parameters DC point consideration
- S-parameter generation from time-domain acquisitions: Max. Frequency consideration
- S-parameter generation from time-domain acquisitions: Frequency Step consideration
- Comments on automation of TDR/TDT measurements
- Impedance measurements on a running DUT TX
- Summary

TDR/TDT four-port setup for Differential TDR & TDT concept diagram



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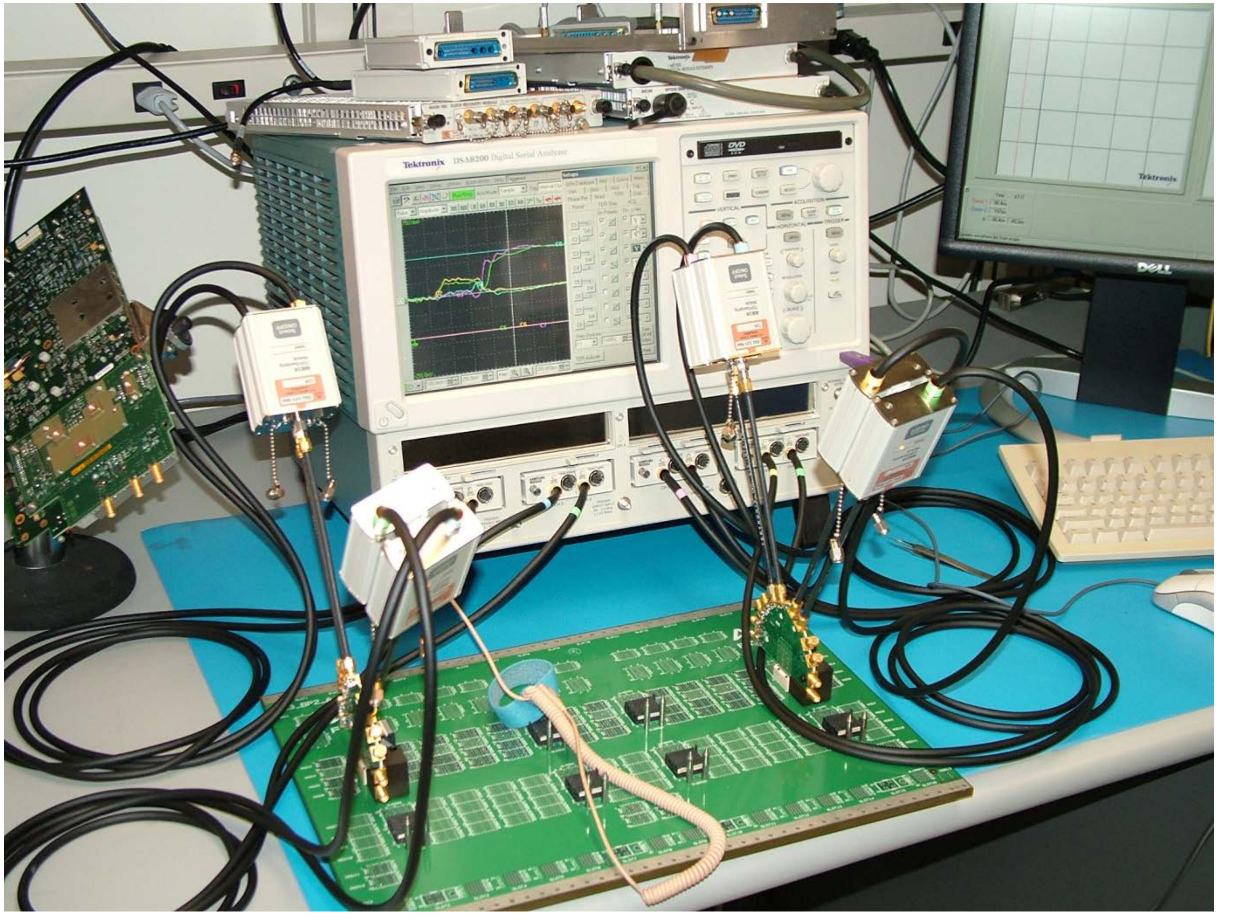
TDR/TDT setup for Differential TDR & TDT practical example for high speed systems

TDR modules can reach all the way to the DUT, however: The cabling is somewhat movement-sensitive. It is a good practice to tape down the cables.

(Figure shows an 8-port measurement)



TDR/TDT measurements flow

1. TDR system needs to be de-skewed;
   - automated (e.g. "S-parameter Wizard", a Tek supported free tool)
   - manual (better for special cases, e.g. true differential)
     (Deskew Pulses first, then Acquisition)

   Use latest oscilloscope firmware to avoid de-skewing problems
2. Set up the system (>256 averages, desired step polarity)
3. Measure the electrical length of the DUT, set timebase accordingly
4. Acquire (preferably via IConnect) and Save the time-domain response files of the DUT and of Cal References.
   The "S-parameter Wizard" automates this step.
5. Using IConnect or other package calculate the frequency domain response with desired step and max. frequency; review and save S-parameter files.

Note: Time-domain reflectometry (TDR) and transmission (TDT) based network measurements of S-parameters are aka SDNA or TDNA.

DUT electrical length vs. timebase setting

Acquisition settings of an TDR/TDT system for measurements of 25 Gb/s components				
This spreasheet answers the question 'what time/div should the TDR/TDT system be set to?'				
And the question 'what is the longest DUT that can be measured?'.				
TDR setup: Assuming that				
the TDR oscilloscope's Rec. Length (RL) is	4000	[Samples]		
and we are using a module with	50	[GHz]	bandwidth:	
It then follows that:				
the minimum Sample Rate (SR) should be	100	]GS/s]	(Nyquist vs. BW)	
i.e. the Sample Interval (Si) should be:	10	[ps]		
Practically it is better to keep farther from Nyquist, so a somewhat higher resolution is adviseable;				
good final selection is e.g.	2.5	[ps]	(sample interval), i.e.	
(Nyquist of this is	200	GHz, sufficient for our 25 Gb/s work)		
so the time/div setting is	**1000**	**[ps/div]**		
Based on the above, how long a DUT can be measured?				
length of acquired record is	10000	[ps], i.e.	10	[ns]
The DUT has to settle completely within this time span.				
Rough guidence for the DUT electrical length (either TDR or TDT) is that the DUT				
should end after at most	0.3	of the acquired record;		
(user should verify to what degree is the signal settled, and if higher or lower fraction should be used).				
so the TDR system above can measure				
a DUT of length up to	3	[ns]		
In many situation the DUT is longer, and so a longer time span is necessary. Native TDR record length				
can be extended by a 'stitching' algorithm - built into e.g. the IConnect package, which suppports				
the record length up to	1,000,000	[samples]		
This extends				
the maximum length of the DUT to an electrical lengt	**750**	**[ns]**		

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DUT electrical length vs. timebase setting summary

For measurements to 40 … 50 GHz :

- Set Sample Interval to 2.5 ps (1ns/div, 4k RL)
- Max. device length w/o stitching is about 3 ns
- Max. device length with stitching is about 750 ns.
- Stitching is built into IConnect for total record length corresponding to desired f step of 10 MHz (100ns total record length)
- If possible (new HW) use the Enhanced Accuracy feature of IConnect for suppression of low level coherent noise

S-parameters DC point consideration

- TDR/TDT signal has a DC component; IConnect preserves the DC value, so the 1st point of the generated Touchstone file is at 0 Hz and truthfully captures the magnitude at that point.
- In case of AC-coupled systems the insertion loss of the 1st point will be very large, correctly capturing the loss of DC path

However:

- Most AC coupling have a time constant slower than the time window of acquisition…
- … the generated S-parameter files therefore don't completely describe the low frequency behavior of the system.

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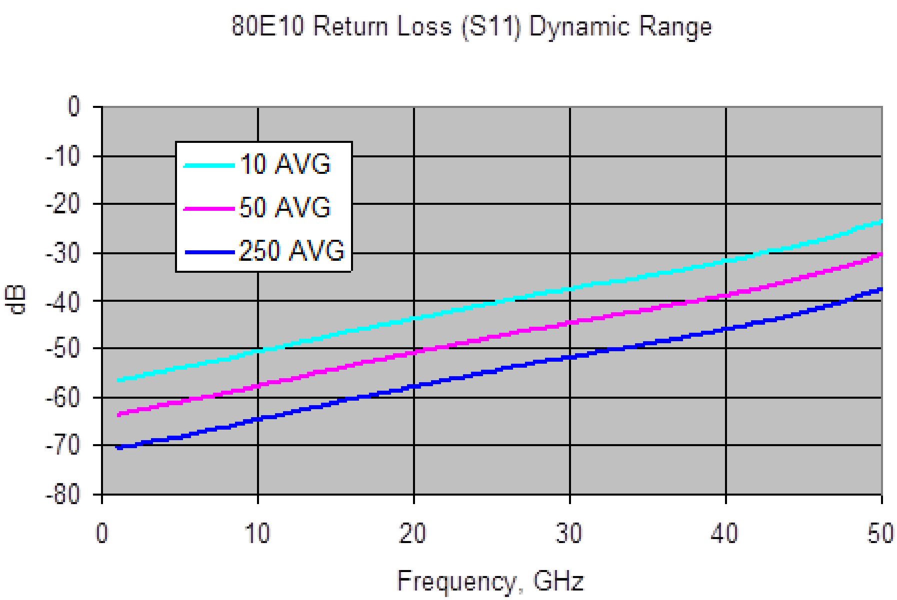
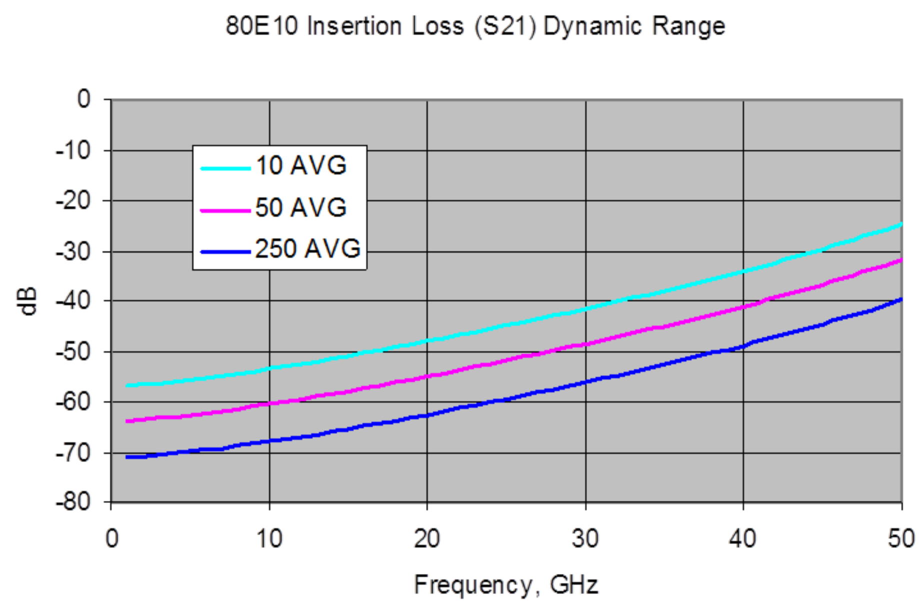
S-parameter generation from time-domain acquisitions: Max. Frequency consideration

The tool converting the time-based to frequency-based data is typically Tektronix IConnect tool, other tools exist.
IConnect allows setting the Max. Frequency and the Frequency Step

- As you grow the Max. Frequency setting, at some point (depending on the energy acquired at that frequency) the S-parameters (at that frequency) grow noisy, then lose correlation to reality.
- Best performance results (80E10, DSA8200, IConnect, short DUT):





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S-parameter generation from time-domain acquisitions: Frequency Step consideration

IConnect allows setting the Frequency Step ; lowering the Frequency Step allows nearly arbitrarily fine frequency step. What does this really mean:

- IConnect simply extends the time-domain record beyond the last acquired point to provide a higher resolution fft.
  Is this valid?
- As long as the assumption that the acquired record was settled is indeed correct, this ‘arbitrarily fine’ resolution is valid.

Problem area:

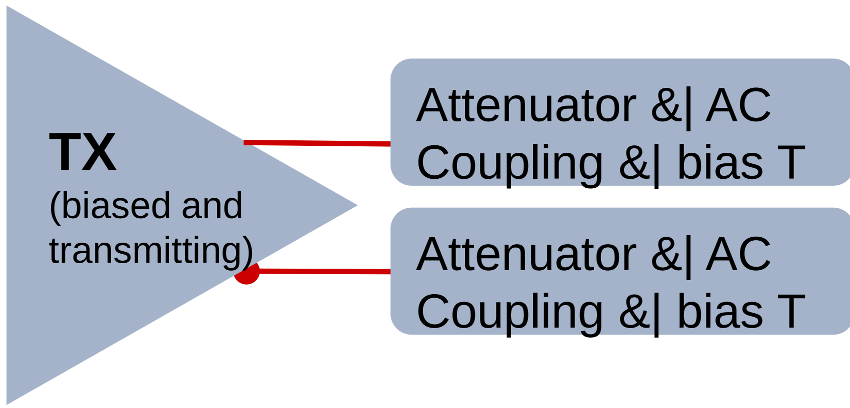
- AC coupled systems are rarely measured over a time window large enough to allow settling of the time record. In such case the ‘settled trace’ data assumption was violated, and consequently at low frequencies the fine frequency step data will likely be incorrect (suggesting no AC coupling droop except at DC).

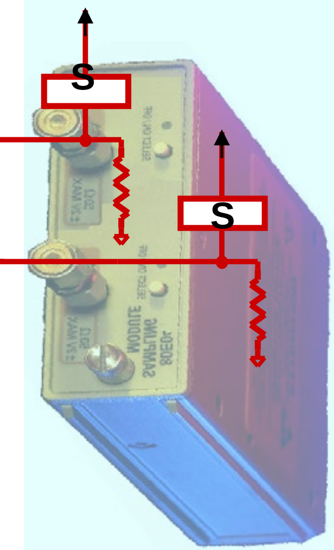
Comments on automation of TDR/TDT measurements

- Currently a S-parameter Wizard automates the whole process, including deskew.
  Limitation: max. record length of 4000 samples, limited flexibility (e.g. acquisition of an active TX not supported).
- Manual process supports up to 1 MS RL. Manual processing of a 2-port or a 1-port data is reasonable and yields a good insight.
- Running a completely manual acquisition and analysis of an 4-port or higher is tedious and error prone; at least minimal automation is highly recommended.
- Connecting two sampling modules nose-to-nose (e.g. for the Through calibration) can cause interesting artifacts if the through delay is very short. Use latest oscilloscope FW; and consider keeping a short semirigid as a part of the system.

Impedance measurements on a running DUT TX

- Both TX and the TDR need to remain in their operating bias
- Adjust attenuation so the measurement step size will roughly match the expected reflected energy (reflected from the channel)





TDR Module

- Heavy average will remove the uncorrelated TX energy from the acquired TDR step
- Oscilloscope math manipulation amplifies the step back to normal range for IConnect processing
- Manual measurement (do not use the S-parameter Wizard)

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Summary:
Settings for 40 Gb/s measurements

Requirements:

- The S-parameters should be captured to 40 GHz
- Frequency step spacing: 5m or less: 10 MHz; 5 MHz for longer (See the parallel presentation from Greg for details)

Acquisition settings: 2.5 ps sample spacing, and sufficiently long record length to capture at least 3x of electrical length of the DUT

-end.