DSL-Cable Measurements with Bode100

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Contact support@omicron-lab.com for technical support.

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Note: Basic procedures like setting-up, adjusting and calibrating Bode 100 are described in the operational manual of Bode 100.

Note: All measurements in this application note have been performed with the Bode Analyzer Suite V2.21. Use this Version or a higher Version to perform measurements according to this application note.

Download the latest version at http://www.omicron-lab.com/downloads.html

1 Executive Summary

This application note explains how to measure electrical parameters of DSL-Cables such as attenuation, crosstalk and phase delay. This is necessary to determine if a cable complies with a certain normative standard like e.g. IEC 62255-3.

The application note was done in cooperation with AESA Cortaillod. AESA Cortaillod has over 30 years experience in cable testing and quality control of telephone and LAN cabling as well as power lines or coaxial cabling. The company's headquarters is located in Colombier, Switzerland. For more information feel free to visit: www.aesa-cortaillod.com

2 Measurement tasks

During the process of selecting a cable for a specific application it is advisable to verify the electrical characteristics outlined in the cable's data sheet.
By analyzing one DSL-Cable pair, the measurement of following parameters is shown in this application note (the parameters for the other pairs are measured the same way).

- Attenuation
- Impedance
- Near End Cross Talk (NEXT) and Far End Cross Talk (FEXT)
- Return Loss (RL)
- Phase delay

3 Measurement Setup & Results

3.1 Used Equipment

The following equipment is required to perform the measurements described in this application note.

- Vector Network Analyzer Bode 100 (incl. measurement accessories)
- DSL-Cable (DUT)
- BALUNs (3x)
- Connection accessories
- Calibration cable

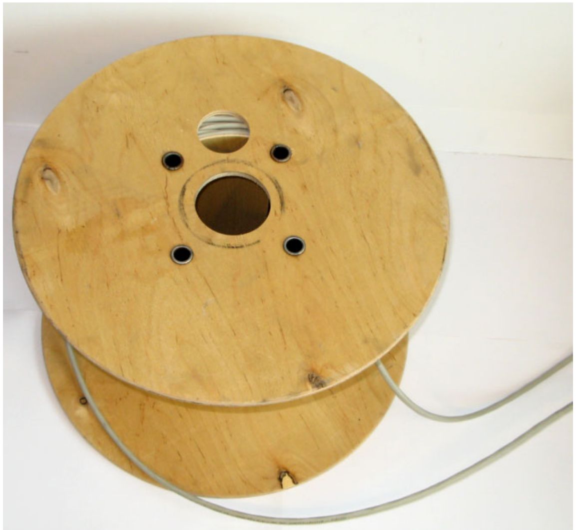
The used items are explained in the following sections.

3.1.1 DSL-Cable:

The DSL-Cable used for the measurements in this application note had following properties:

- Type: Copper cable 4x4x0.5 vDSL (CAT3)
- Manufacturer: Nexans Fumay France
- Physical properties: 4 quads 0.5mm with general braid/alu foil SF-UTQ (QIMF)
- Trade mark: ET 392121
- Model/marking: Nexans-Alcatel-Lucent 1 ACxx
- Length: 100m

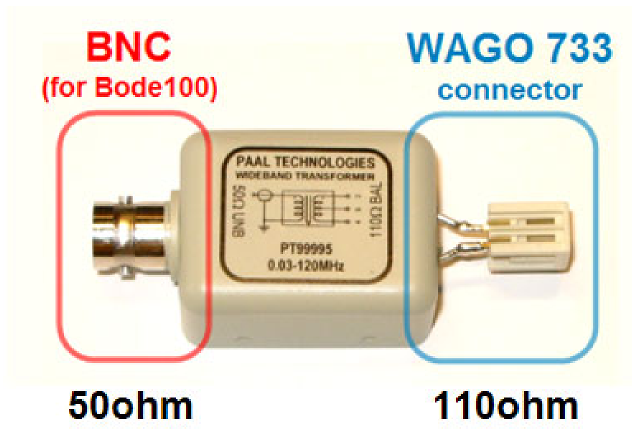
During the measurements the DSL-Cable is wrapped on a wooden cable reel.



Picture 1-1

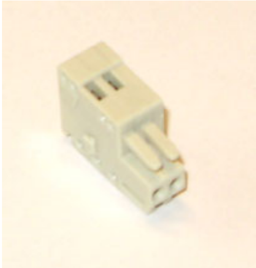
3.1.2 BALUN:

A BALUN as shown in the picture is used to match the output impedance of the Bode 100 (50 ohm) with the cable impedance of 110 ohm. The used BALUN has a balanced output signal and a frequency range from 30 kHz up to 120 MHz.



3.1.3 Connection accessories:

To connect the BALUN and the DSL-Cable we use 2 pin Wago-733 connectors.



(female plug)

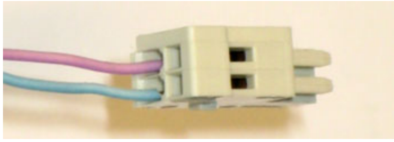
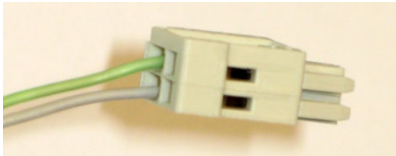
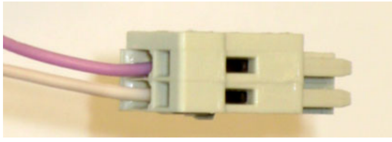
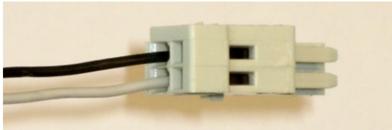
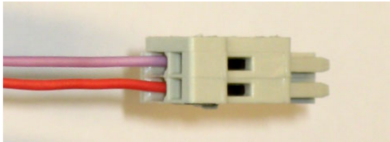
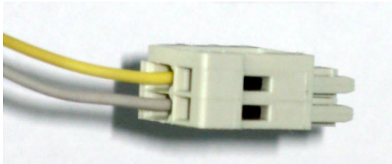
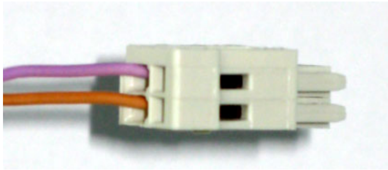
(male plug)

Three special connectors **O**pen, **S**hort and **L**oad are used for the calibration later on. The load resistor has a value of 110 ohm.

Picture 1-5

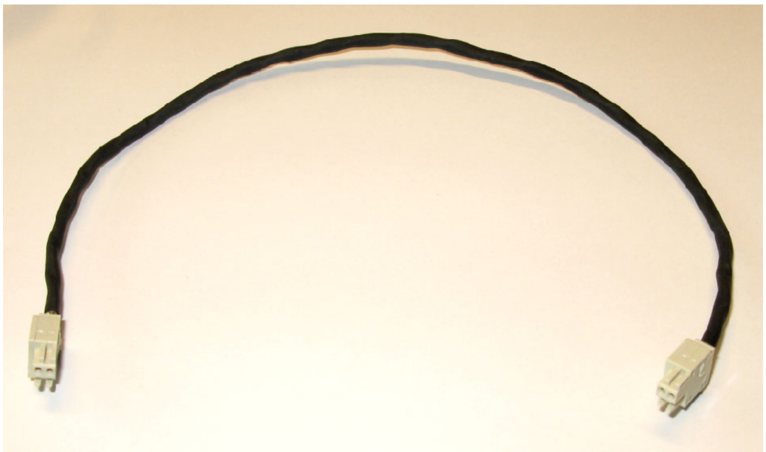
Connection table:

The different cable pairs of the DSL-Cable are connected with WAGO-733 female plugs.

Pair Nr.	Quad	Short name	Color	Picture
1	1	Q1/1	White Grey	
2	1	Q1/2	Orchid Blue	
3	2	Q2/1	Green Grey	
4	2	Q2/2	Orchid White	
5	3	Q3/1	Black Grey	
6	3	Q3/2	Orchid Red	
7	4	Q4/1	Yellow Grey	
8	4	Q4/2	Orchid Brown	

3.1.4 Calibration cable:

To minimize the influence of the BALUNs, BNC cables and connectors we have to calibrate our measurement setup. Therefore a calibration cable with two female plugs is required. The explicit use of our calibration cable will be shown in 3.3.



Picture 3-13

3.2 Measurement setup instructions:

- The measurement examples covered in this application note are only performed for one pair. The other wire pairs are measured exactly the same way.

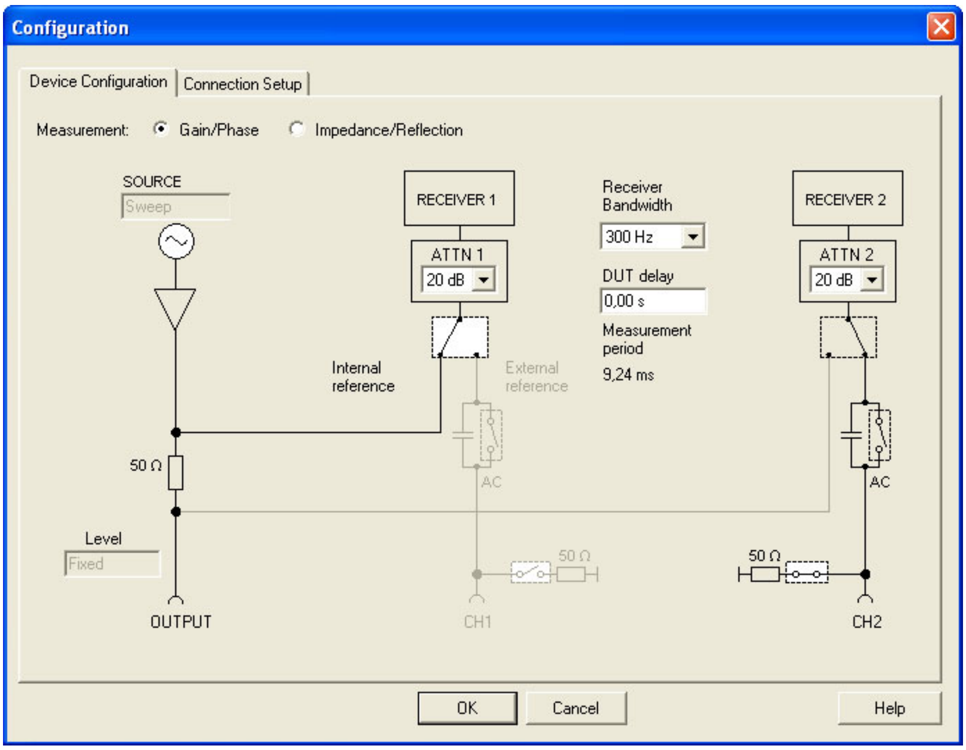
- The used DSL-Cable consists of 4 quads. Every quad has 2 pairs. To obtain an accurate measurement result all unused pairs (of every quad) should be connected to a LOAD resistor at the near and far end. This additional information is not mentioned at every measurement setup.

3.3 Attenuation of DSL-Cables:

All signals are attenuated when transmitted along cables. Too much attenuation can cause signals to be lost in the noise. To measure the attenuation of a DSL-Cable, follow the steps below.

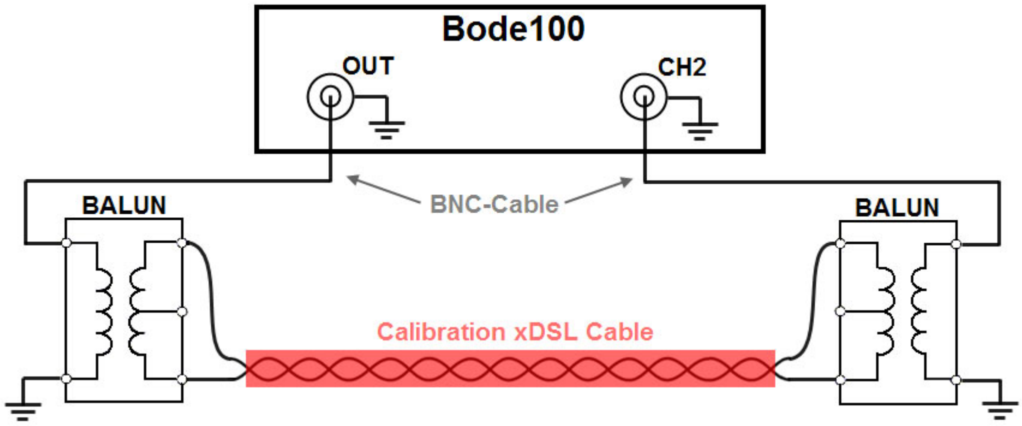
Start your Bode Analyzer Suite, select "Frequency Sweep" and configure Bode 100 as shown.

- Mode: Frequency Sweep
- f(min): 10 kHz
- f(max): 40 MHz
- Reference: Internal
- Attn CH2: 20 dB
- Receiver Bandwidth: 300 Hz
- DUT delay: 0 s
- Number of points: 401
- Impedance CH2: 50Ω
- Source Level: 0 dBm
- Sweep mode: linear

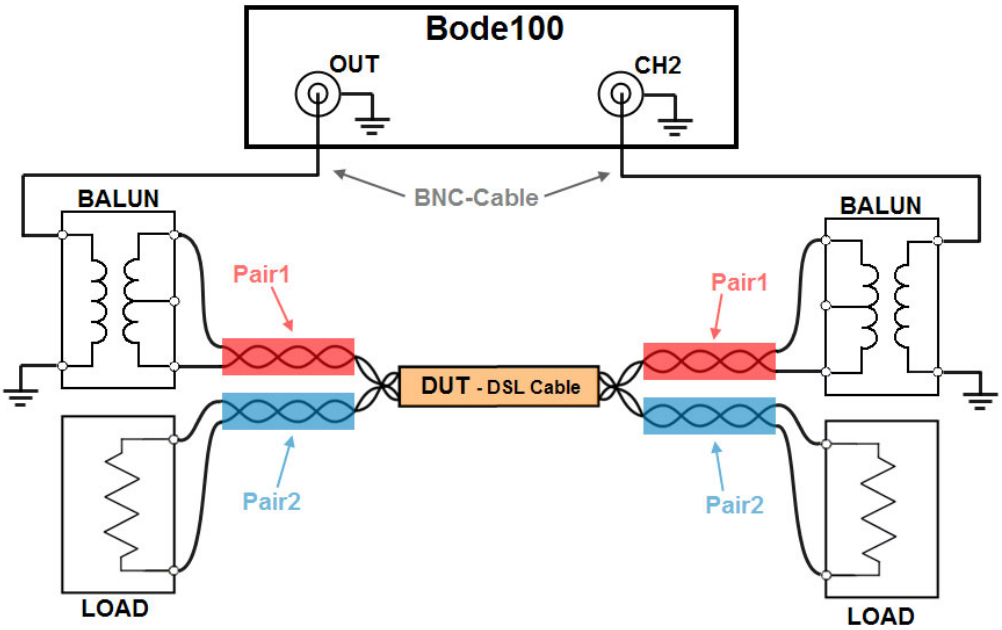


To minimize the influence of the BALUNs and cables used to connect the DUT to Bode 100 it is advisable to perform a THRU calibration as shown in the manual in the section "Calibration in the Gain/Phase mode".

Calibrate Bode 100 and the used BALUNs with a calibration cable.

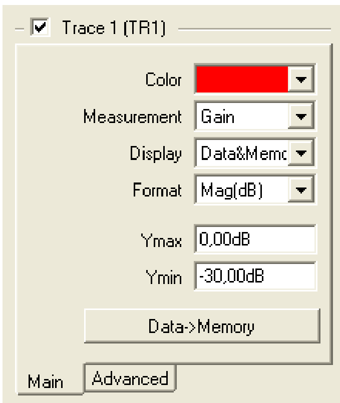


After the calibration connect Bode 100's output and input (CH2) as shown.

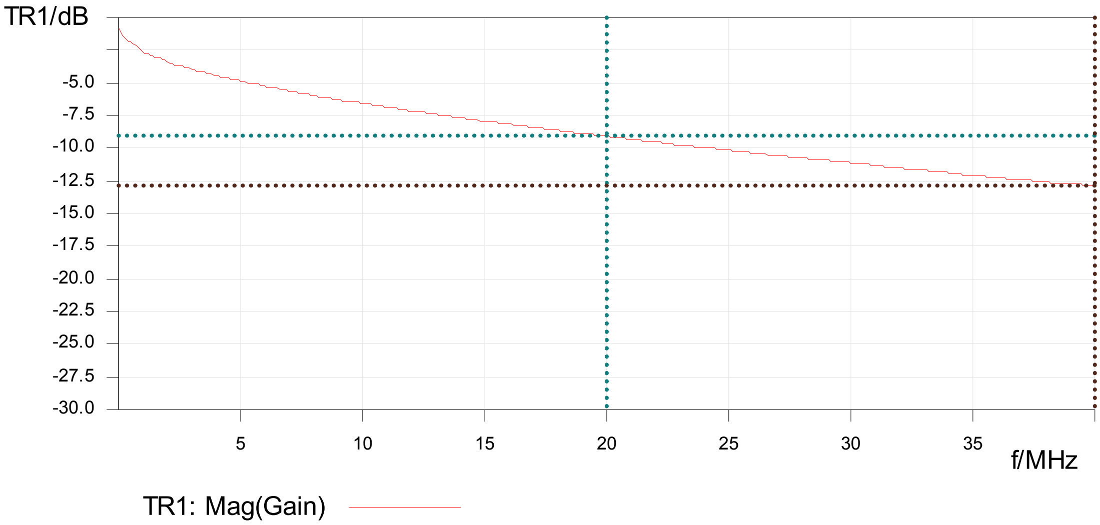


Note: Pair1 and Pair2 are in the same quad.

Activate Trace 1 to measure the attenuation of the DSL-cable as shown below:



Now start the frequency sweep measurement to record the attenuation.



Result: The maximum attenuation at 40MHz is about 12,9dB/100m (for information on setting the cursors see the Bode 100 User Manual). The attenuation at 20 MHz is about 9dB/100m.

	Frequency	Trace 1		Trace 2	
Cursor 1	20,000 MHz		-9,095 dB		
Cursor 2	40,000 MHz		-12,891 dB		
delta C2-C1	20,000 MHz		-3,796 dB		

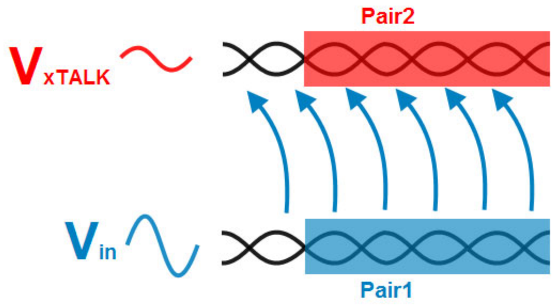
3.4 Theory about Crosstalk, NEXT and FEXT:

3.4.1 Crosstalk:

Crosstalk is signal interference between nearby cables or cable pairs. It is caused by capacitive- and inductive coupling between different transmission pairs.

3.4.2 NEXT:

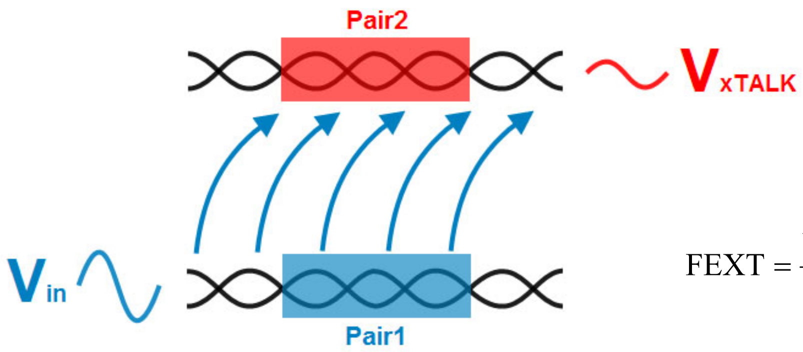
Near End Crosstalk (NEXT) is measured by comparing the signal received at the near end of a neighboring pair (Vxtalk) with the Voltage (Vin) injected into the other pair.



$$NEXT = \frac{V_{xTALK}}{V_{in}}$$

3.4.3 FEXT:

Far End Crosstalk (FEXT) is the coupling between nearby pairs at the far end of the cable pair.

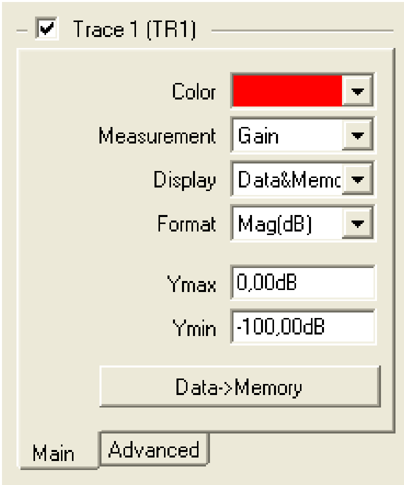


$$FEXT = \frac{V_{xTALK}}{V_{in}}$$

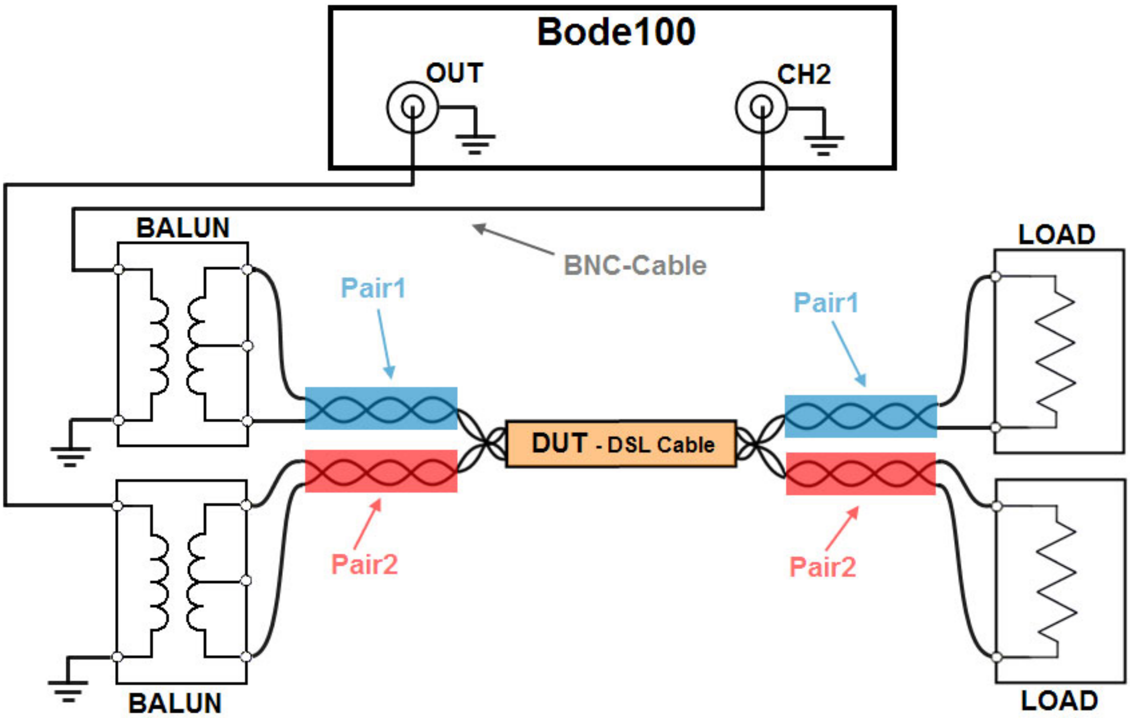
Hint: Far end crosstalk can also be expressed as Equal Level Far End Crosstalk (ELFEXT), which is calculated. ELFEXT is FEXT measured with respect to the attenuated test signal (see Add-On "ELFEXT Measurement with Bode 100").

3.5 NEXT Measurement:

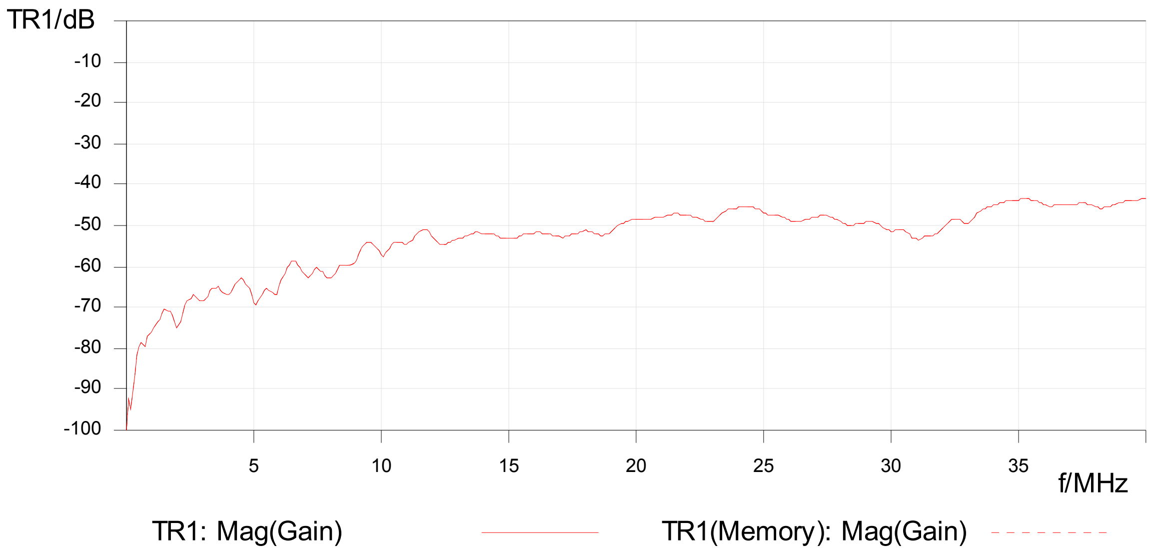
To measure NEXT of two pairs, keep the same settings and calibration as used in the attenuation measurement. Only change the trace1 settings as shown.



Connect your measurement utilities as shown to measure the NEXT between Pair1 and Pair2.



Now you can start the frequency sweep measurement.



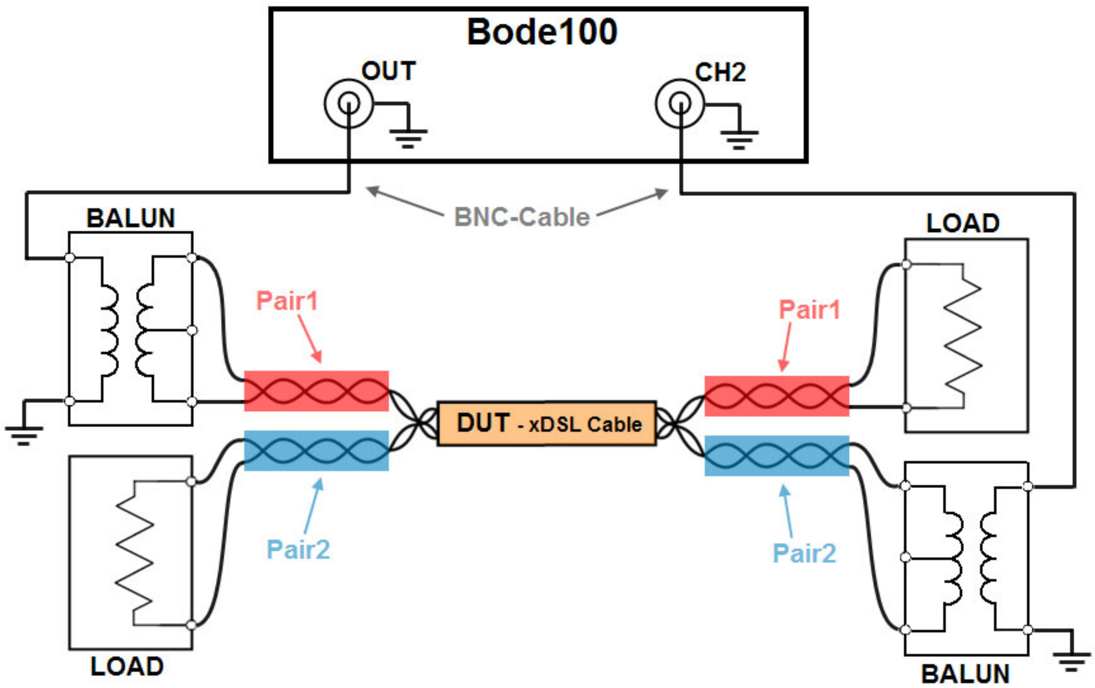
This graph shows the crosstalk (NEXT) between two neighbouring pairs. Our measurement result shows that the signal received at the near end of Pair2 is -40dB or more below the signal sent into Pair1.

3.6 FEXT Measurement:

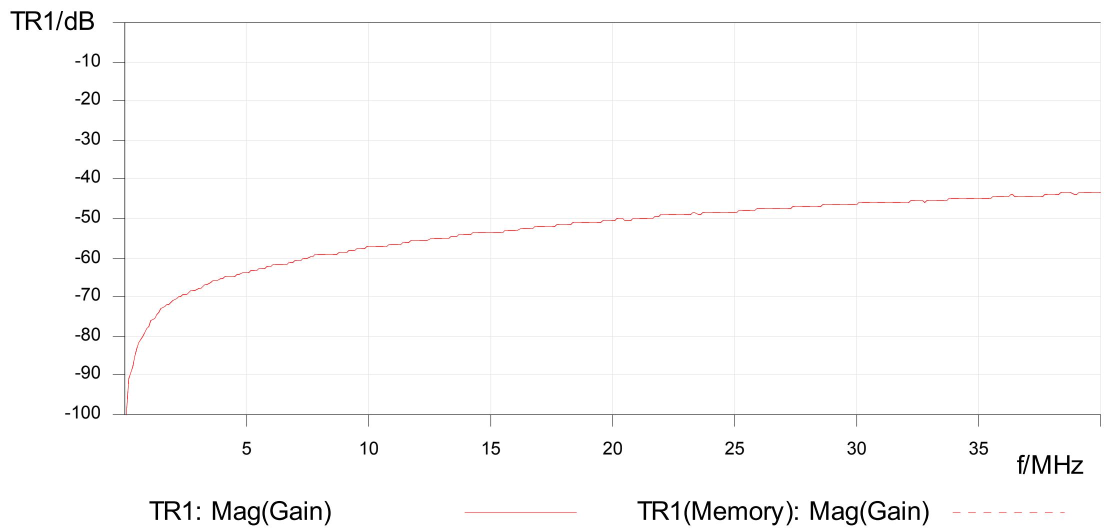
The setup for the FEXT measurement is almost similar to the NEXT setup. Use the same configuration as in the attenuation measurement:

Note: You can use the same calibration as in the attenuation measurement.

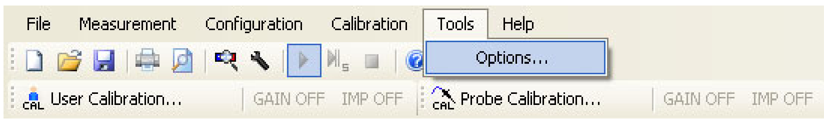
Connect the DSL-Cable as shown and start the FEXT measurement.

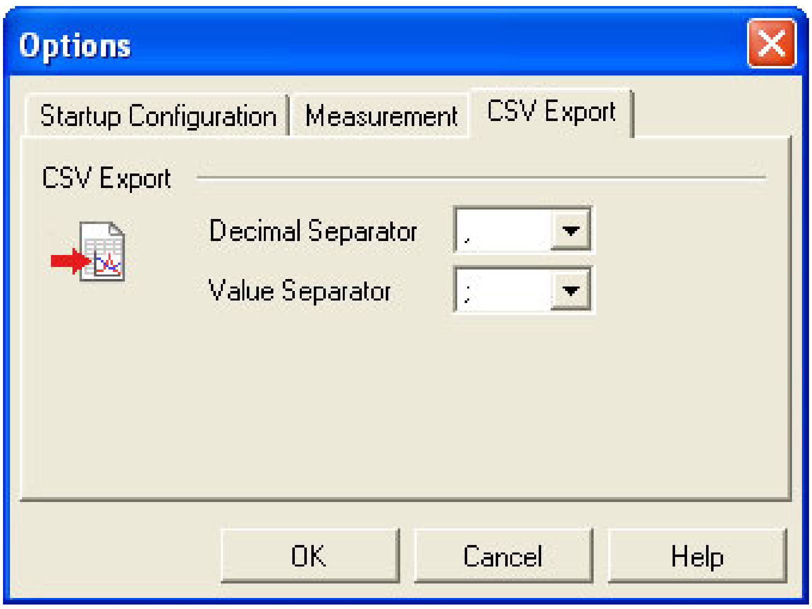


The diagram below shows the result of the FEXT measurement



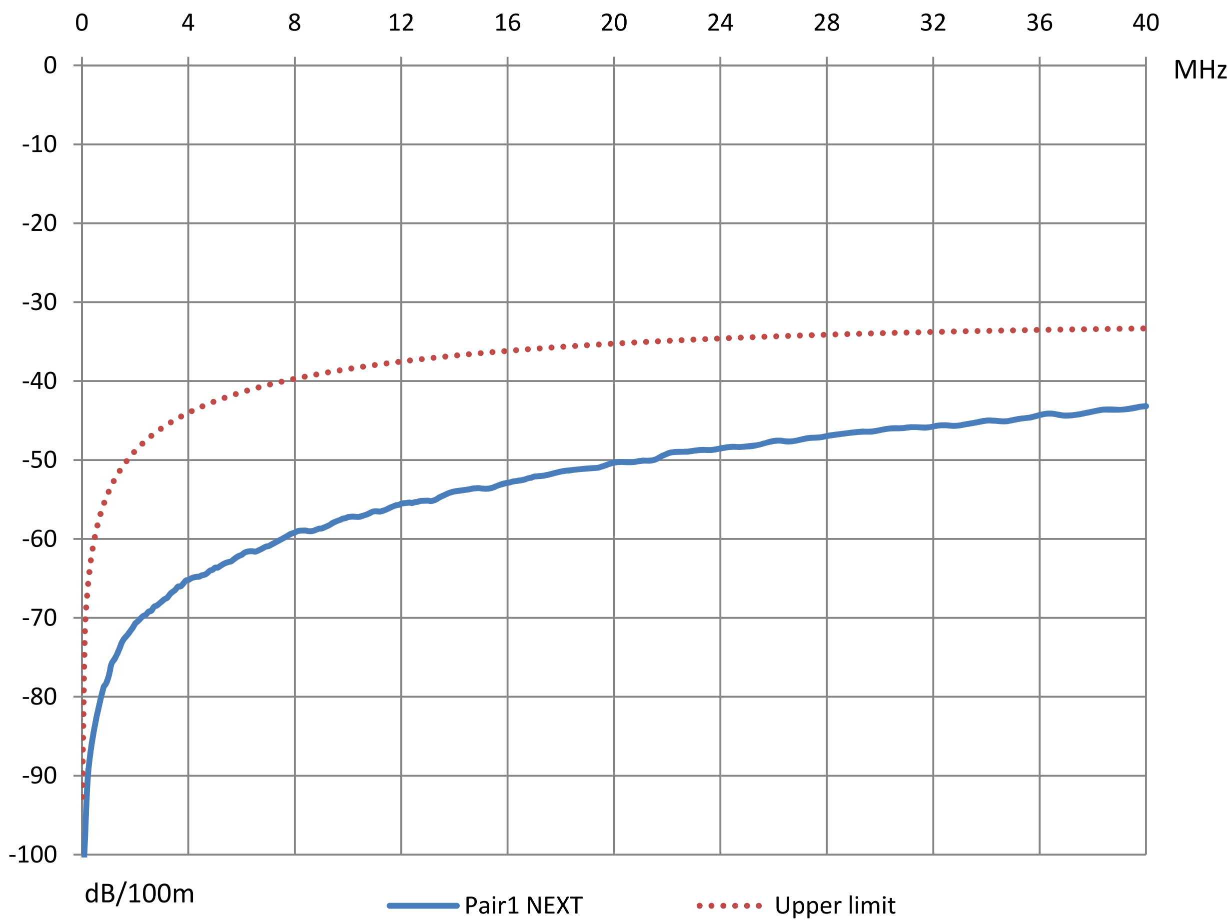
To add an "upper limit" (to find out if the cable passes the requirements defined in the chosen normative std.), export your traces data into CSV File which can be processed in software such as e.g. EXCEL or MATLAB. Before you export the traces data, set the CSV-Export settings according to your requirements as shown.





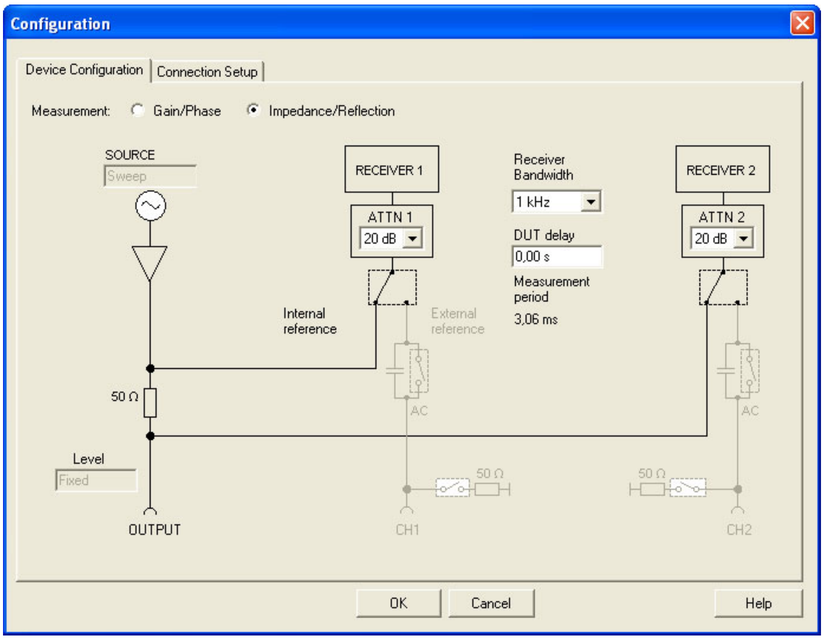
Now press the "Export Traces Data..." button on the right side of the Bode Analyzer Suite. Save the .CSV-File and open with EXCEL or MATLAB.

This graph shows that the FEXT is below the required limit. The used DSL-Cable has passed the crosstalk test. The "Upper limit" is according to IEC 62255-3.

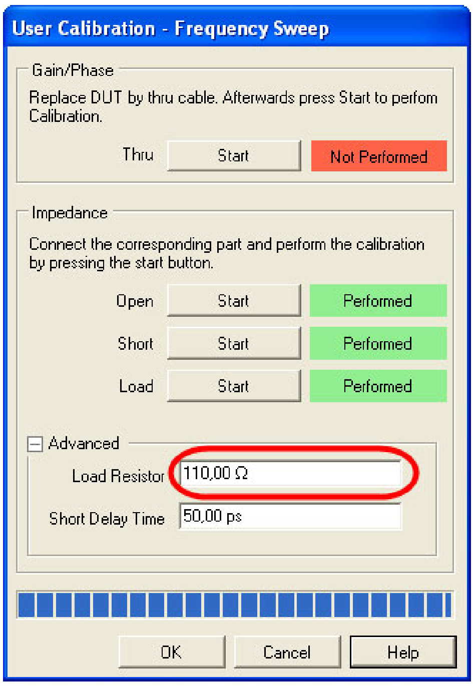


Impedance Measurement:

To adjust a driver unit (transmitter or receiver) to a DSL-Cable it is necessary to know the input impedance. To measure the impedance of the used cable start your Bode Analyzer Suite and configure it as shown.

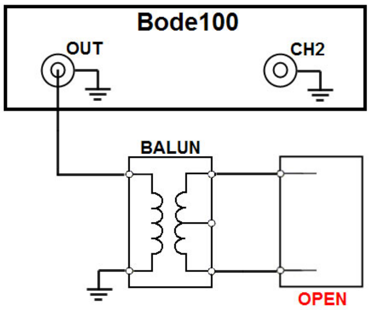


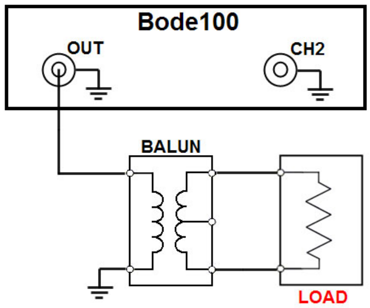
For the impedance measurement you have to set the load resistor to 110 ohm in the advanced settings of the calibration window.

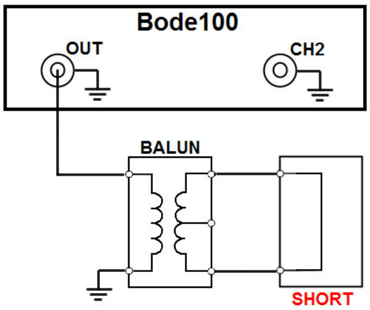


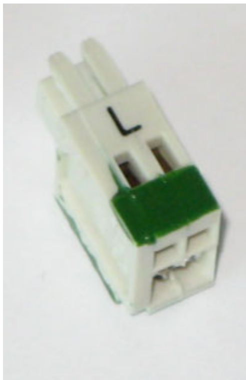
Note: Perform the different impedance calibration modes with an open/short/load connector as described in the User Manual.

Calibrate Bode 100 by using the **O**pen, **S**hort and **L**oad.

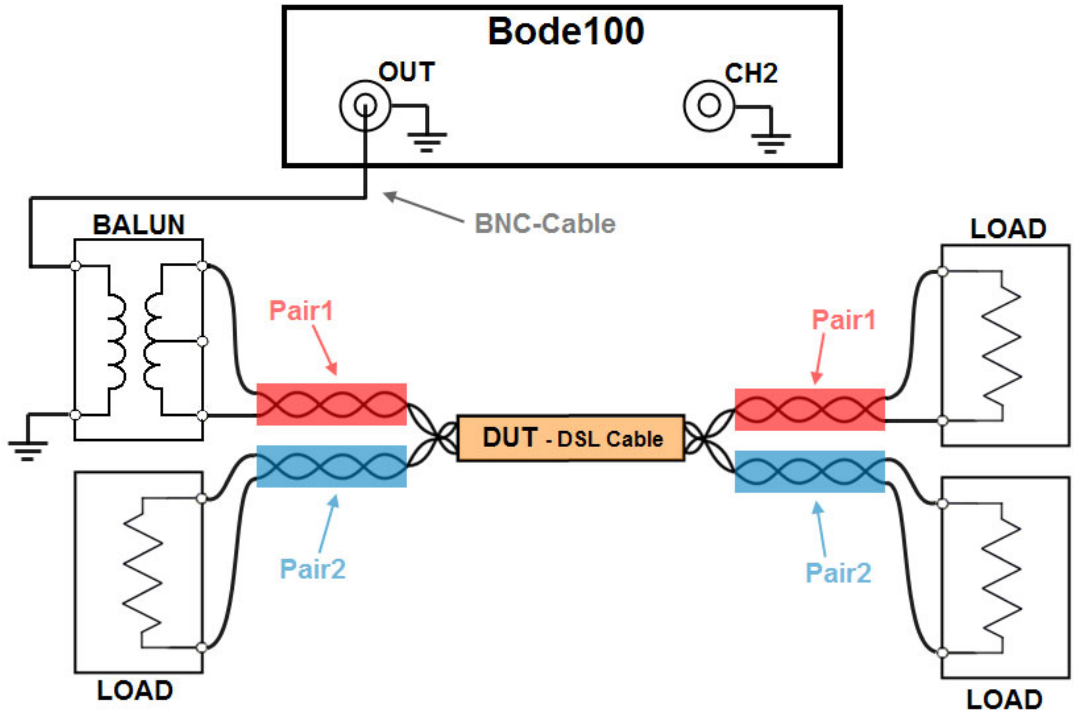




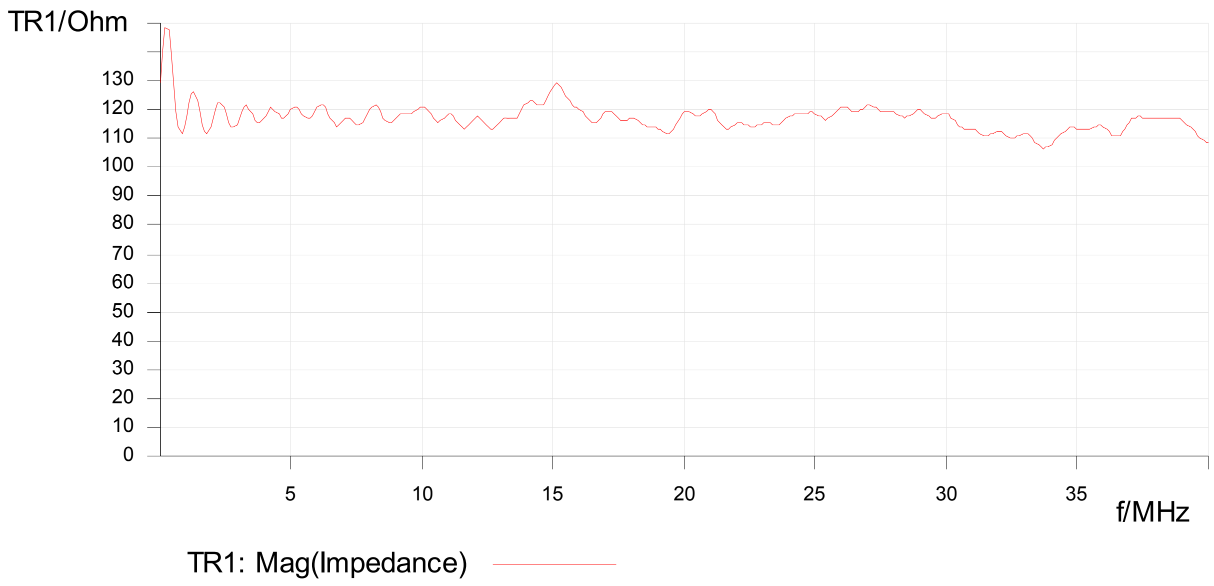




To measure the cable impedance we have to connect the DSL-Cable as shown.



Now start the measurement by pressing the single measurement button.

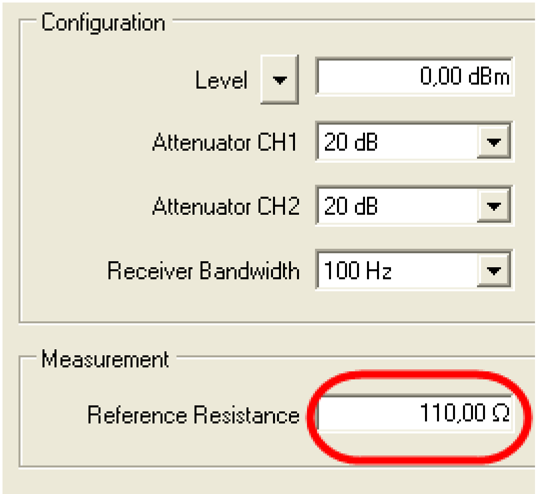


Result: As we can see, the impedance of our DSL-Cable has a slight deviation from the ideal Load (110 ohm). The reason is that the wave resistance of our DSL-Cable, which is 120 ohm.
The ripple is caused by variations and deflections in the cable construction.

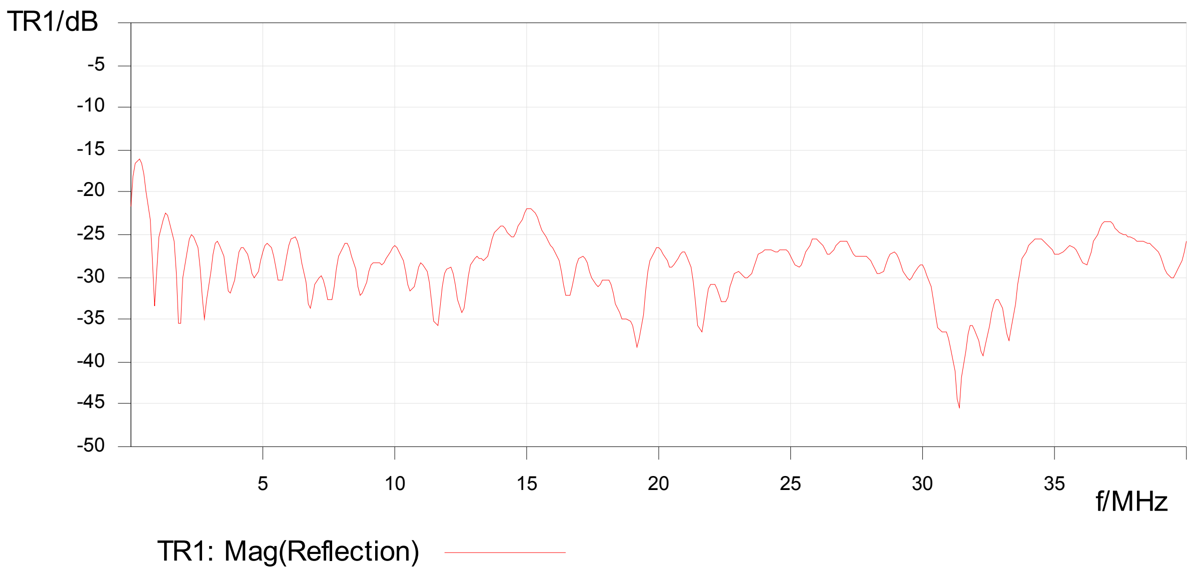
3.7 Return Loss (RL) of DSL-Cables:

To measure the RL of your DSL-Cable configure Bode 100 like shown in "3.7 Impedance Measurement".

Note: Set the reference resistance to 110 ohm.



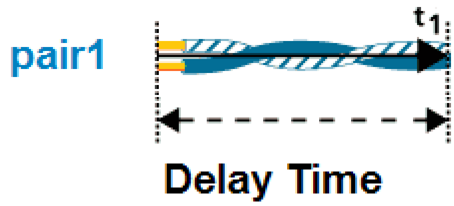
Start the frequency measurement.



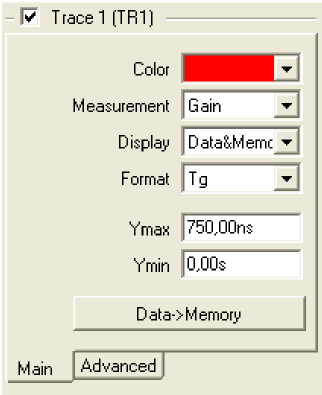
Result: The ripple of the return loss is caused by cable deflections.

3.8 Group delay

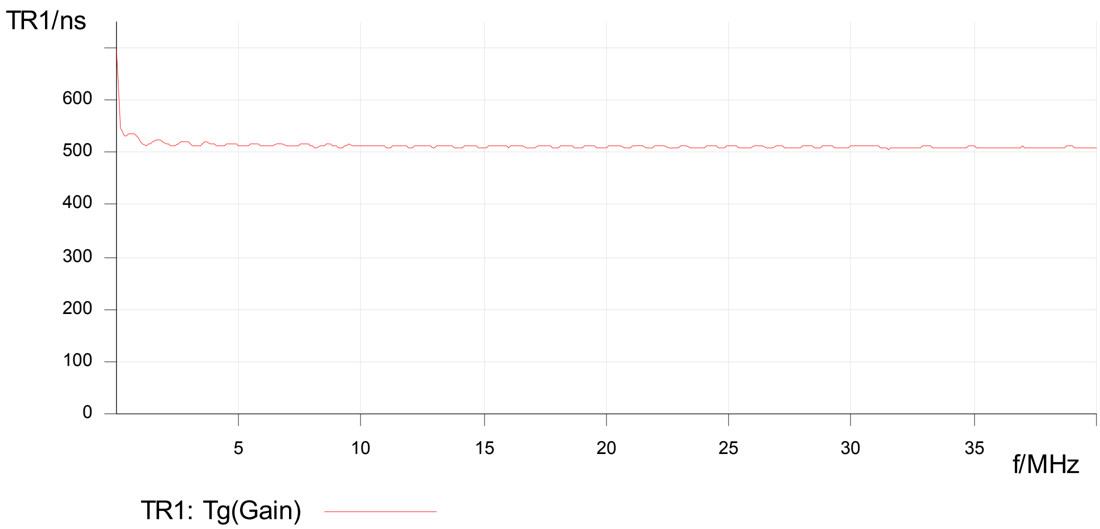
The group delay represents the time which is needed by a signal to pass our DUT.



To measure the group delay, configure the Bode 100 as shown in the attenuation measurement. Calibrate the Bode 100 and set Trace1 to format Tg.



Now the measurement can be started.



Result: The group delay is around 500ns for 100m cable – this is approx. 5ns/1m. It is also possible to calculate the propagation speed like shown in the next section.

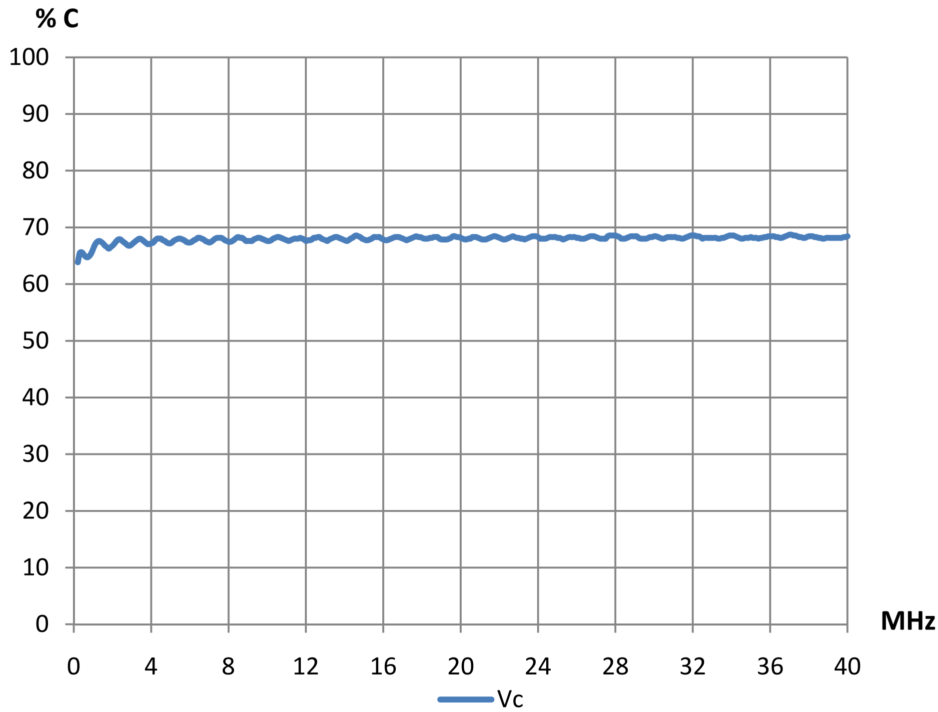
3.8.1 Propagation Speed

The propagation speed is the calculated velocity of a wave passing thru the DUT.

$$v_p = \frac{100m}{Tg}$$

To display the measurement result in a good range, we calculate the velocity factor. It is the propagation speed in ratio to the speed of light in vacuum (3*10^8 m/s). Export the measurement data like shown in "3.6 ELFEXT Measurement" to software like EXCEL or MATLAB. This will allow you to generate a diagram as shown below.

$$v_c = \frac{v_p}{C}$$



4 Conclusion

In this application note it has been shown how electrical characteristics of DSL-Cables like attenuation, crosstalk and phase velocity can measured with Bode 100. All measurements worked out nicely and matched the cable's measurement protocol, which was provided with the cable.