Evaluation of channel micro-reflections

For higher data rates we need to revisit channel characteristics

Ragnar Jonsson and Ramin Farjadrad
Marvell

July 2020

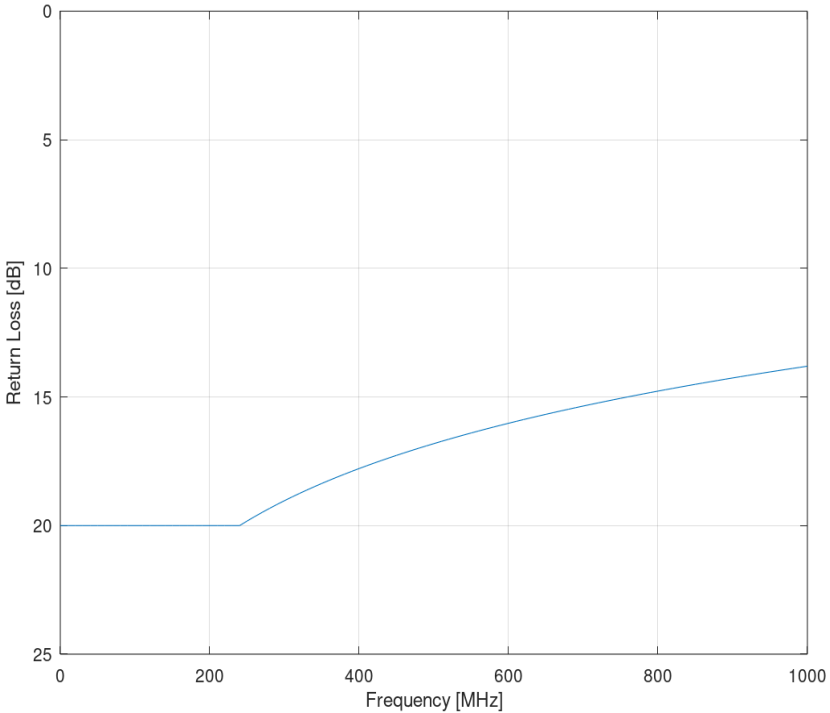
Traditional Limit-Line Cable Specifications

Traditionally echo limitation is defined as frequency mask that limits the return loss

The drawback with this method is that it does not restrict the phase or time domain structure of the channel reflections

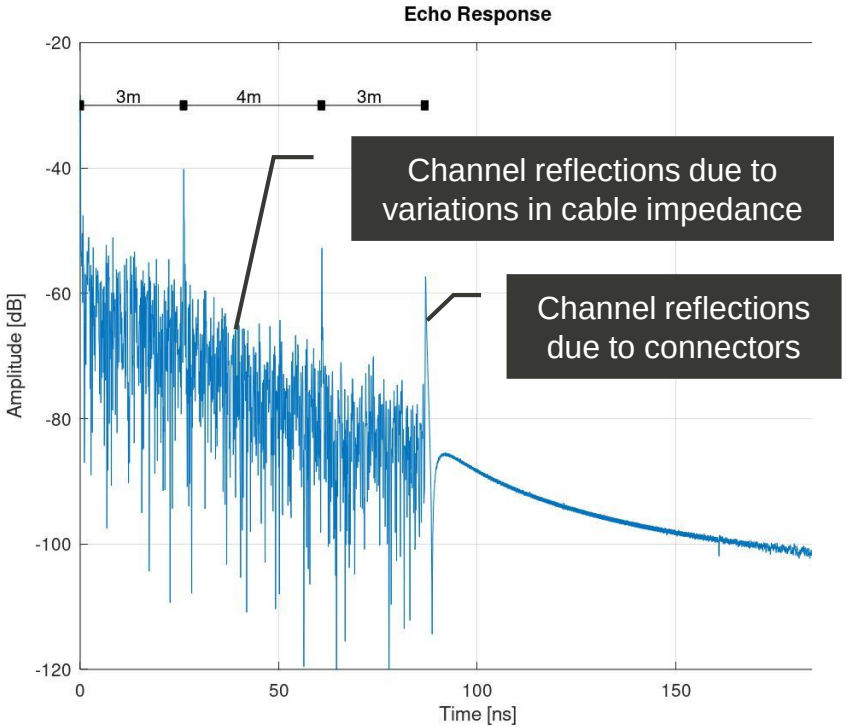
With higher data rates we need more optimized transceiver implementations

This requires constraints on the time domain structure of the channel reflections



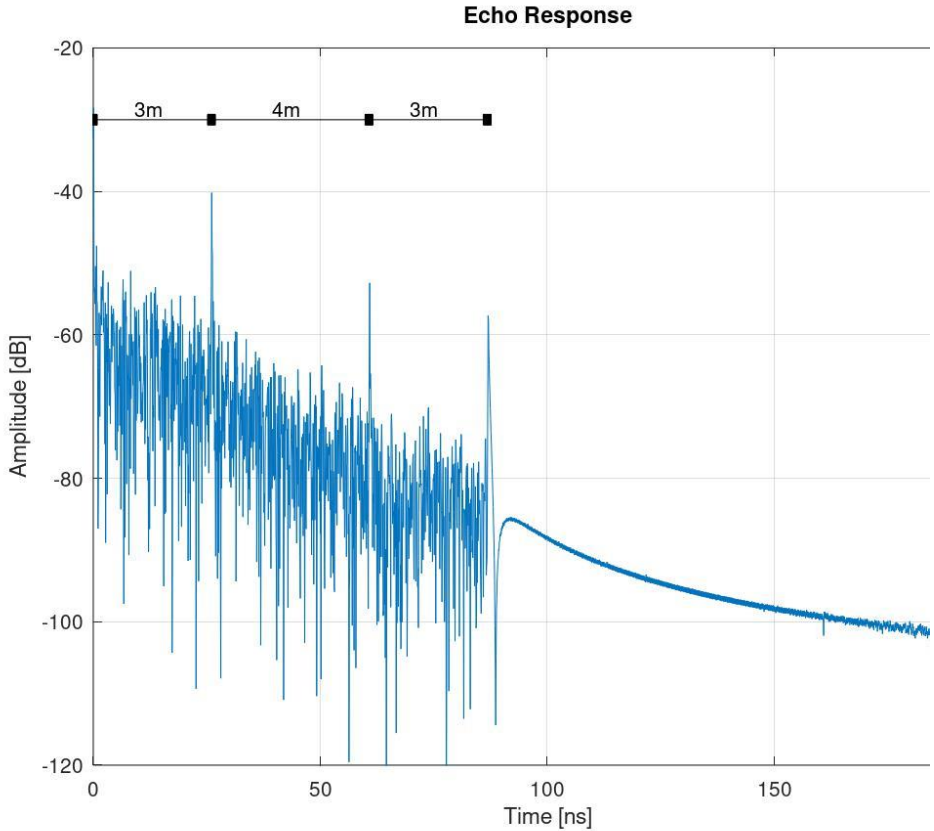
Channel Reflections

- Channel reflections happen on the transmission channel due to impedance mismatch
- The two main sources of channel reflections are connectors and impedance variation along the cable it self
- Connectors typically have relatively strong reflections
- Variations in cable construction will typically introduce smaller reflections along the length of the cable
- The strength of the channel reflections depends on the quality of the cables and the connectors

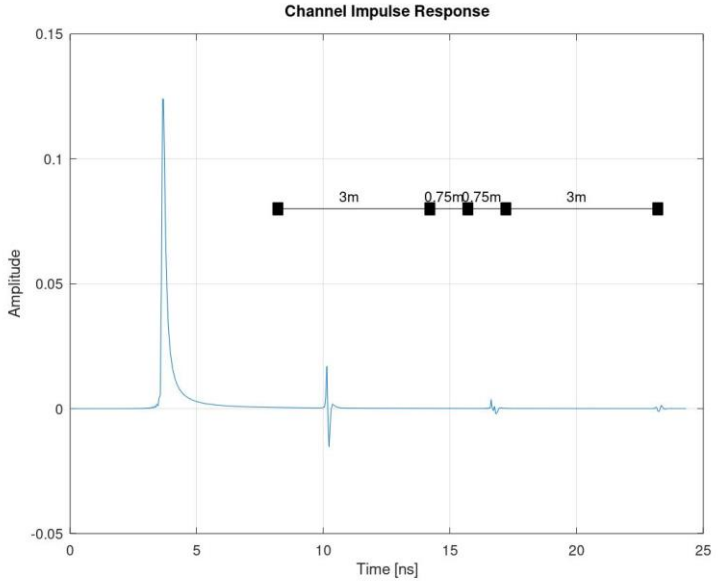


What are Micro-Reflections?

- The term micro-reflection can sometimes cause confusion
- In this presentation we use the term micro-reflections to indicate that we are interested in the time-domain structure of the channel reflections



Micro-Reflections in the Transmit Path



The figure to the left shows the impulse response for the channel **Insertion Loss**

Because of impedance mismatch at the inline connectors there will be reflections that will go back and forth

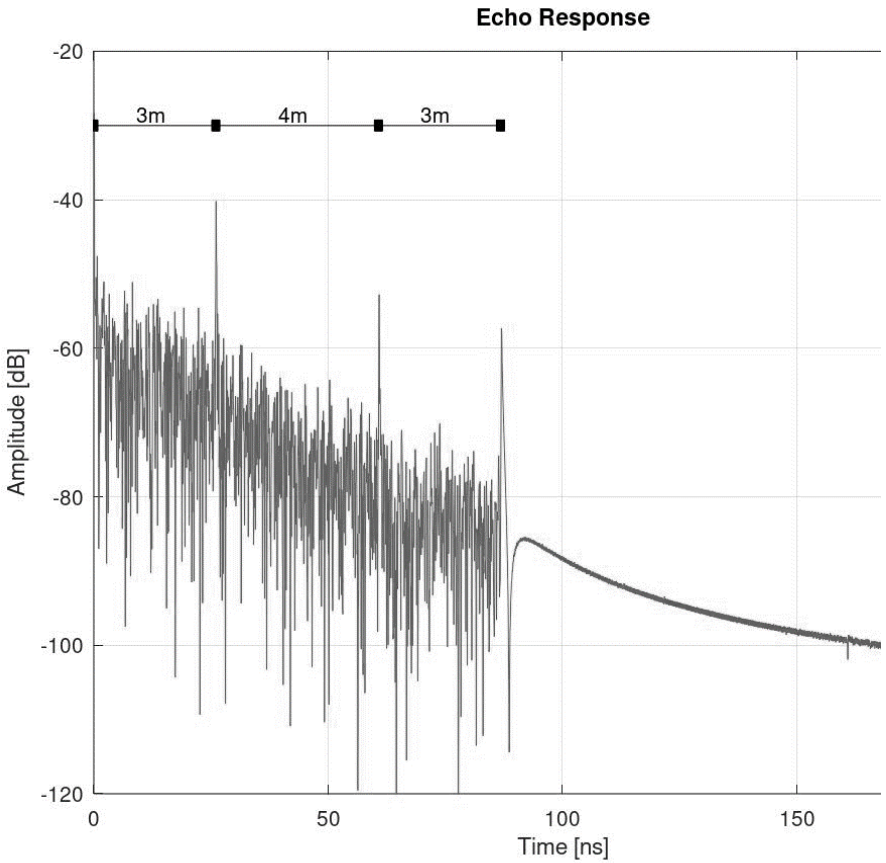
These reflections can show up as smaller delayed pulses in the channel impulse response and make it harder to equalize the received signal

To keep things simpler, we will focus on the echo response of micro-reflections in the rest of this presentation

Why Restrict Micro-Reflections?

Micro-Reflections can impact

- Achievable bit rate on the link
- Achievable reliability of the link
- Complexity of echo cancelers
- Complexity of equalization
- Complexity of ADC
- Complexity of Analog Front End



Simulations of Micro-Reflections

Marvell

Why do Simulation?

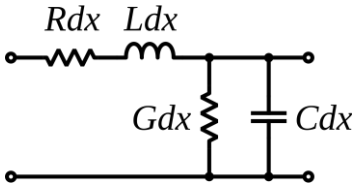
We have limited number of cable measurements

We want to experiment with many different cable structures

We can use the exact same (simulated) cable in different configurations for apples-to-apples comparison

The simulations are to augment (not replace) the cable measurements we have

Channel Model From Transmission-Line Theory



$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

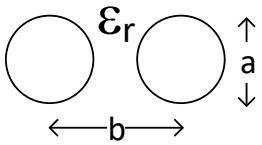
Transmission-Line Theory is used to generate parameterized channel models from channel measurements

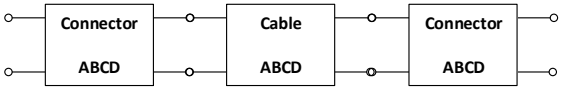
The Primary Coefficients are calculated from the cable properties

We generate two-port model for cable segments based on Primary Coefficients

More complex models are generated by concatenating multiple two-port

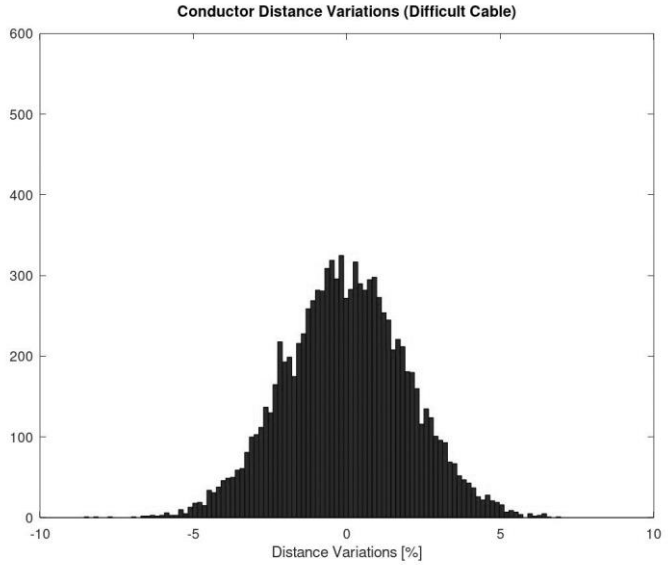
ABCD matrices are used to calculate the composite channel characteristics

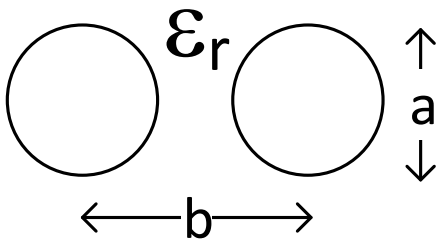




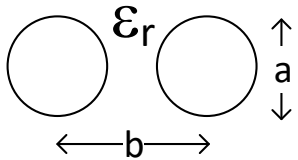
Simulating Micro-Reflections

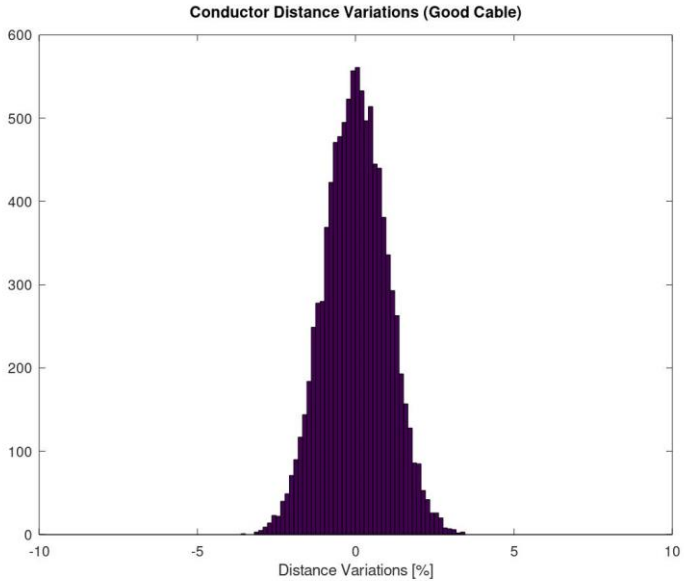
- To simulate micro-reflections in the cable models, the wire distance is varied for every 1mm length segment of the cable
- More variation in wire distance means stronger micro-reflections

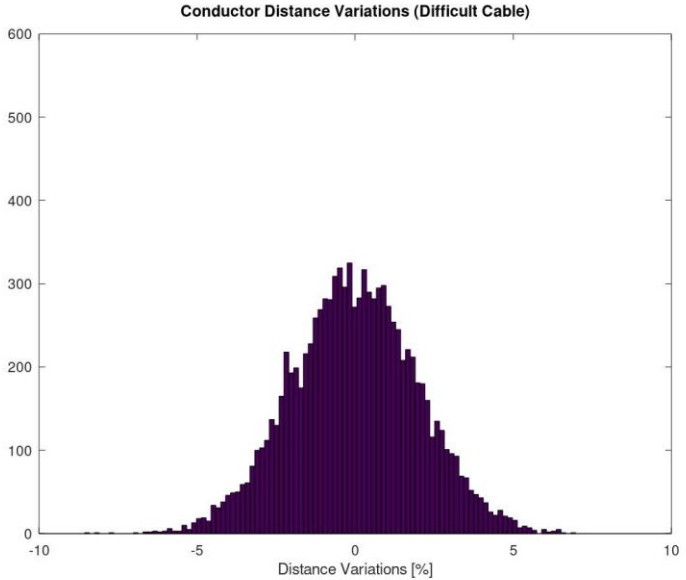




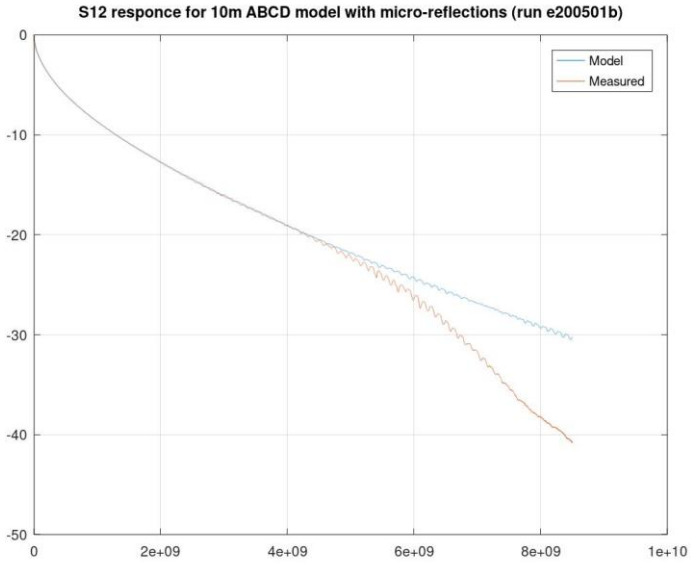
Good vs Difficult Cable (Conductor Distance Variations)

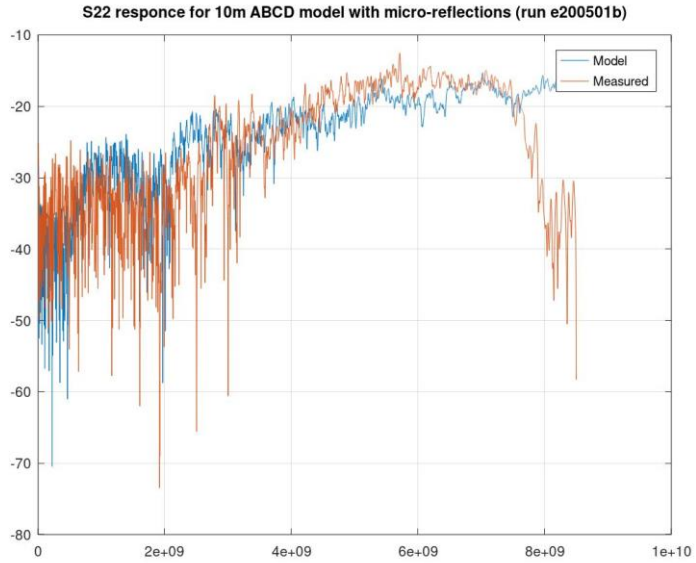






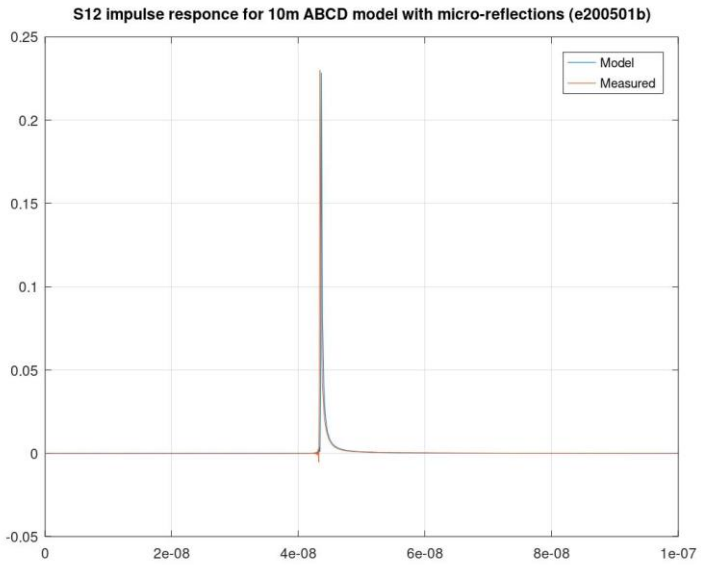
Example Model vs Measurements

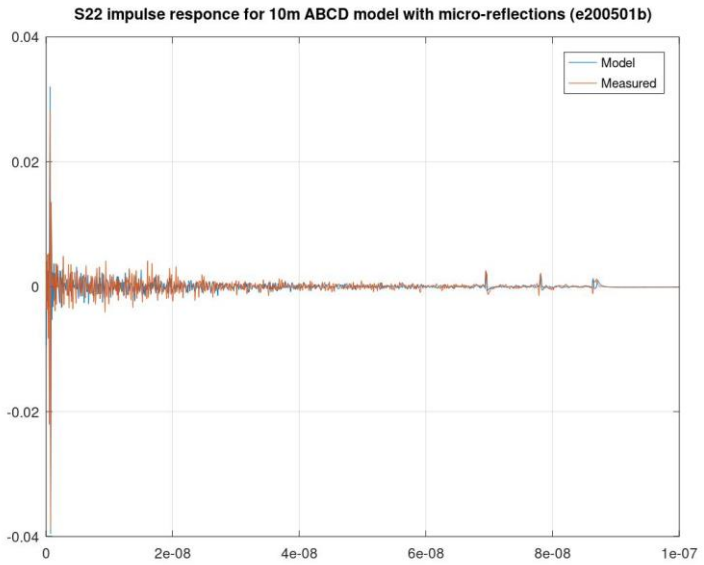




The model was generated by fitting model parameters to measured S-parameters

Example Model vs Measurements



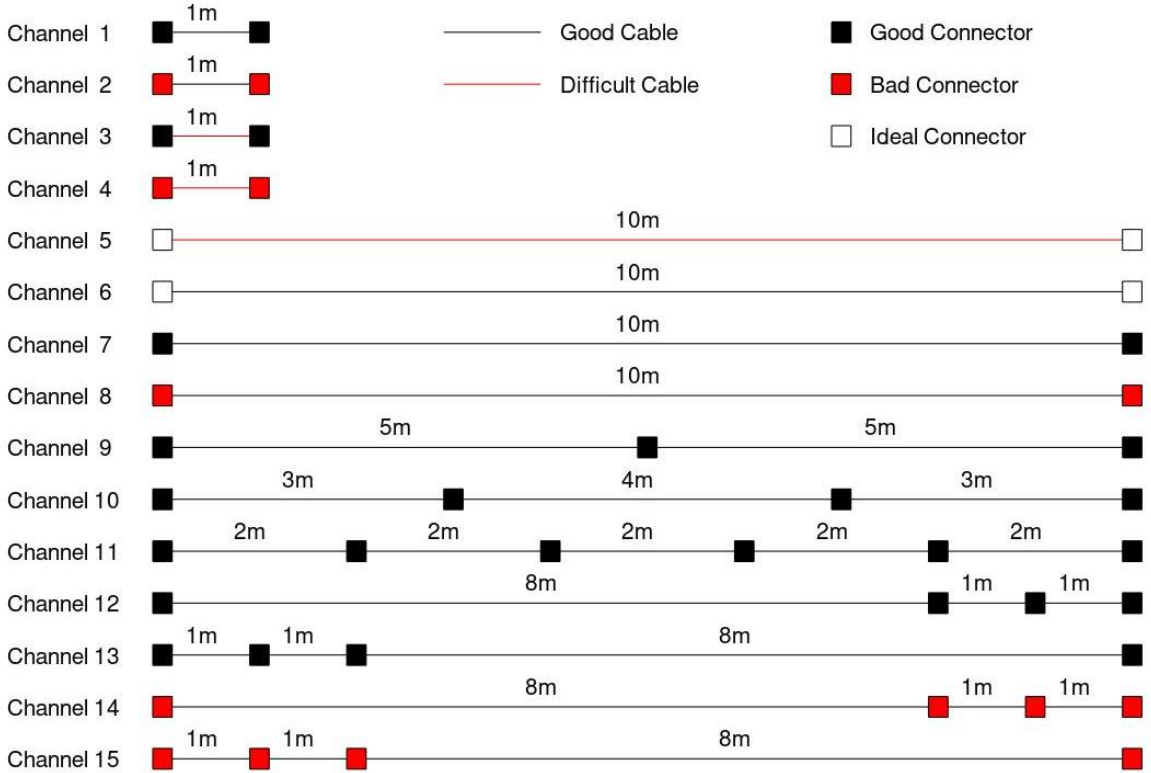


The model was generated by fitting model parameters to measured S-parameters

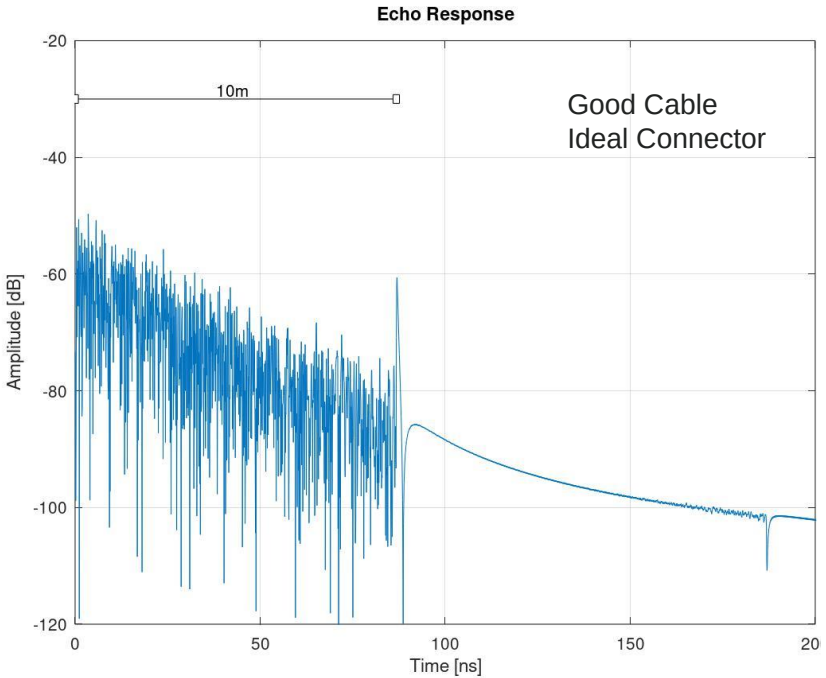
Evaluation of Micro-Reflections

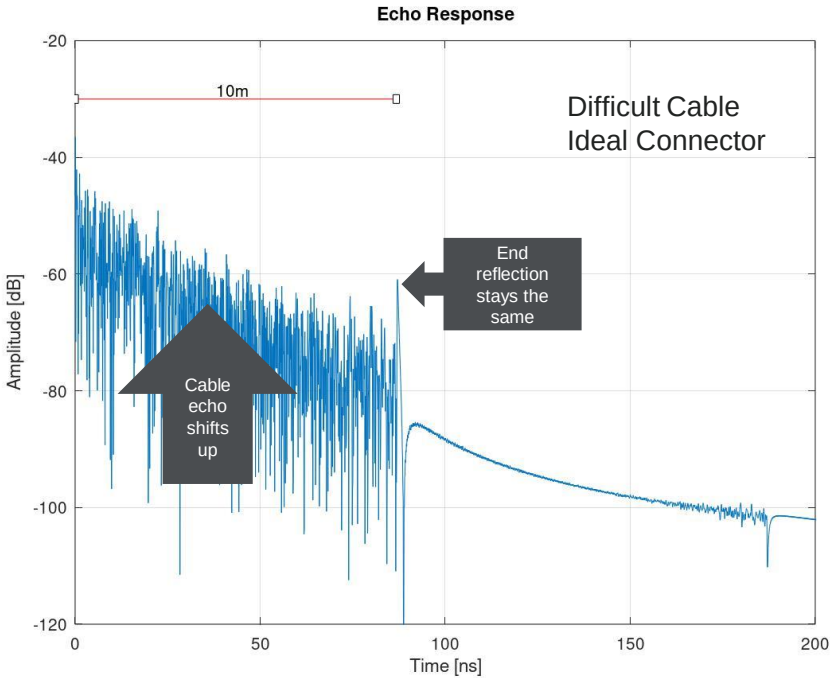
Marvell

Simulated Channels

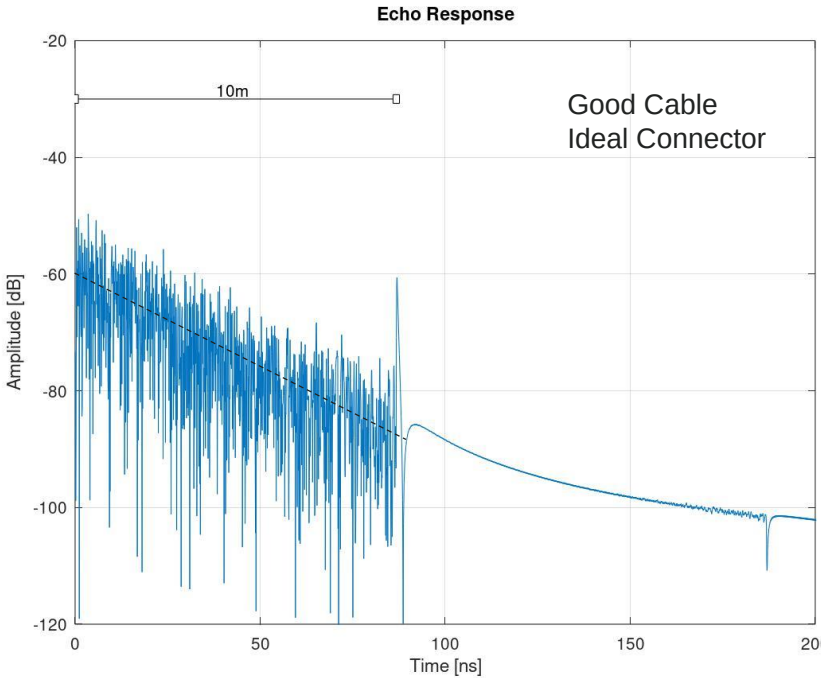


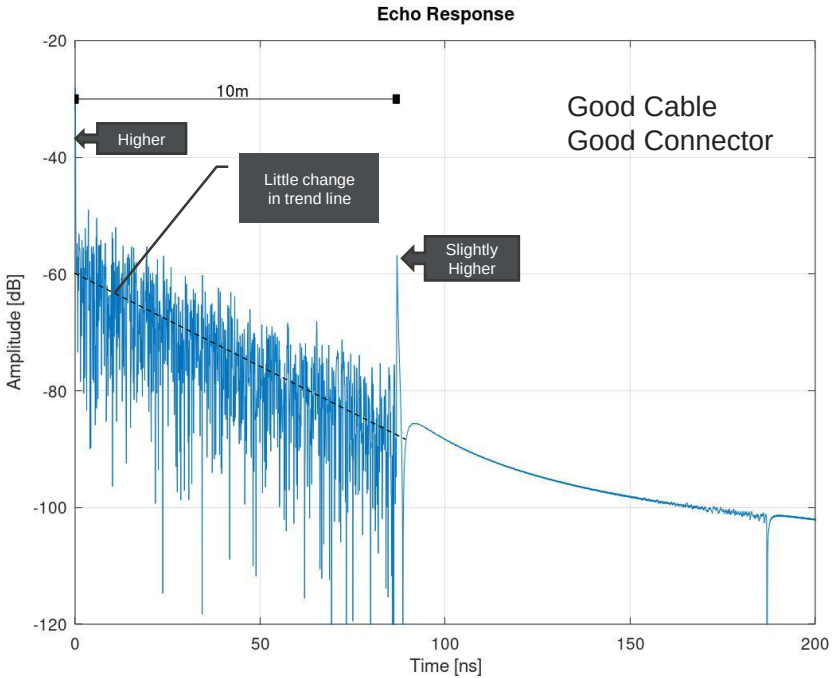
Good vs Difficult Cables (Simulated)



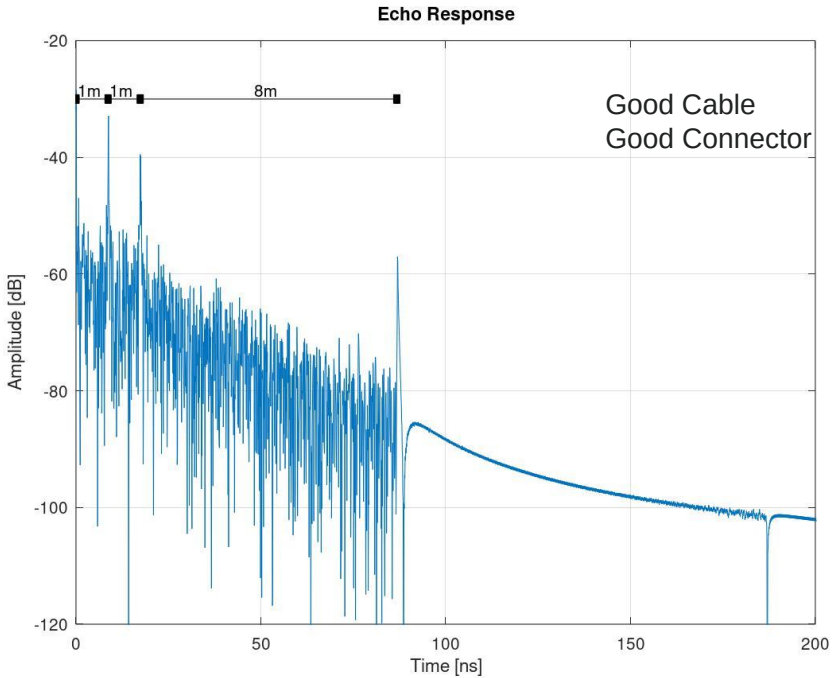


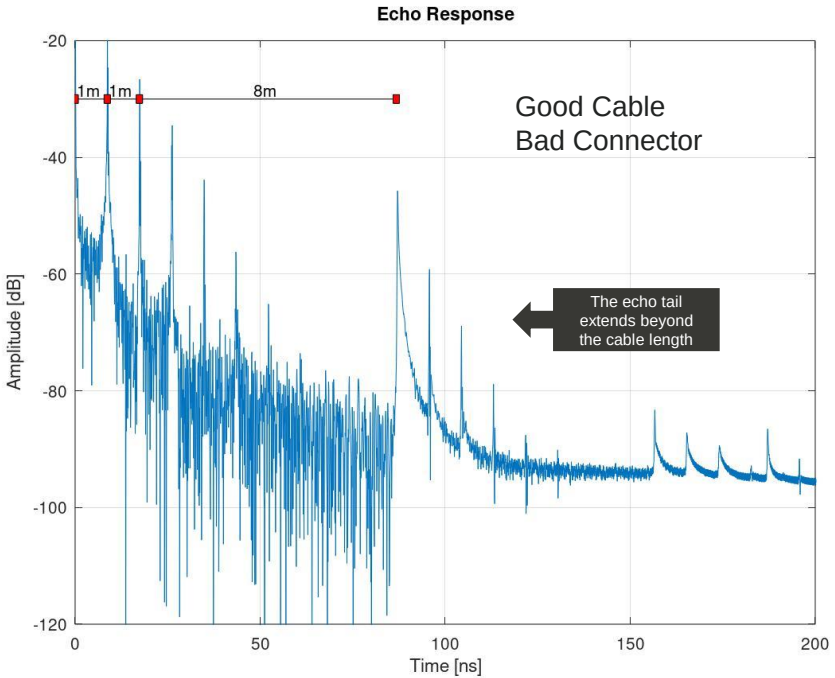
Good vs Bad Connectors (Simulated)



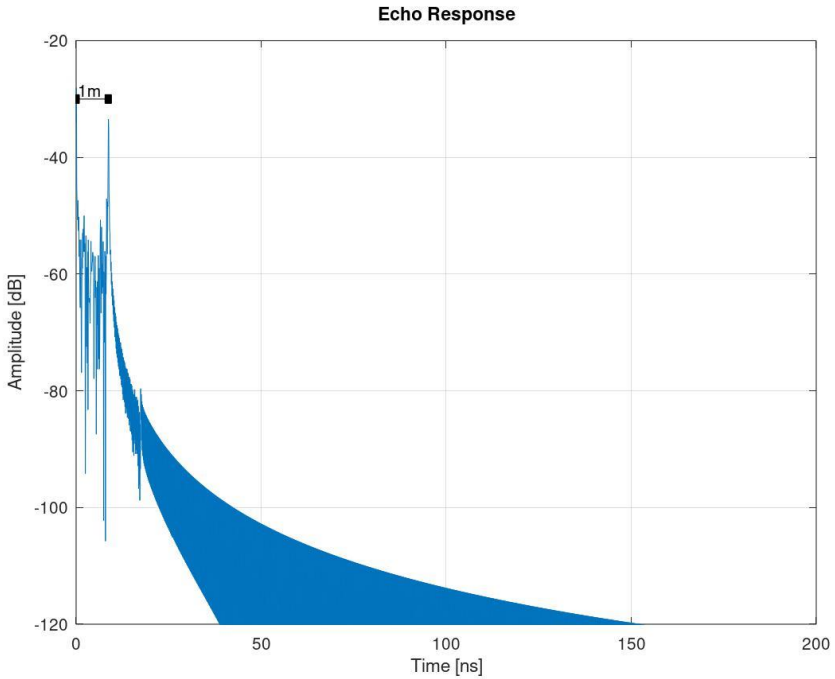


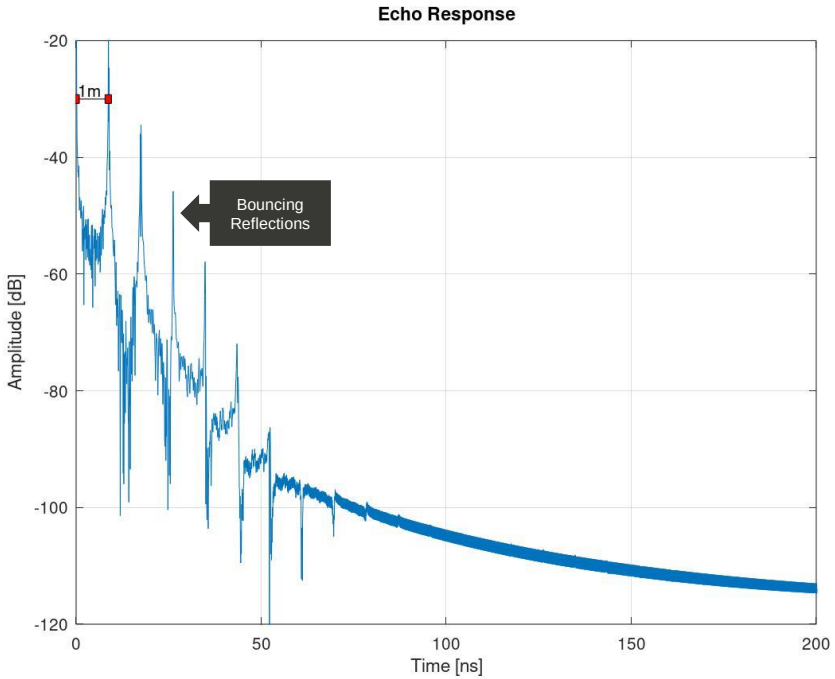
Extended Echo Response



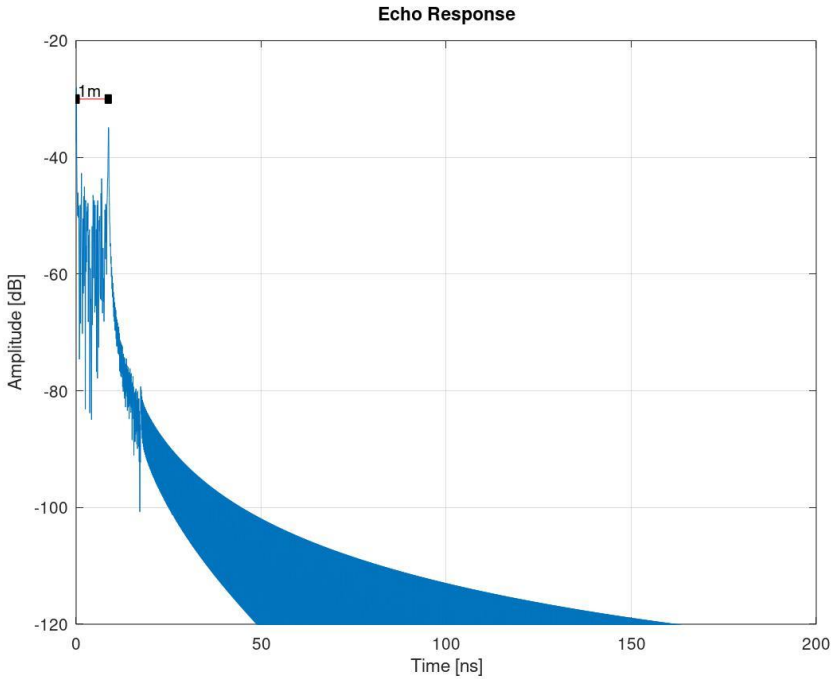


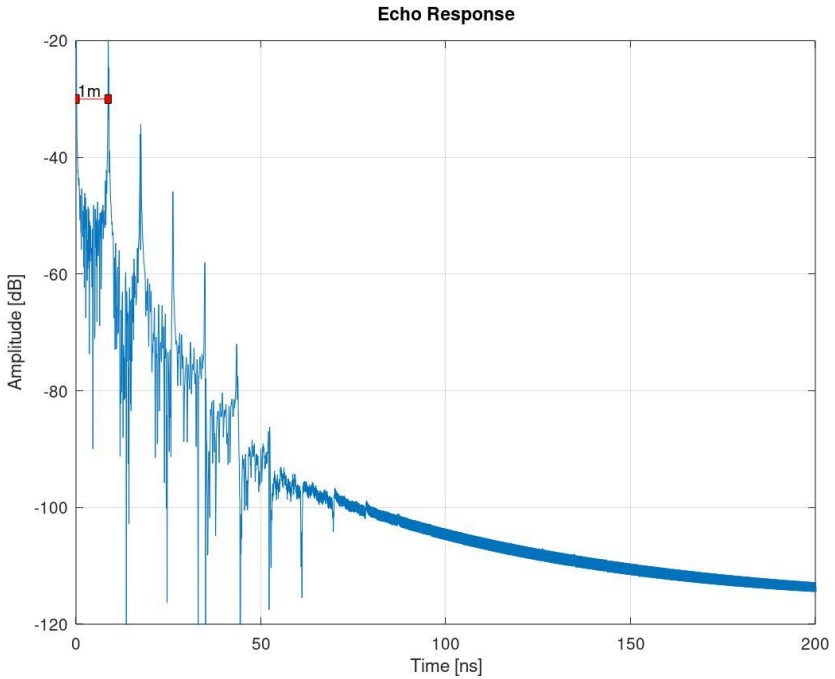
Channels 1 & 2


Echo Response
1m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
200
Time [ns]

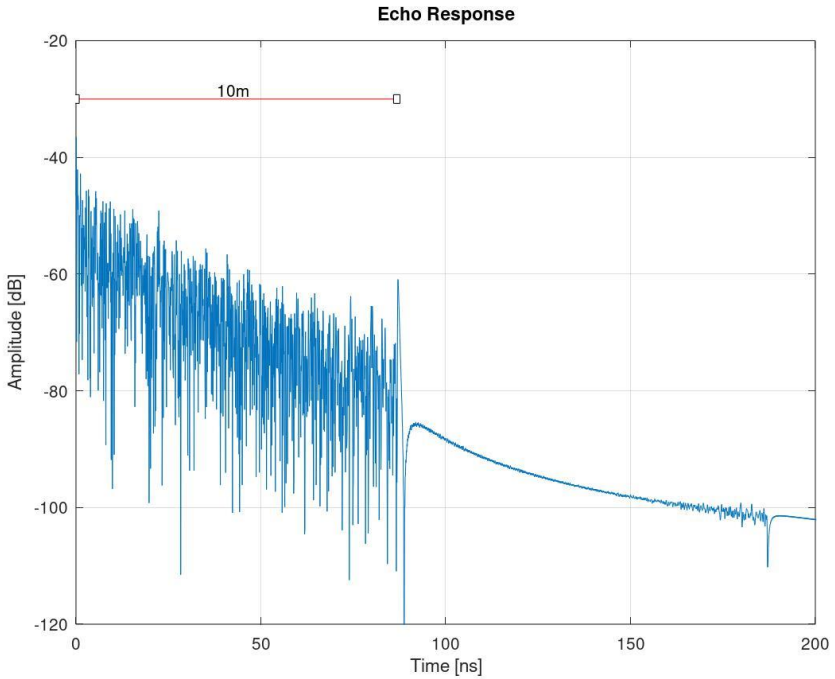

Echo Response
1m
Bouncing Reflections
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
200
Time [ns]

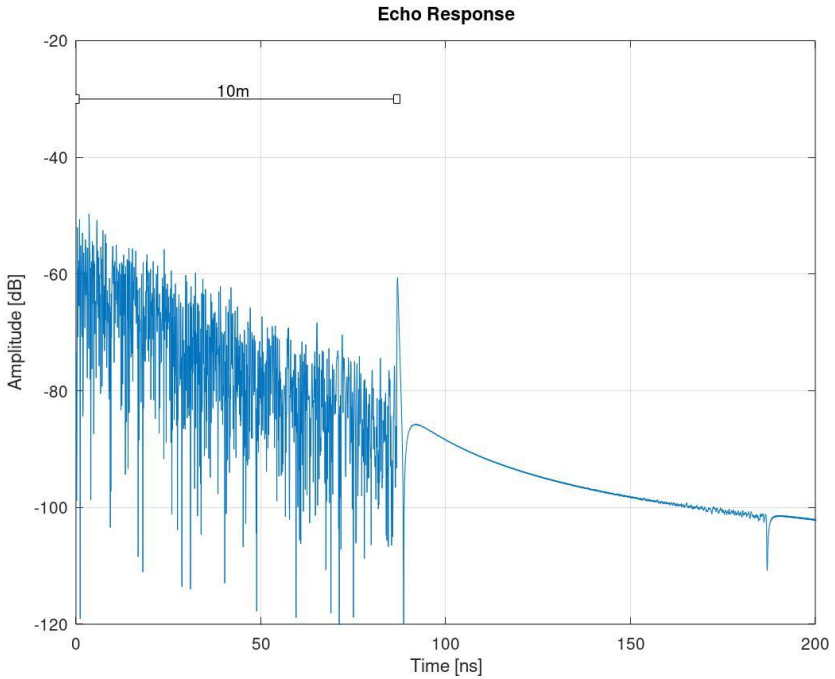
Channels 3 & 4


Echo Response
1m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
200
Time [ns]

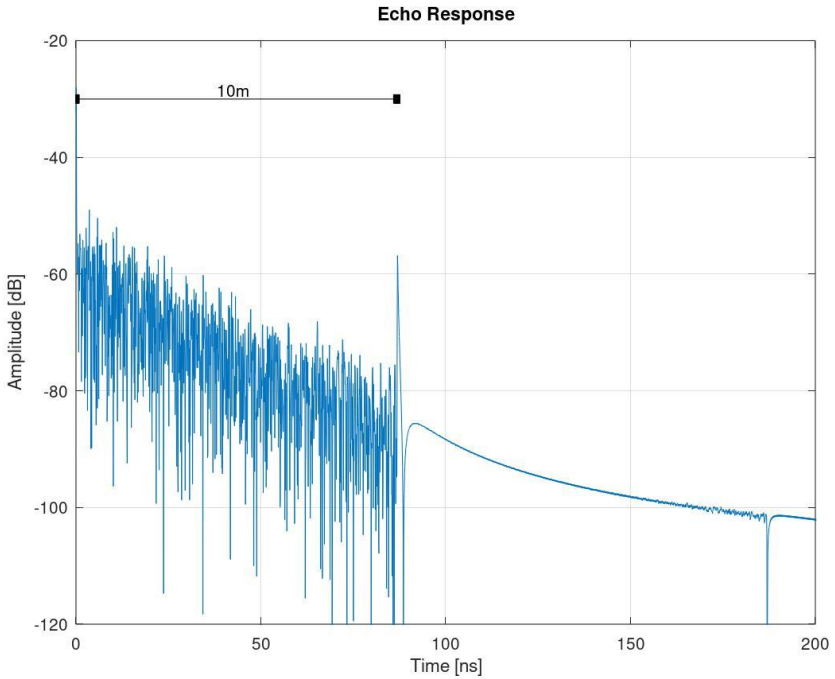

Echo Response
1m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
200
Time [ns]

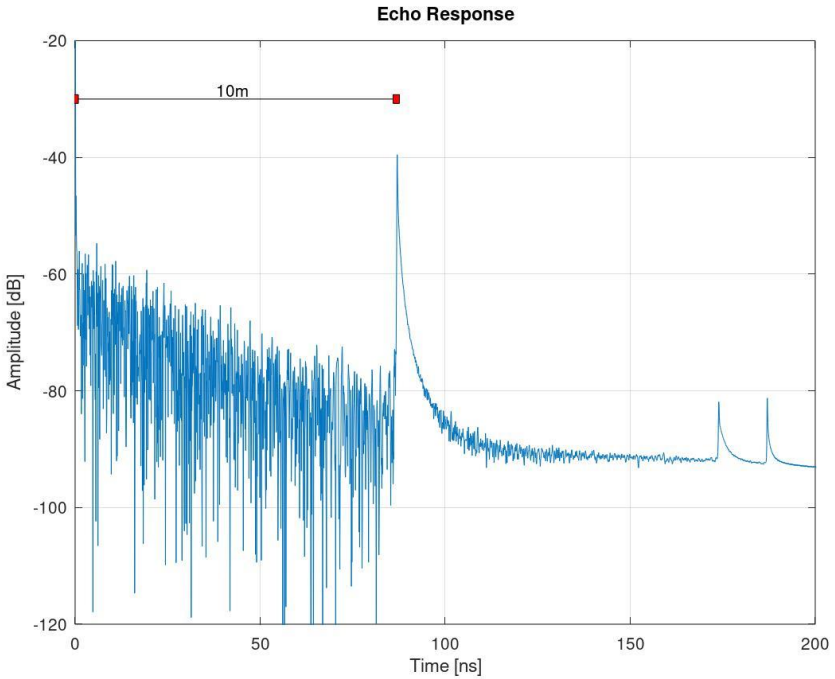
Channels 5 & 6


Echo Response
10m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
200
Time [ns]

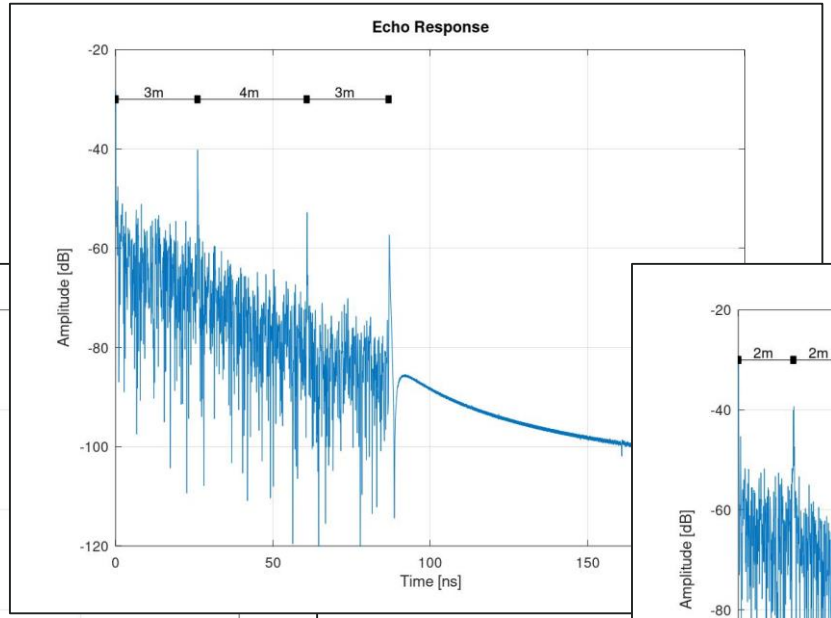

Echo Response
10m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
200
Time [ns]

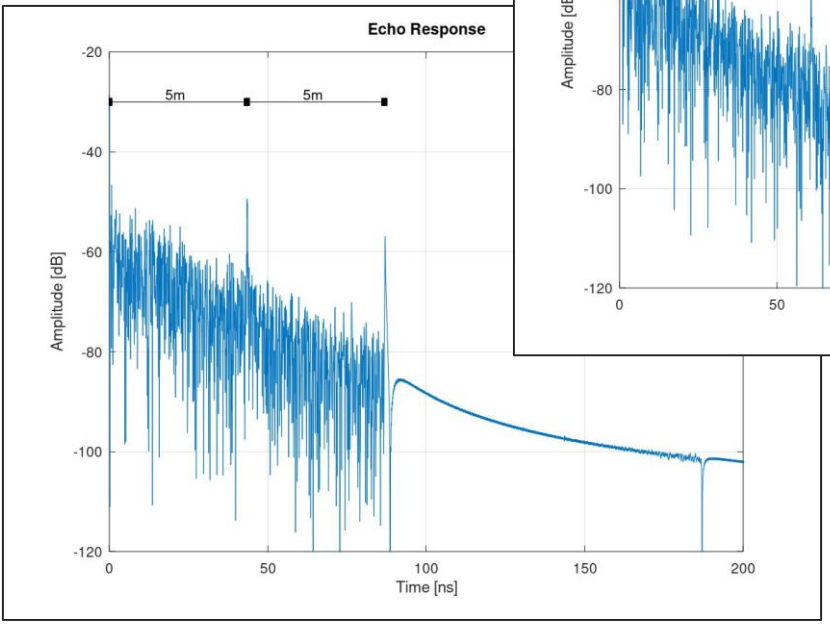
Channels 7 & 8

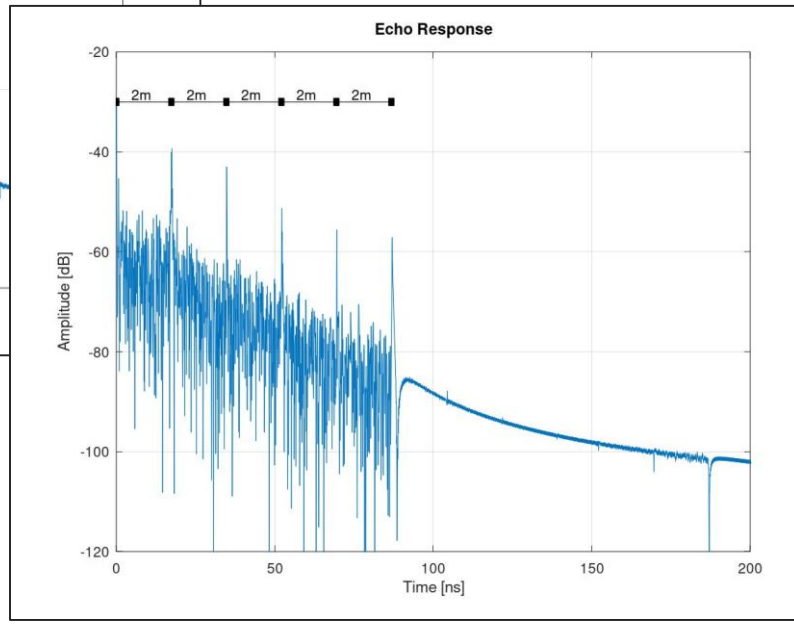

Echo Response
10m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
200
Time [ns]


Echo Response
10m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
200
Time [ns]

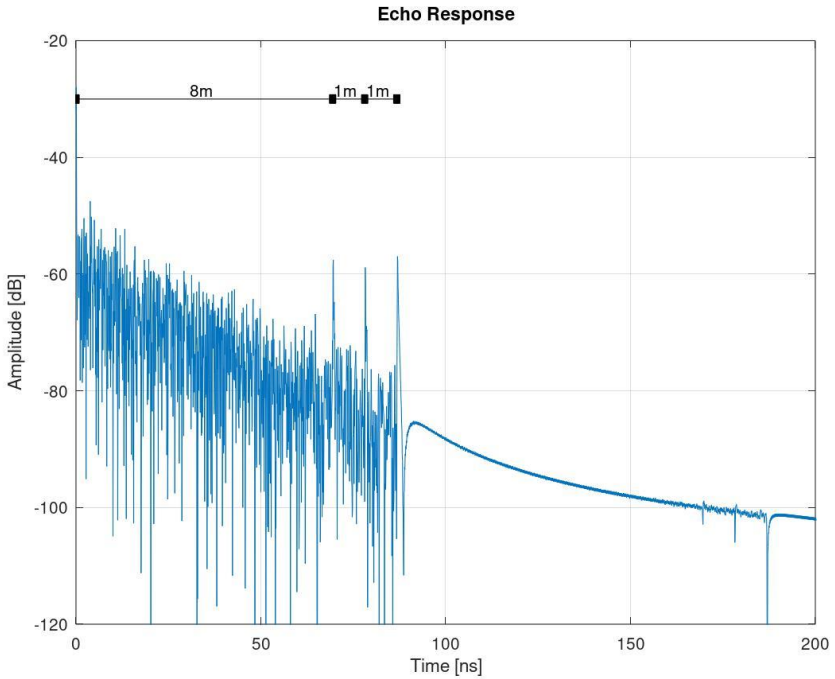
Channels 9, 10 & 11

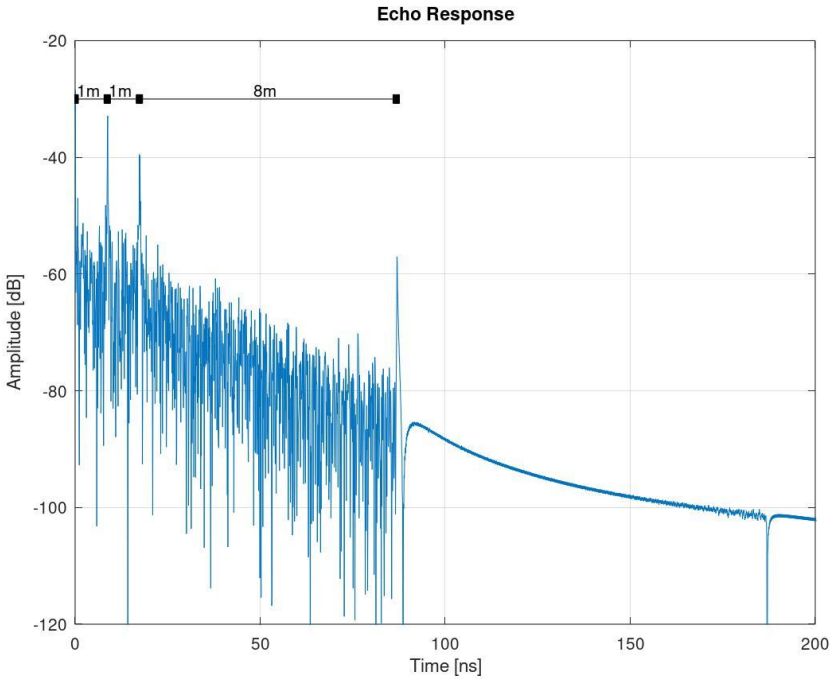




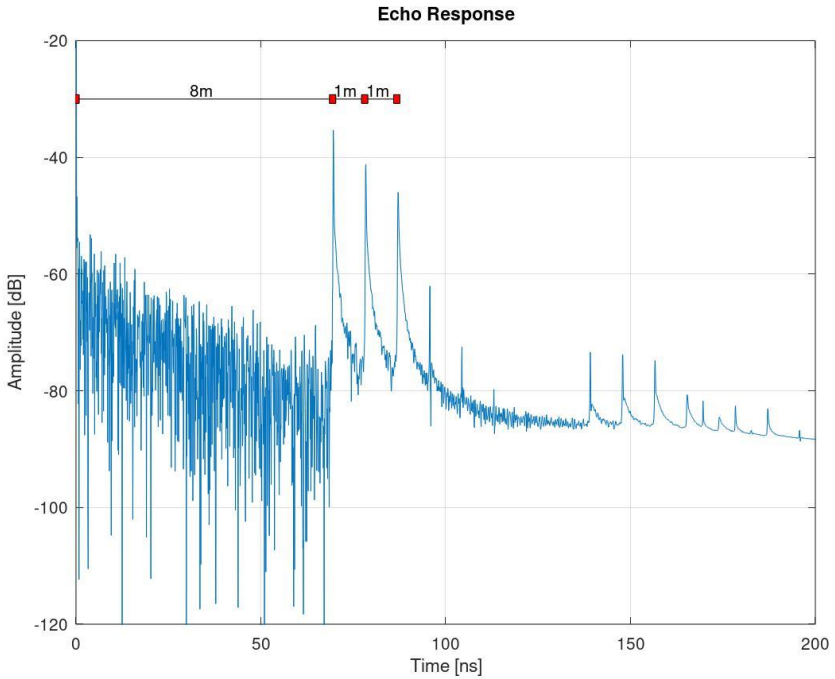


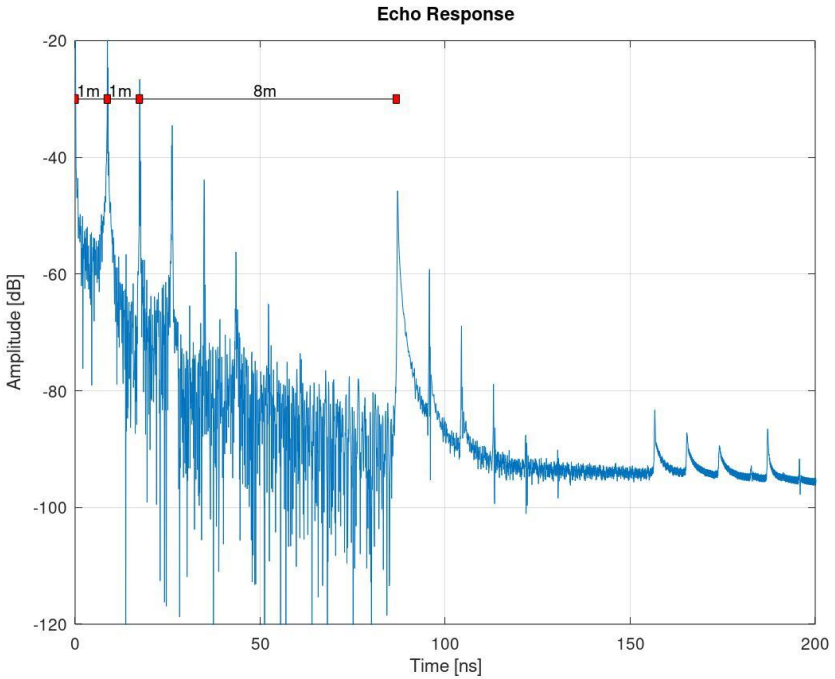
Channels 12 & 13





Channels 14 & 15



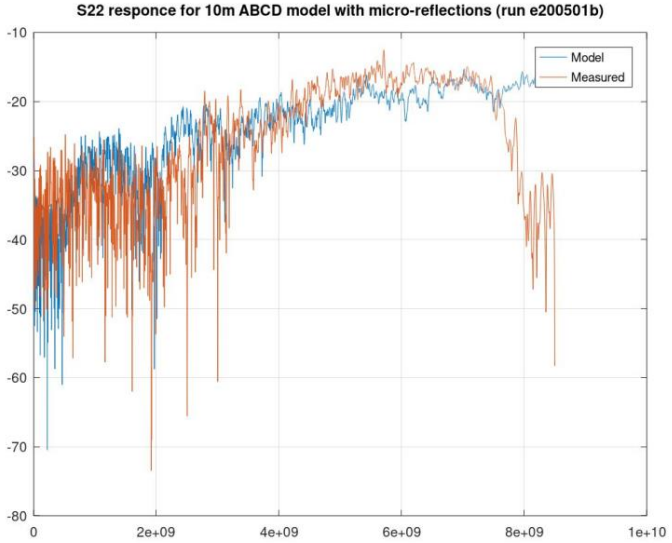


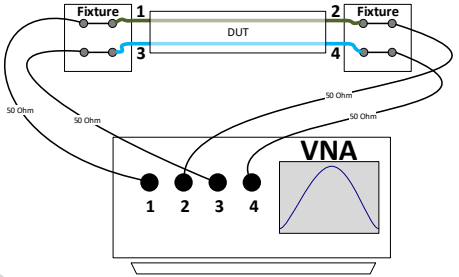
We Need Channel Measurements

Channel simulations are good for evaluations of different scenarios

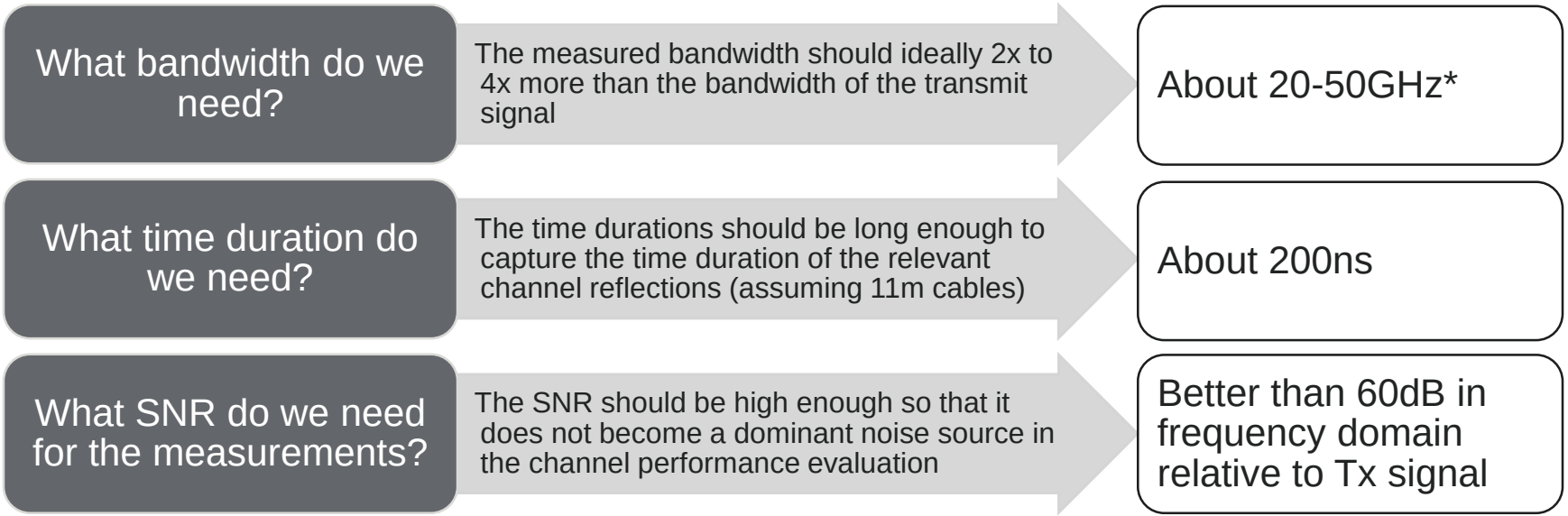
However, simulations are inherently limited by the accuracy of the assumptions used in the models

We need real channel measurements to evaluate what to expect for real channels





Accuracy of Channel Measurements



* Widely available measurement equipment will go as high as 20GHz, but 50GHz equipment is available. If we use multi-lane implementations for 50G and 100G, then we can use less bandwidth.

Conclusion

For higher data rates we need to revisit how we constrain channel reflections

Micro-reflections and time domain structure of the echo is important

Echo simulations demonstrated how different impairments effect the echo

We need real cable measurements to evaluate expected channel characteristics

MARVELL

Thank You

Essential technology, done right™