Method for Restricting Micro-Reflections

Contribution to IEEE 802.3cy

Ragnar Jonsson and Ramin Farjadrad
Marvell

October 2020

Introduction

Echo cancelation is a powerful method to increase the performance of a communication system, and echo-canceler based communication systems have better performance than systems using other duplexing methods

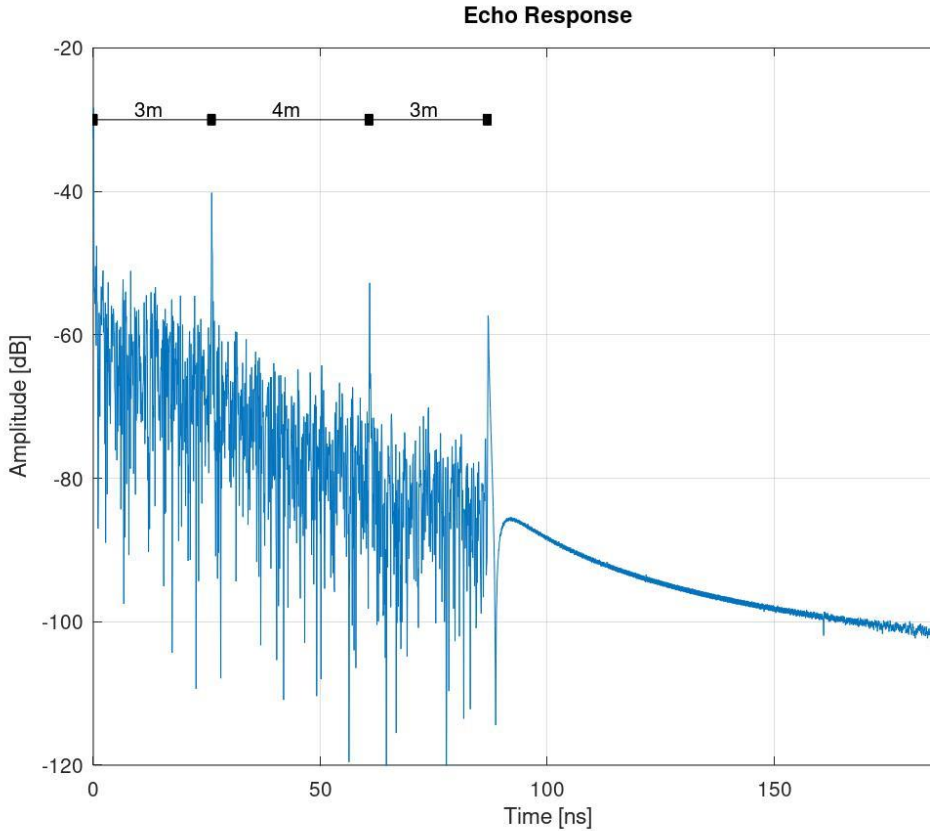
The echo canceler size will increase with increasing sampling rate

To mitigate this we suggest to define limits for micro-reflections

We share some simulation results to demonstrate how the suggested limits help control return loss

What are Micro-Reflections?

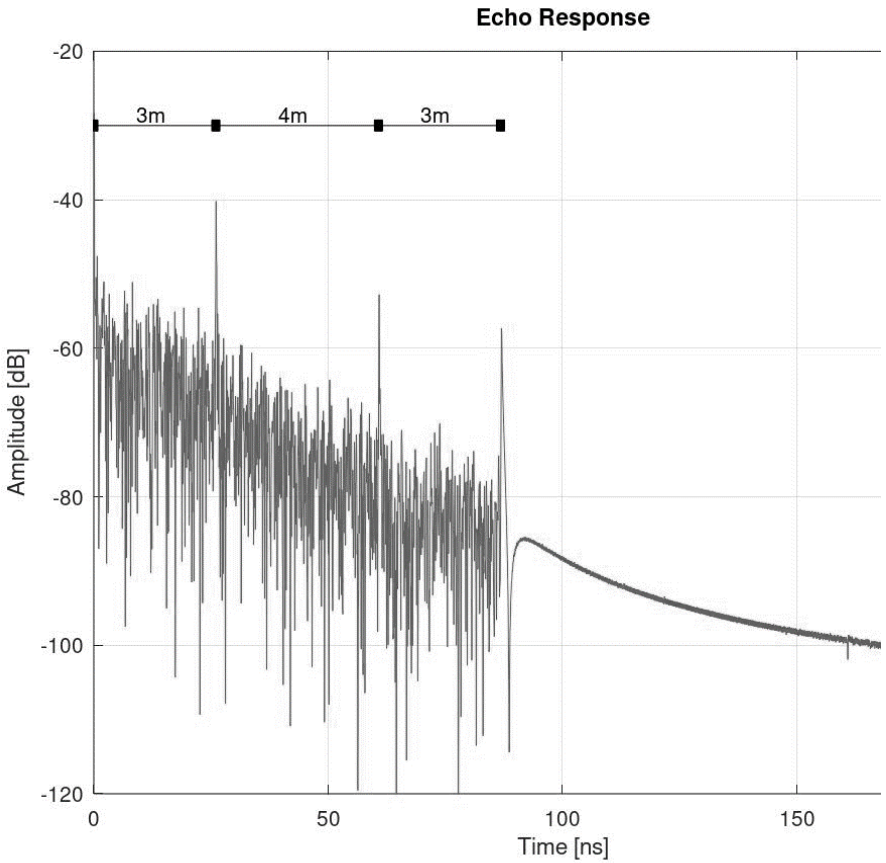
- The term micro-reflection can sometimes cause confusion
- In this presentation we use the term micro-reflections to indicate that we are interested in the time-domain structure of the channel reflections
- We will distinguish between larger reflection at connectors and the much smaller micro-reflections along the cable



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



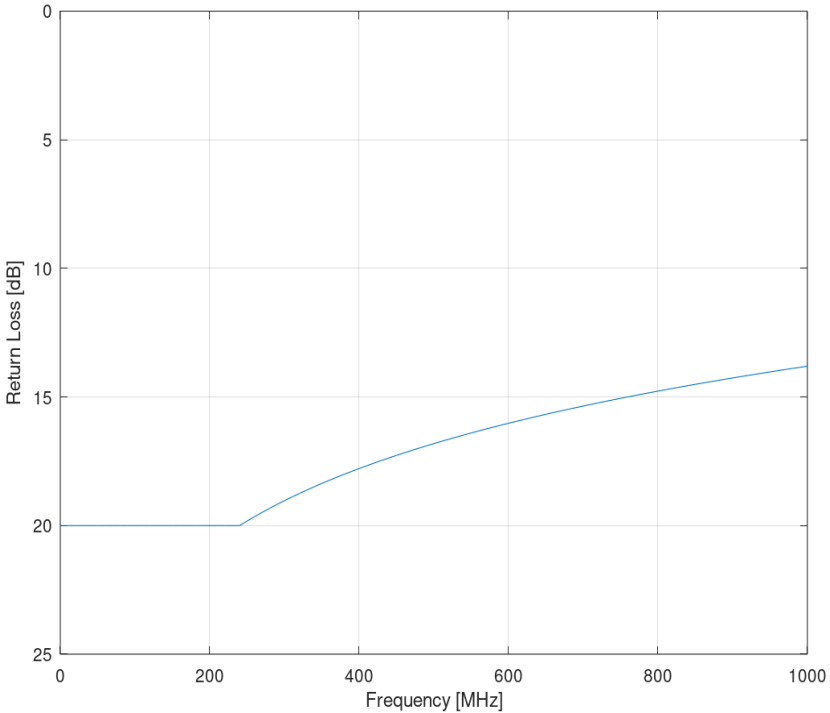
Traditional Limit-Line Cable Specifications

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

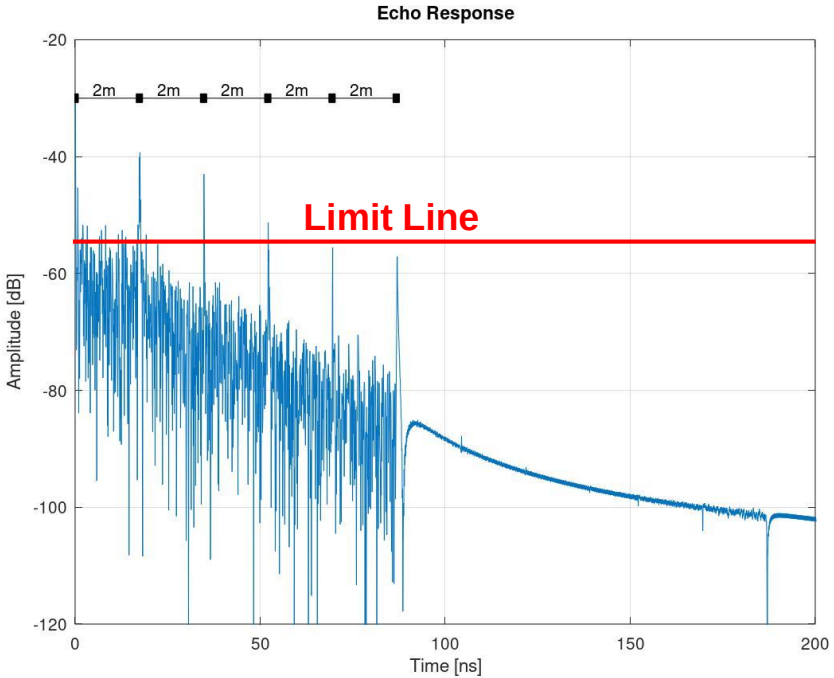
The drawback with this method is that it does not restrict the phase or time domain structure of the channel reflections

With higher data rates we need more optimized transceiver implementations

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



Alternative Time-Domain Approach to Limit Echo

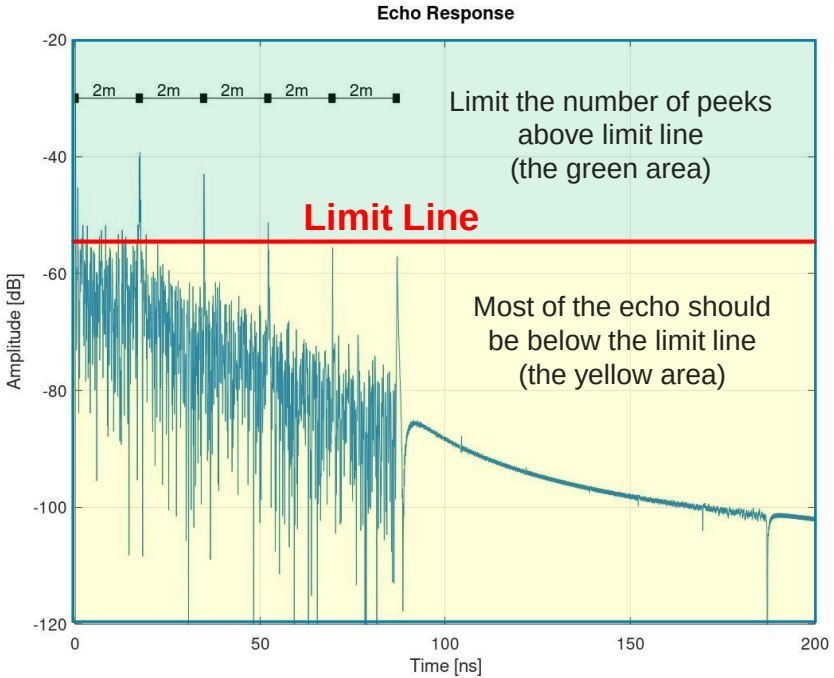


The time-domain structure of the echo signal is more important than the frequency domain properties

The PHY design can take advantage of the echo time-domain structure to implement more efficient echo cancelers

We suggest using a simple limit line that **most** of the echo must stay below

Alternative Time-Domain Approach to Limit Echo

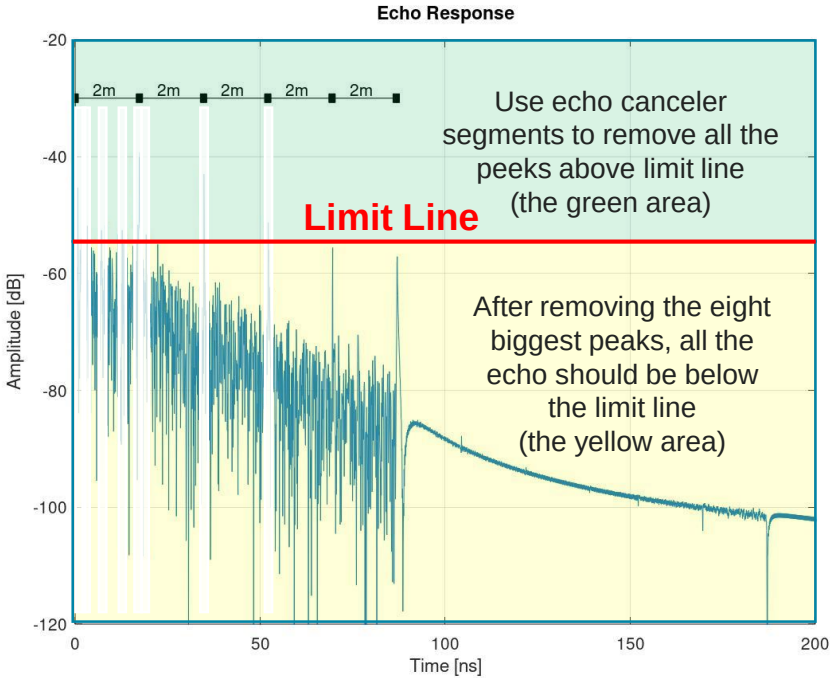


Most of the signal should be low the limit line

Some of the echo peeks can go above the limit line

The number of peeks going above the limit line is restricted both in number and duration

Alternative Time-Domain Approach to Limit Echo

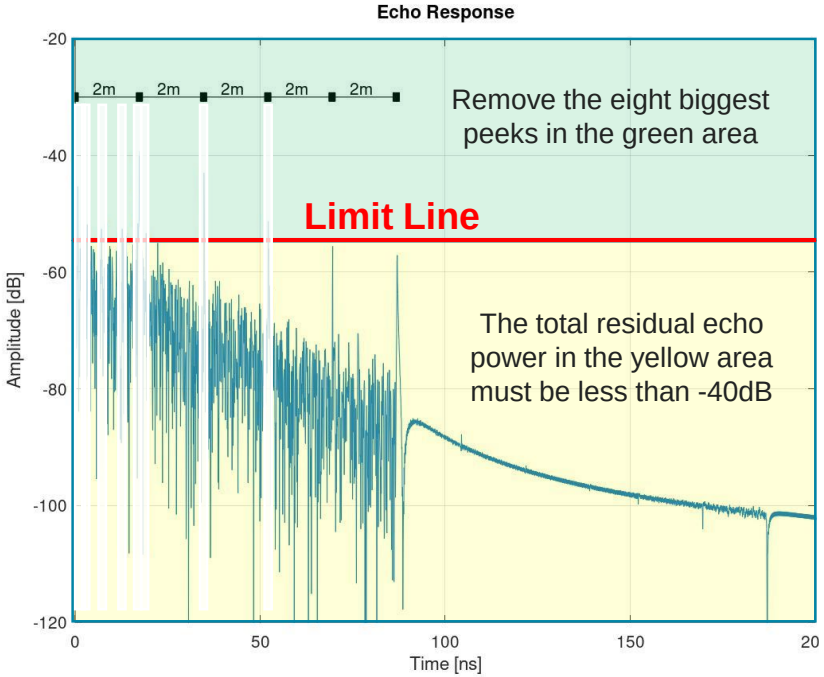


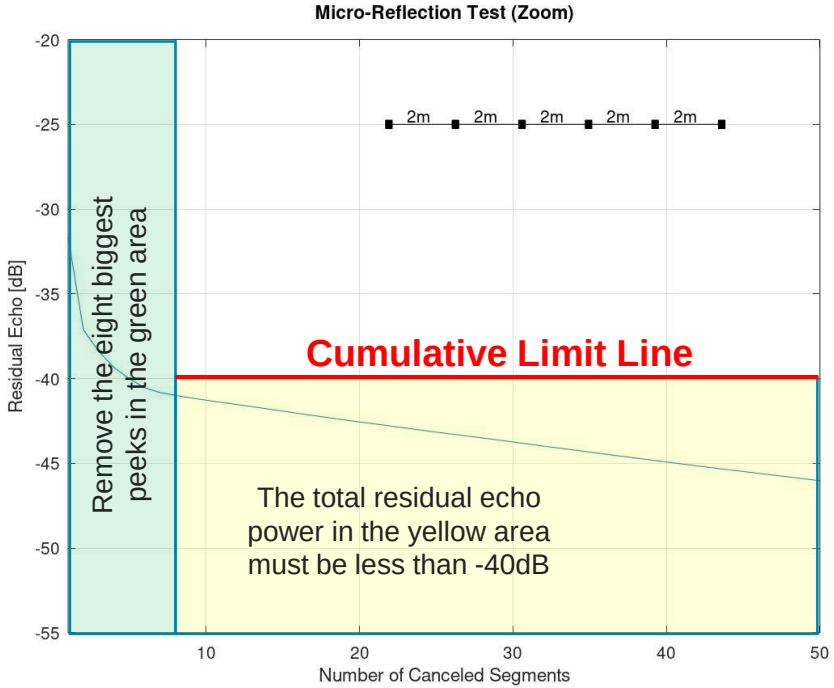
The PHY design can concentrate on canceling the peeks above the limit line

This can be done by deploying several movable echo canceler segments to the echo peeks

This leads to significant savings in the echo canceler implementation

Limit Echo Power After Removing Biggest Peaks





We can relax the requirements by using limit on the cumulative echo power after removing the biggest peeks.

Suggested Limit on Micro-Reflections

Limit on Micro-Reflections

In order to limit the noise at the receiver due to micro-reflections, the normalized residual echo power for each link shall not exceed -40 dB (NOTE 1) relative to the transmit power.

Method for calculating normalized residual echo power:

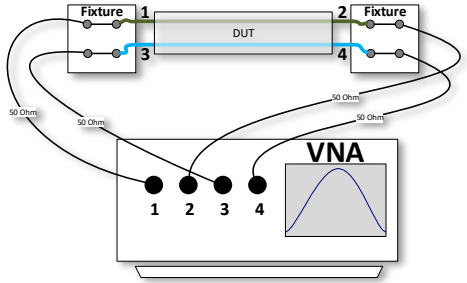
The time-domain reflection response for the link is measured using Time Domain Reflectometry. The first 200ns (NOTE 2) of the time-domain reflection response is divided into 0.3ns (NOTE 3) segments. The normalized power (the power of the reflection normalized by the power of the transmit pulse) is calculated for each segment and the segments ordered according to magnitude of the normalized power, from highest to lowest. After discarding the 8 (NOTE 4) segments (2.4 ns) with the highest normalized power, the total normalized power sum of the remaining segments is the normalized residual echo power for the link.

For further discussion:

- NOTE 1: This value constraints the quality of the cable itself. This value could also be defined to depend on the channel IL
- NOTE 2: This value needs to be long enough to deal with the longest possible echo tail.
- NOTE 3: This value determines the length of each segment used to cancel echo from large impedance discontinuities (connectors)
- NOTE 4: This value determines how many large impedance discontinuities can be handled

Measuring Micro-Reflections

- One way to evaluate the micro-reflections is to use normal Vector Network Analyzer to measure S-parameters for the channel under test (DUT)
- The differential S11 and S22 parameters (magnitude and phase) can be converted to time-domain echo signals
- The time domain echo signals can be analyzed to evaluate micro reflection characteristics




```
function h = RJf2t(H,f,T,N)

%RJf2t - Impulse (time) response for a given frequency response.
%Usage:
%  h = RJf2t(H,f,T,N)
% where <H> is the frequency response given at frequencies <f>,
% <T> is the sampling interval, and <N> is the number of output
% samples (must be even).


%%% find size %%%
NN = prod(size(H));

%%% test arguments %%%
if( nargin < 2 )
  f = [0:NN-1]./(NN-1)*pi;
end;
if( nargin < 3 )
  T = 1;
end;
if( nargin < 4 )
  N = 256;
end;
N2 = ceil(N/2);

%%% find problem spots %%%
ix = find(H == H);
H = H(ix);
f = f(ix);

%%% re-shape arguments %%%
H = H(:);

%%% interpolate frequency response %%%
Hs1 = spline(f*T,H,[0:N2]/N2/2);
ang_N = angle(Hs1(N2+1));
x0 = ang_N/(pi);
Hs1 = Hs1.*exp(-j*2*pi*x0*[0:N2]/N2/2);
Hs = [real(Hs1(1)) Hs1(2:N2) real(Hs1(N2+1)) conj(Hs1(N2:-1:2))];

%%% find impulse response from IDFT %%%
h = real(ifft(Hs));

%%%%%%%%%%%%%%%%%%%% End of RJf2t.m %%%%%%%%%%%%%%%%%%%%
```

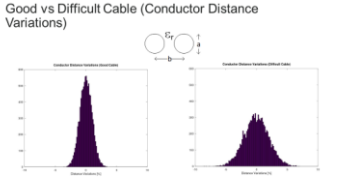
This is experimental code that is provided “as is”.

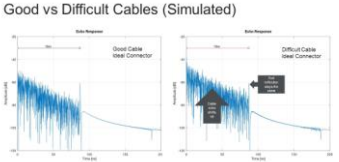
Simulations of Micro-Reflections to Demonstrate Limits

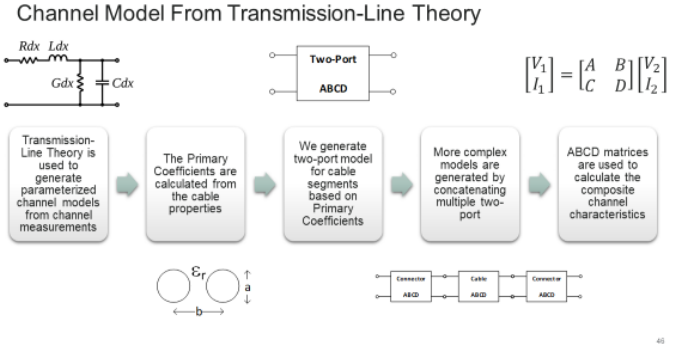
Marvell

Earlier Simulations

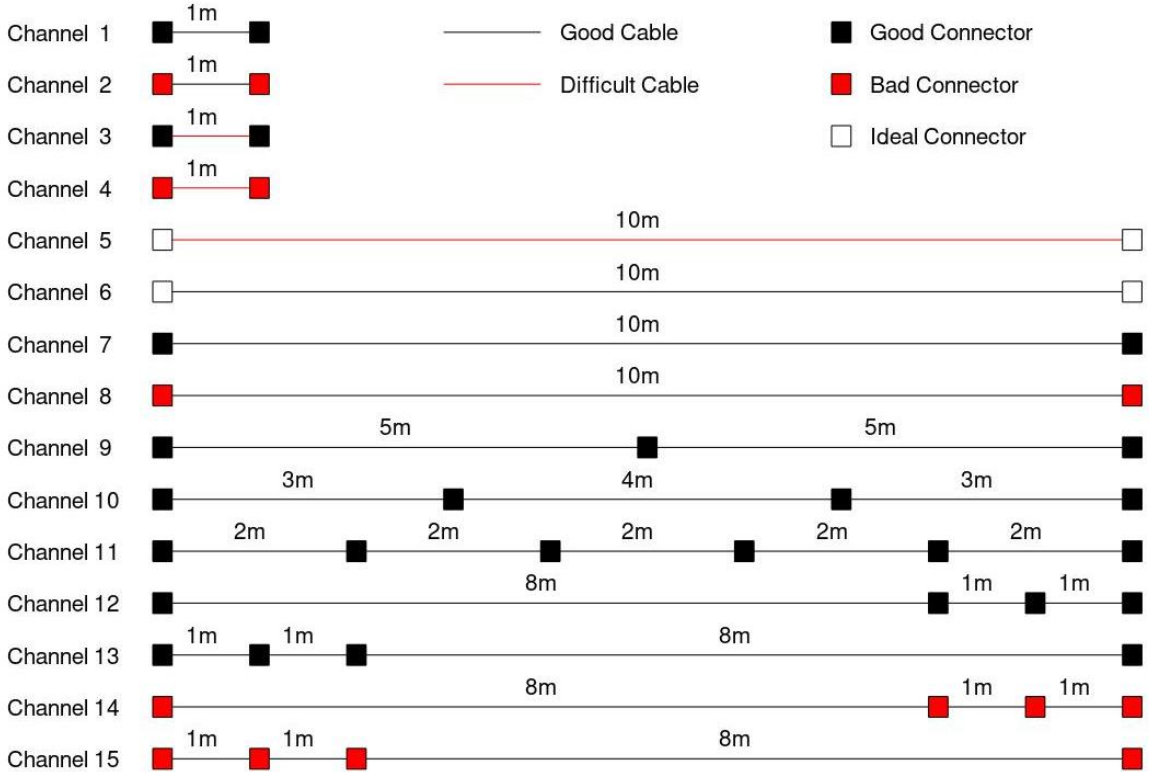
- In July we presented simulations that demonstrated how micro-reflections behave for different cables (see jonsson_3cy_01a_0720)
- Following is evaluation of how these simulated channels would be evaluated with the suggested micro-reflection limits.



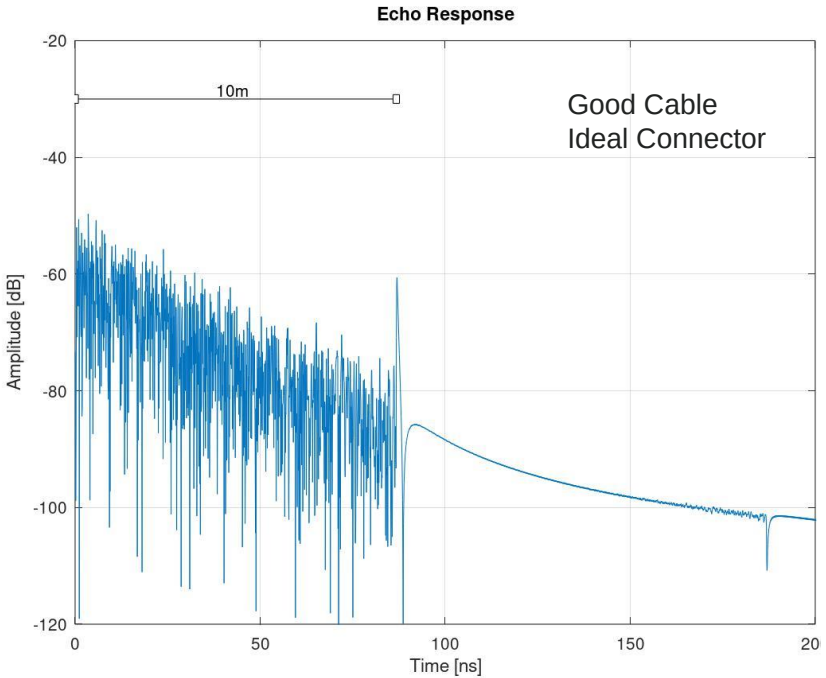


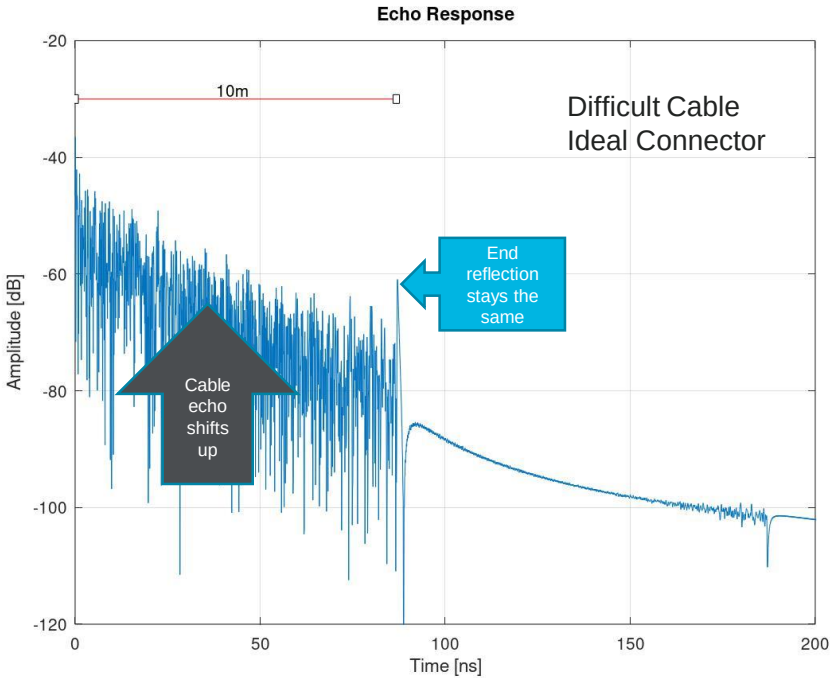


Simulated Channels

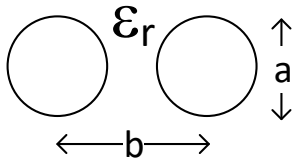


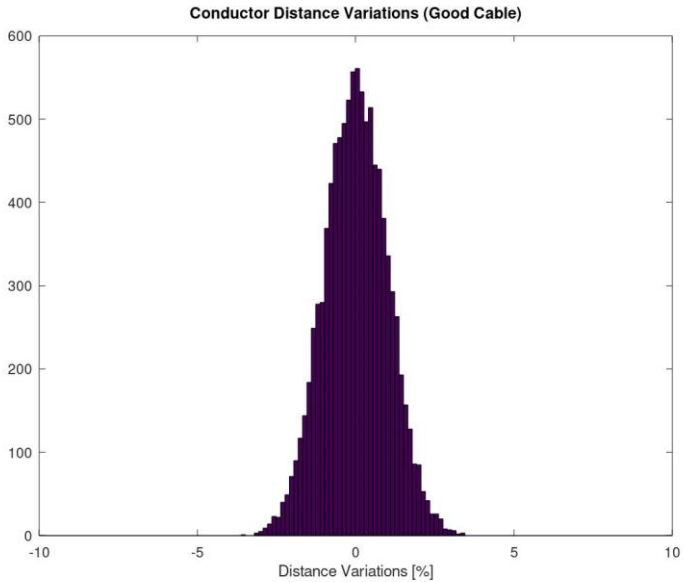
Good vs Difficult Cable (Simulated)

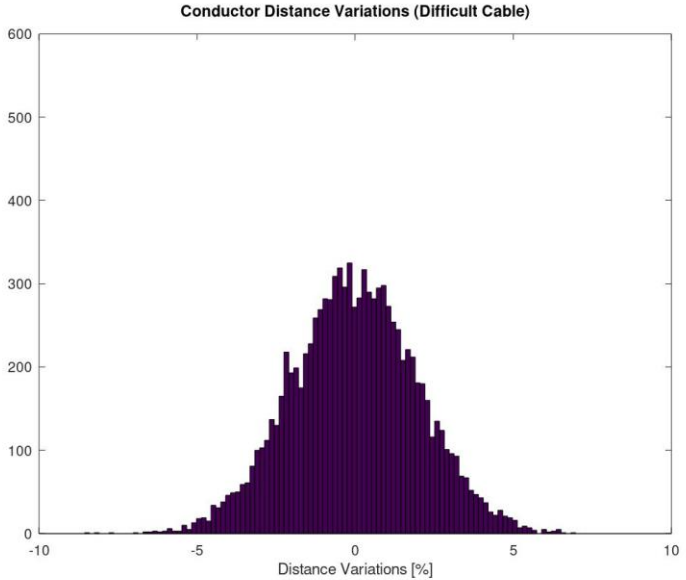




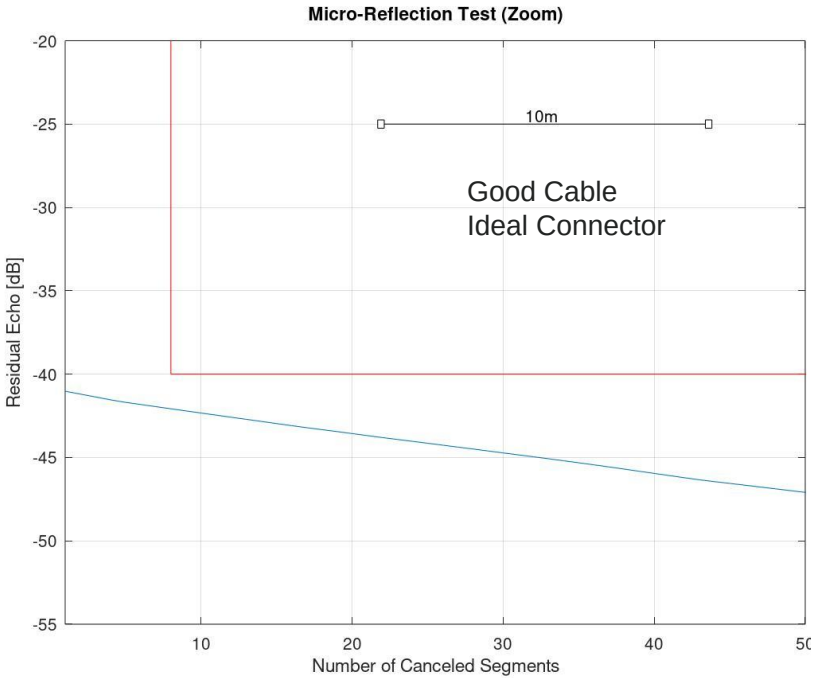
Good vs Difficult Cable (Conductor Distance Variations)

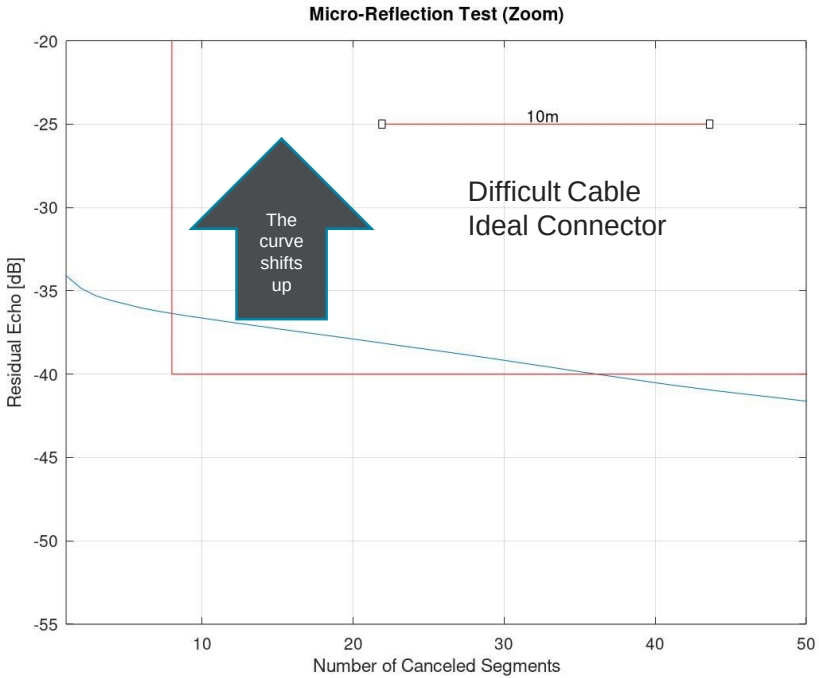




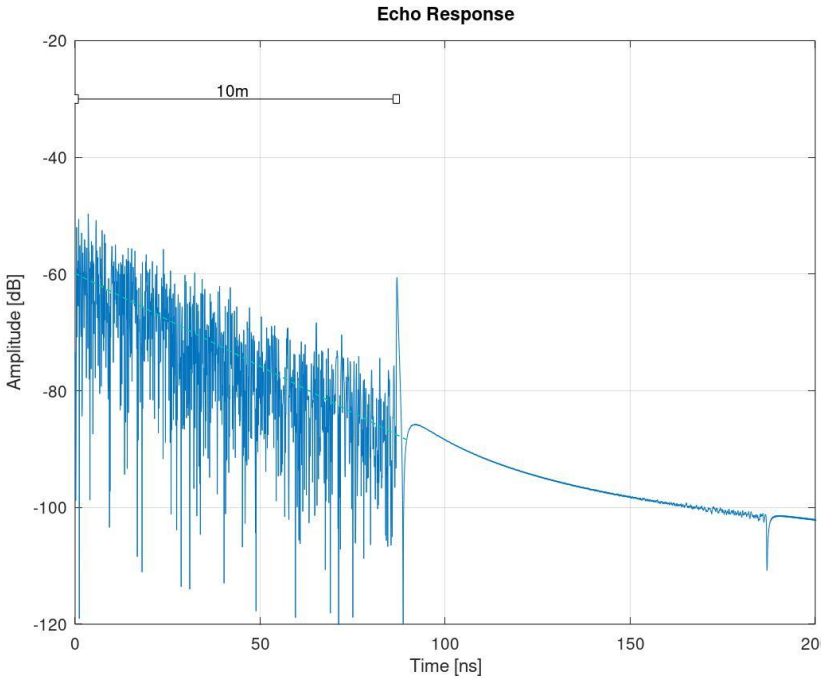


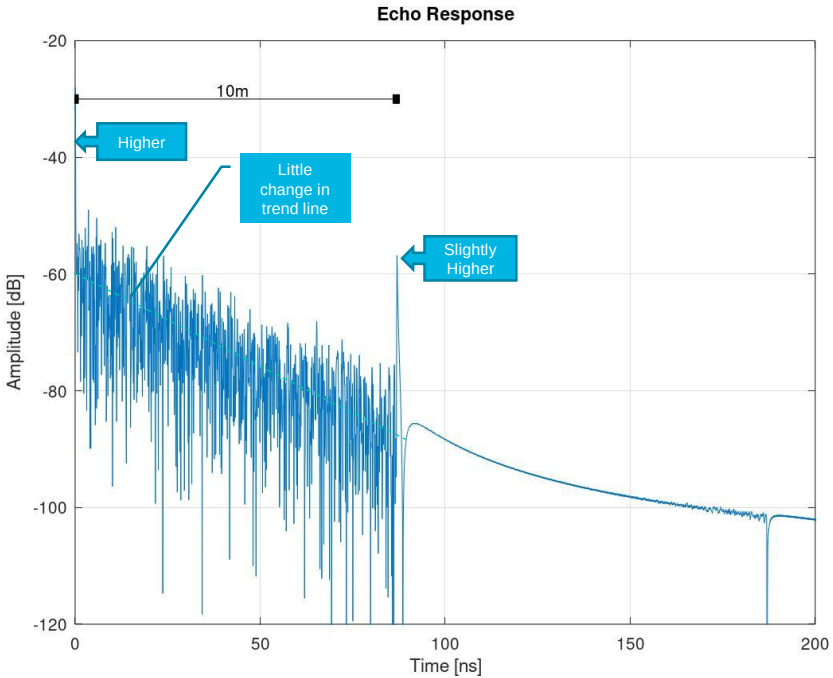
Good vs Difficult Cable (Simulated)



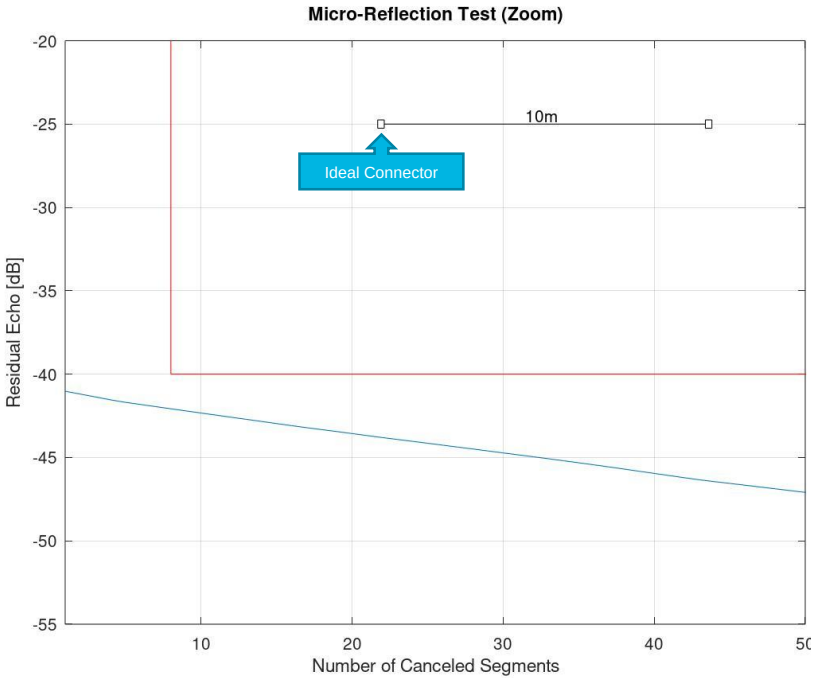


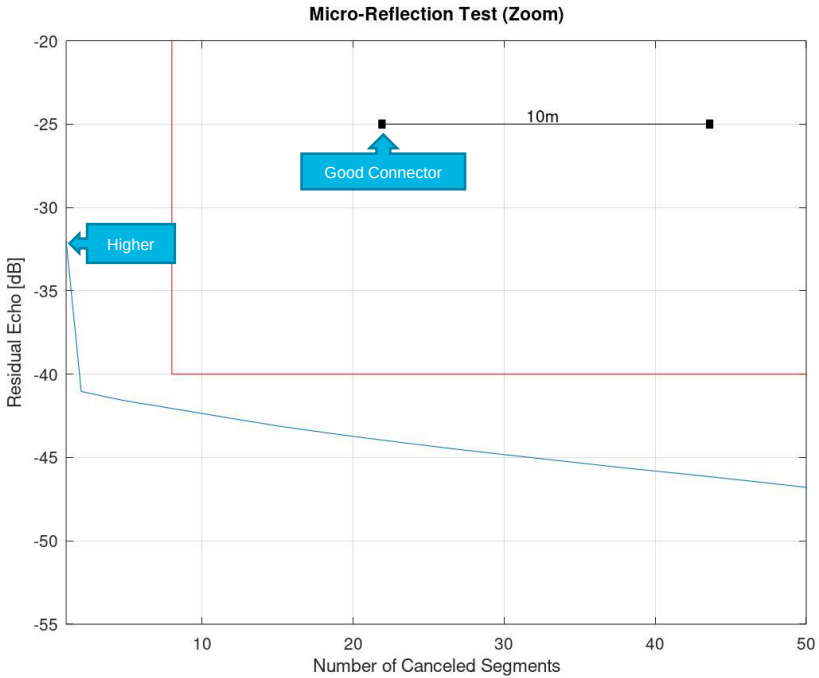
Effect of Connectors



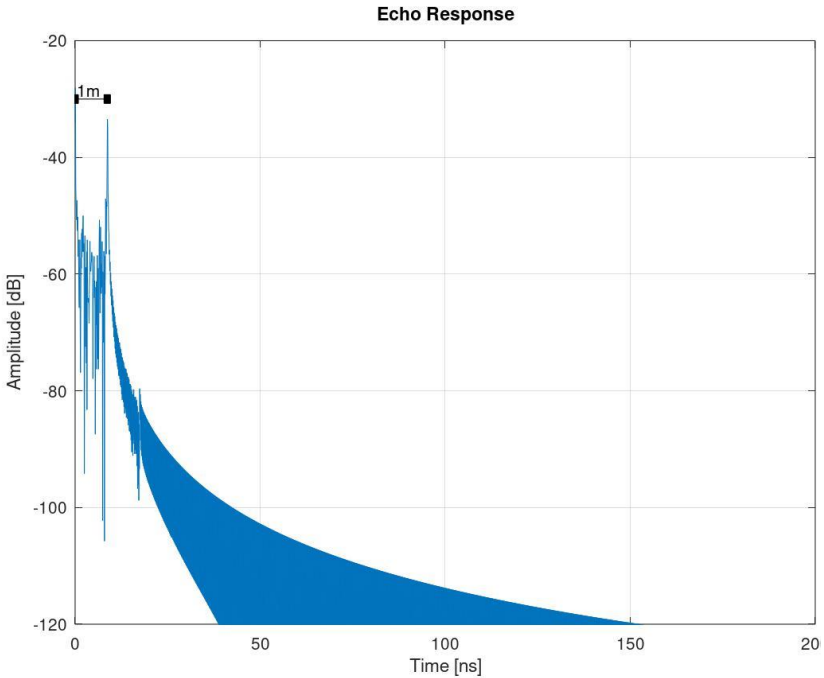


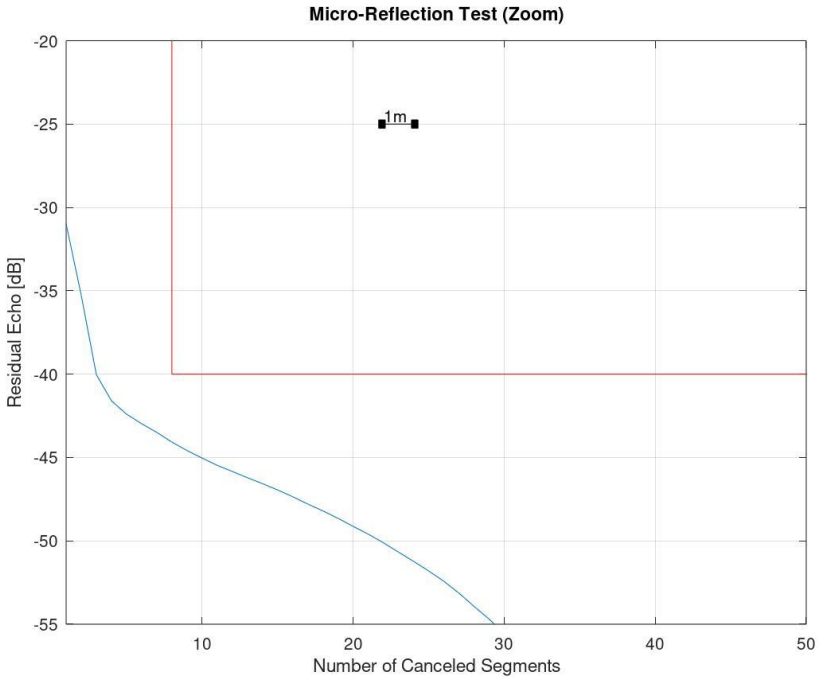
Effect of Connectors



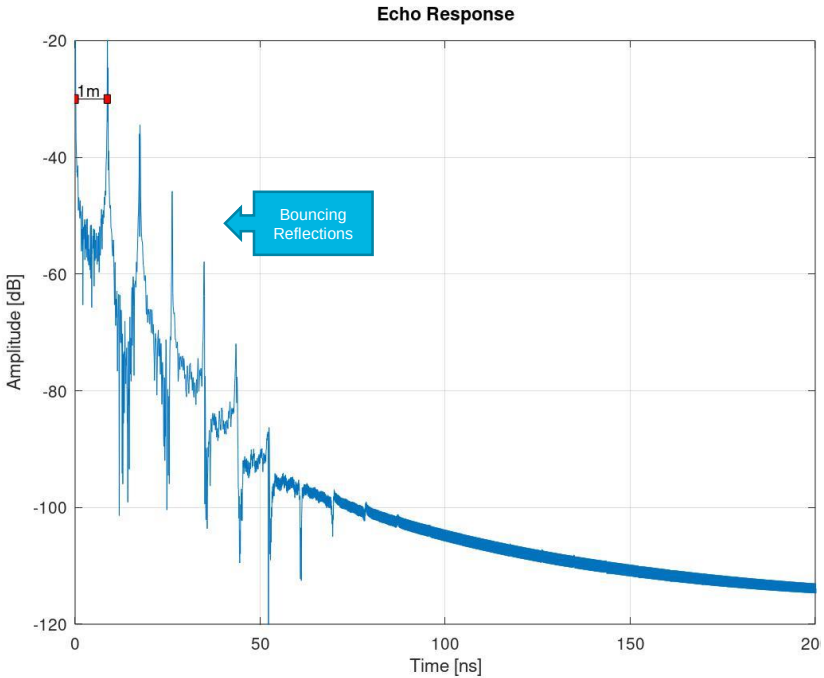


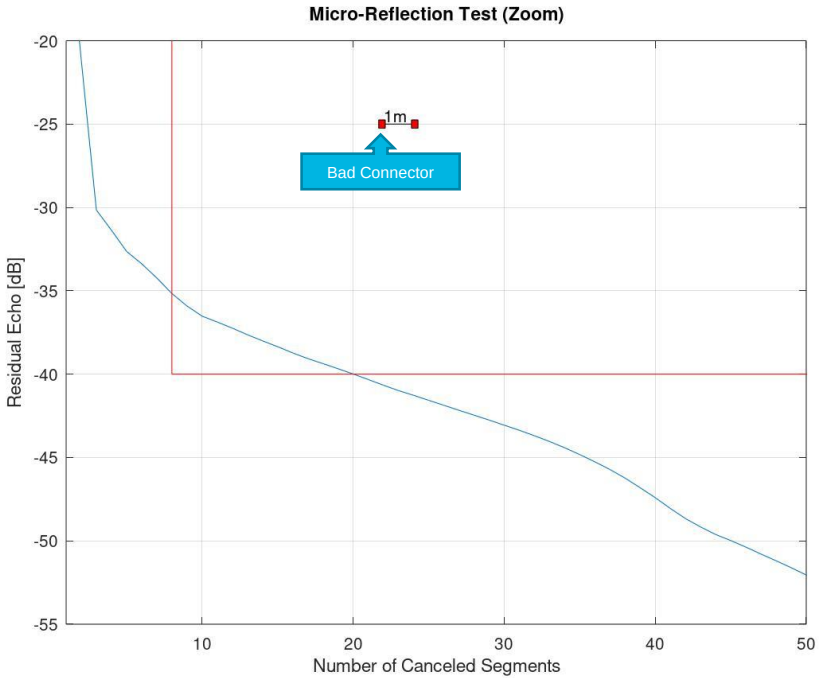
Channel 1


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

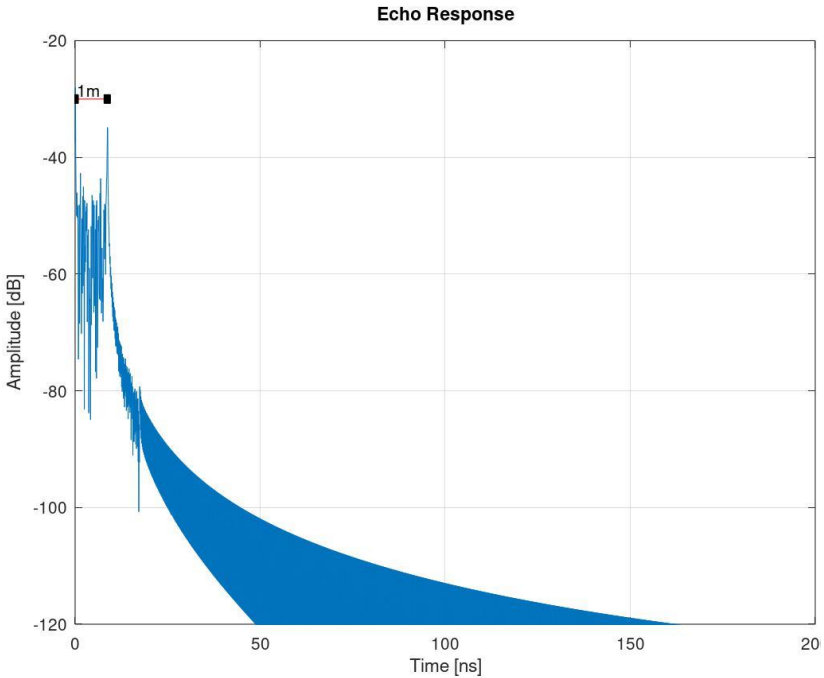

Micro-Reflection Test (Zoom)
1m
-20
-25
-30
-35
-40
-45
-50
-55
Residual Echo [dB]
10
20
30
40
50
Number of Canceled Segments

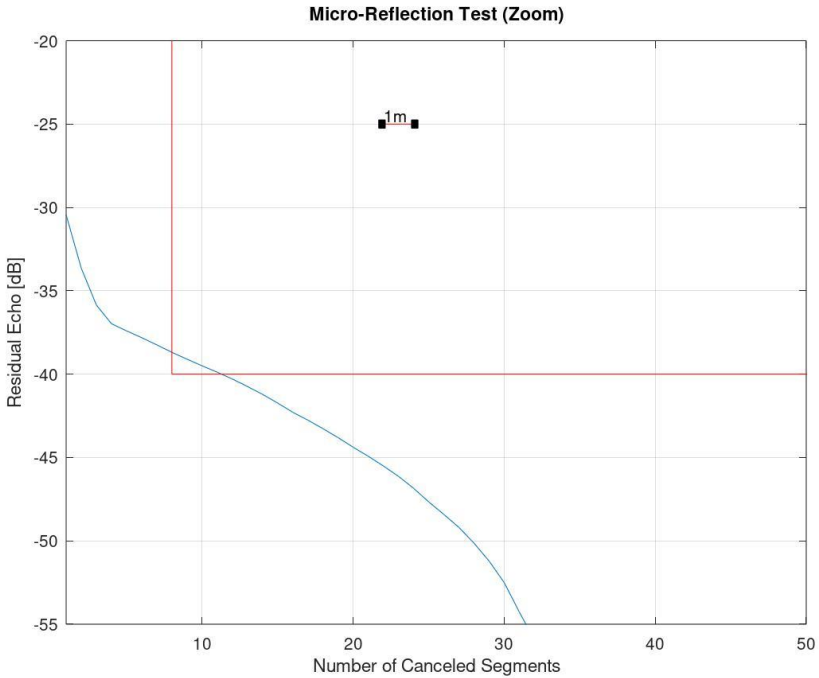
Channel 2


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

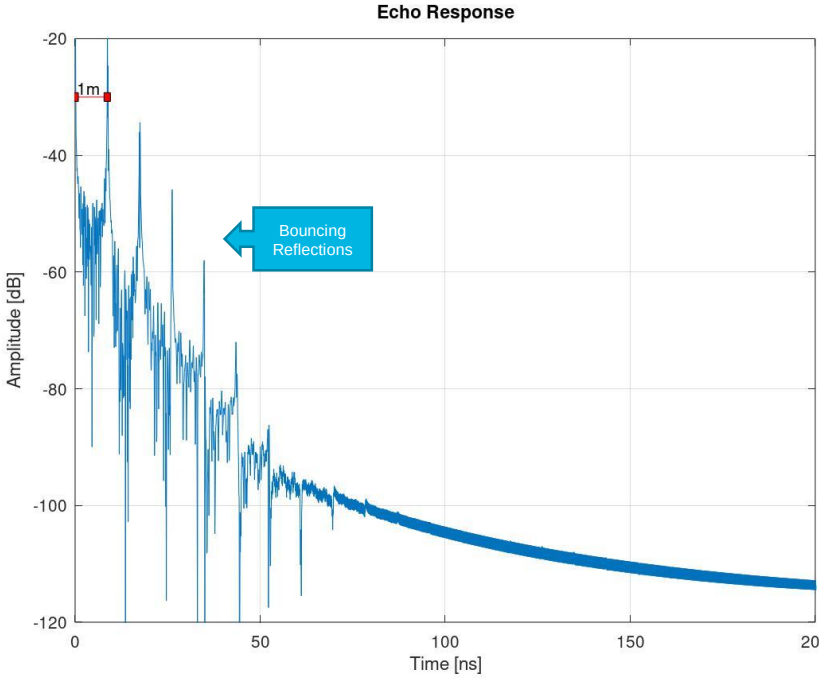

Micro-Reflection Test (Zoom)
1m
Bad Connector
Residual Echo [dB]
Number of Canceled Segments
-20
-25
-30
-35
-40
-45
-50
-55
10
20
30
40
50

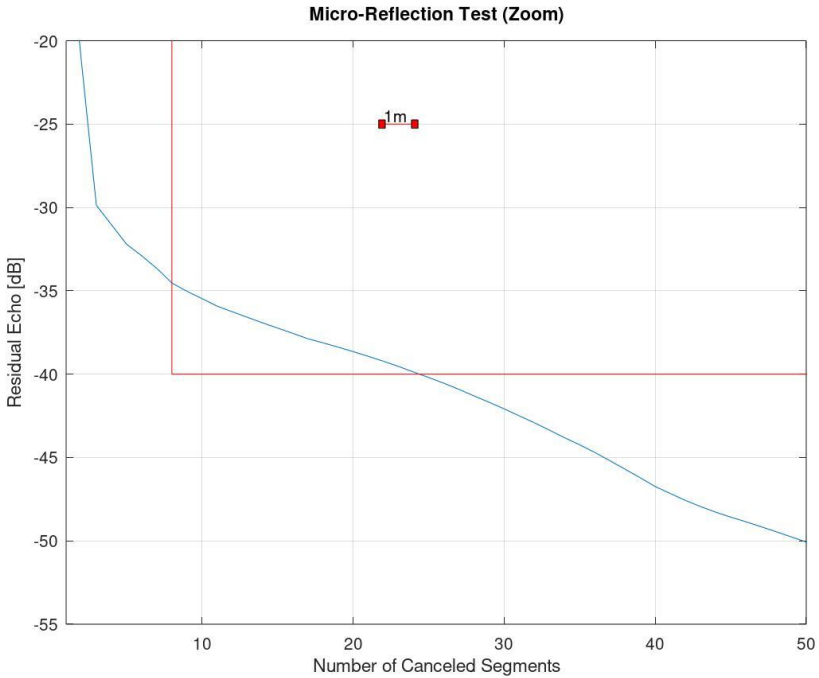
Channel 3


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

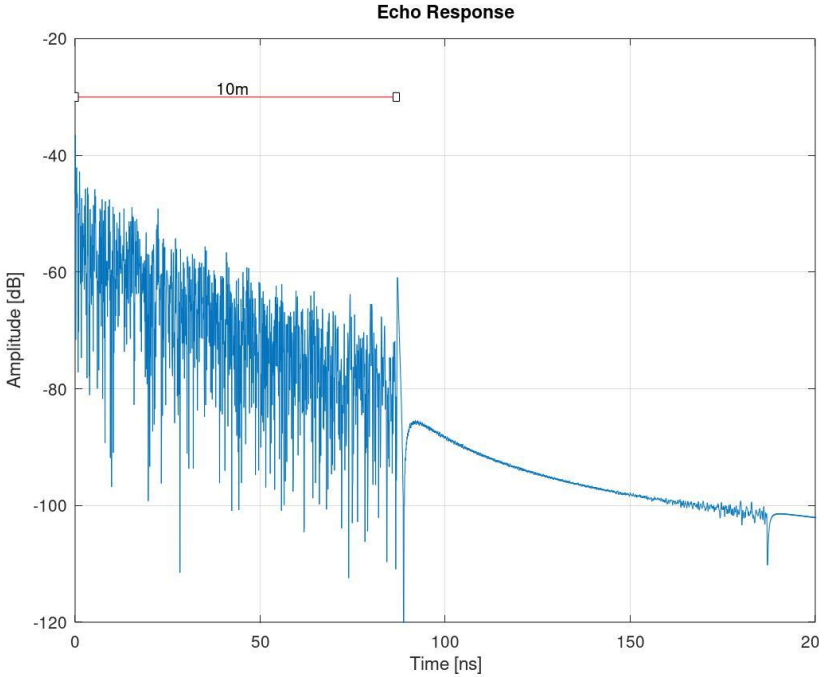

Micro-Reflection Test (Zoom)
1m
-20
-25
-30
-35
-40
-45
-50
-55
Residual Echo [dB]
10
20
30
40
50
Number of Canceled Segments

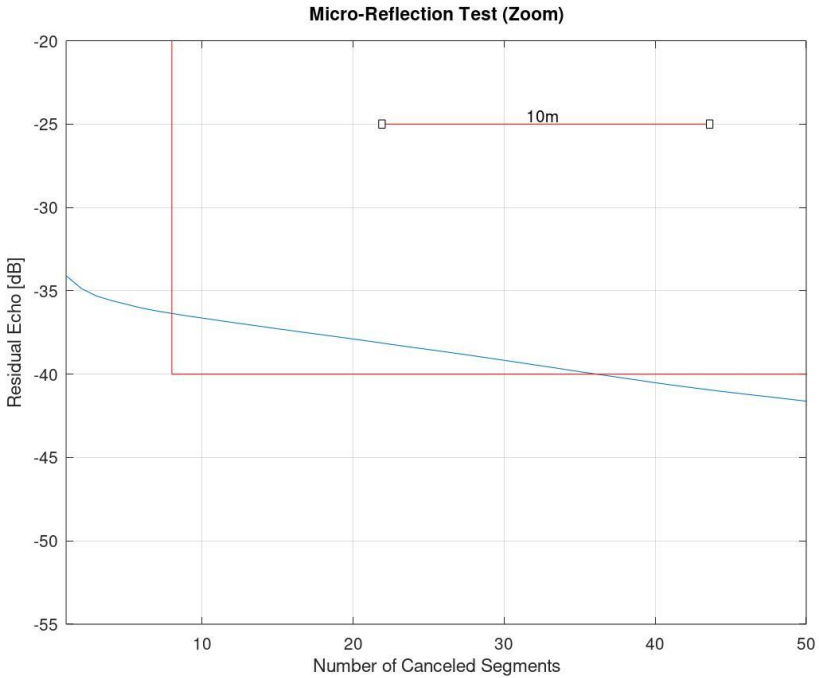
Channel 4


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

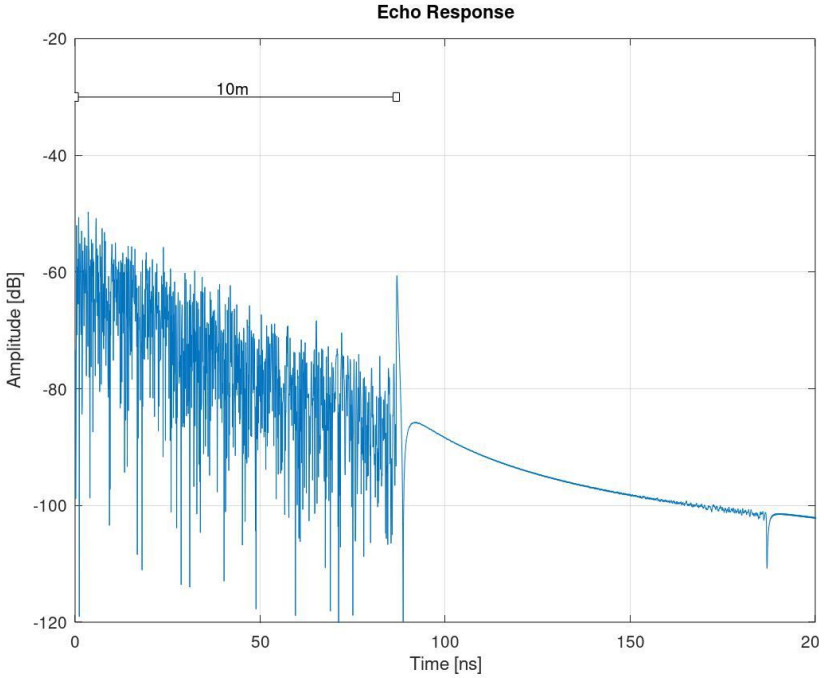

Micro-Reflection Test (Zoom)
1m
Residual Echo [dB]
Number of Canceled Segments
-20
-25
-30
-35
-40
-45
-50
-55
10
20
30
40
50

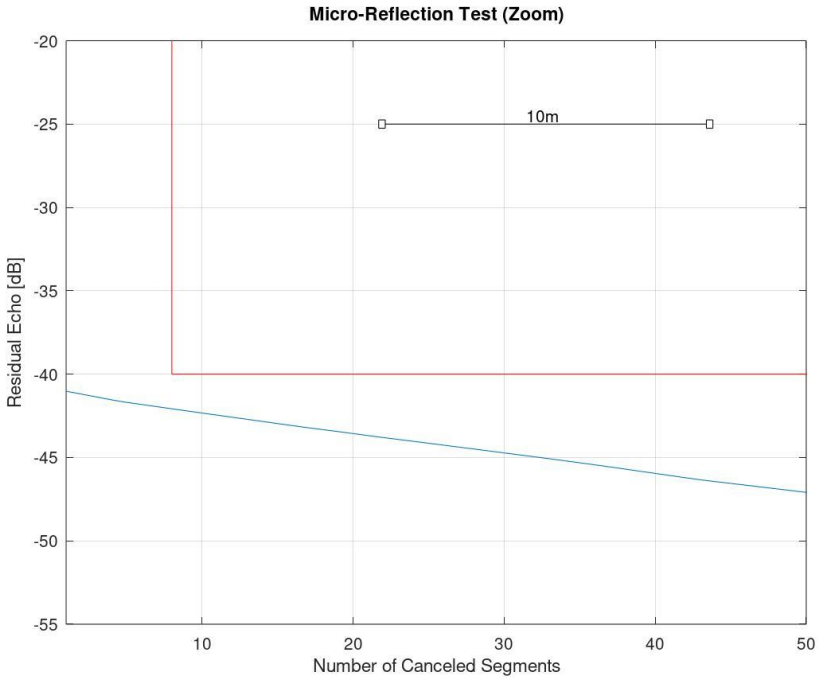
Channel 5


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

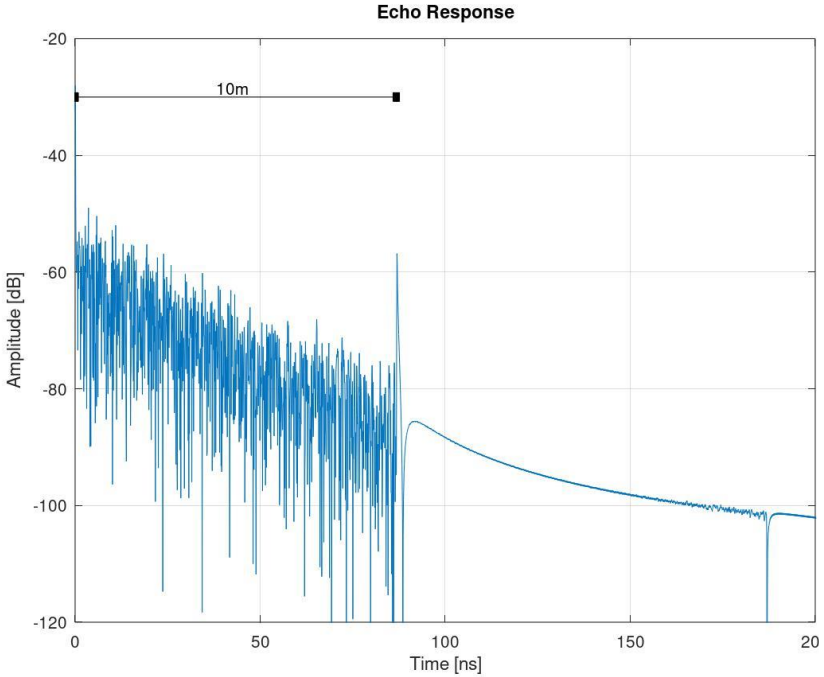

Micro-Reflection Test (Zoom)
10m
-20
-25
-30
-35
-40
-45
-50
-55
Residual Echo [dB]
10
20
30
40
50
Number of Canceled Segments

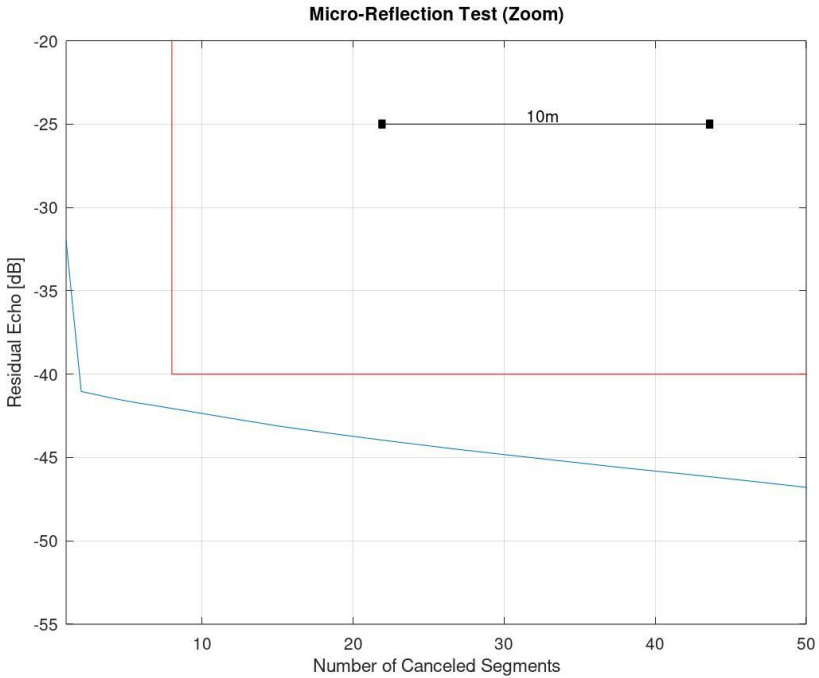
Channel 6


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

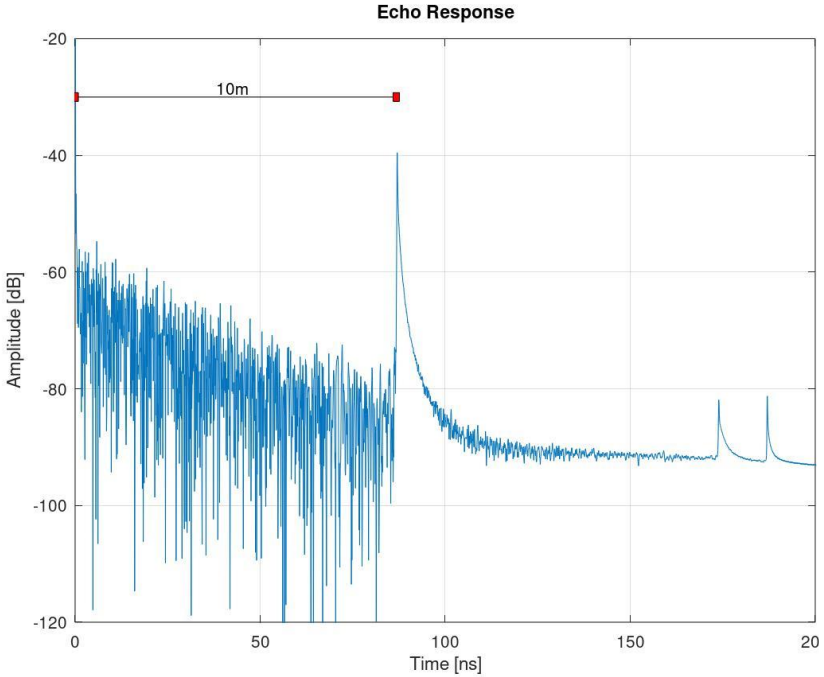

Micro-Reflection Test (Zoom)
10m
-20
-25
-30
-35
-40
-45
-50
-55
Residual Echo [dB]
10
20
30
40
50
Number of Canceled Segments

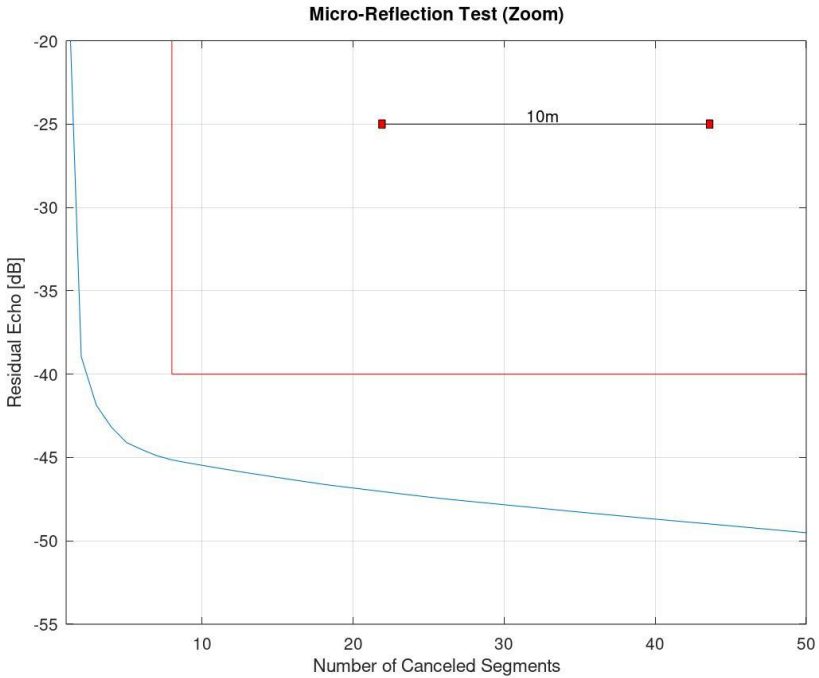
Channel 7


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

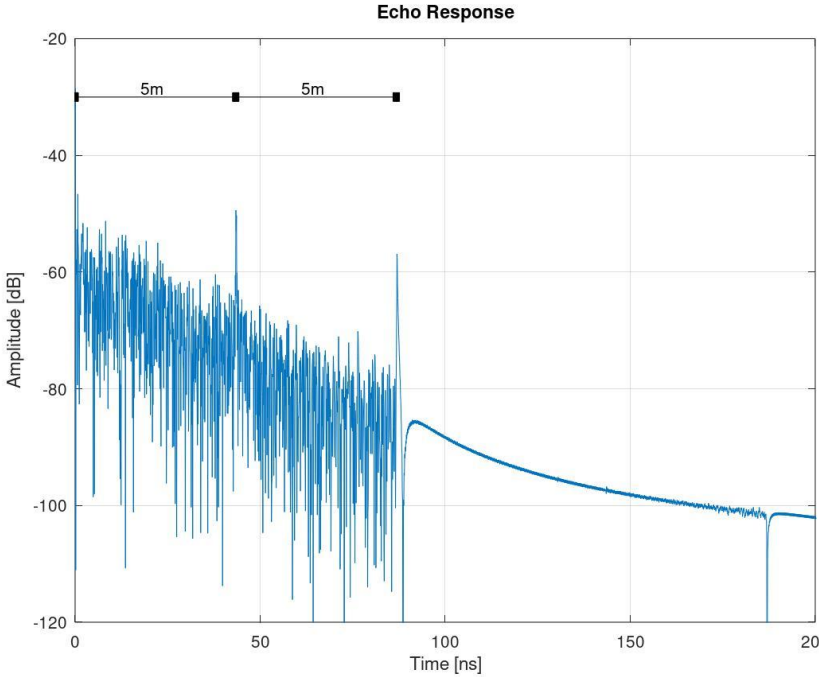

Micro-Reflection Test (Zoom)
10m
-20
-25
-30
-35
-40
-45
-50
-55
Residual Echo [dB]
10
20
30
40
50
Number of Canceled Segments

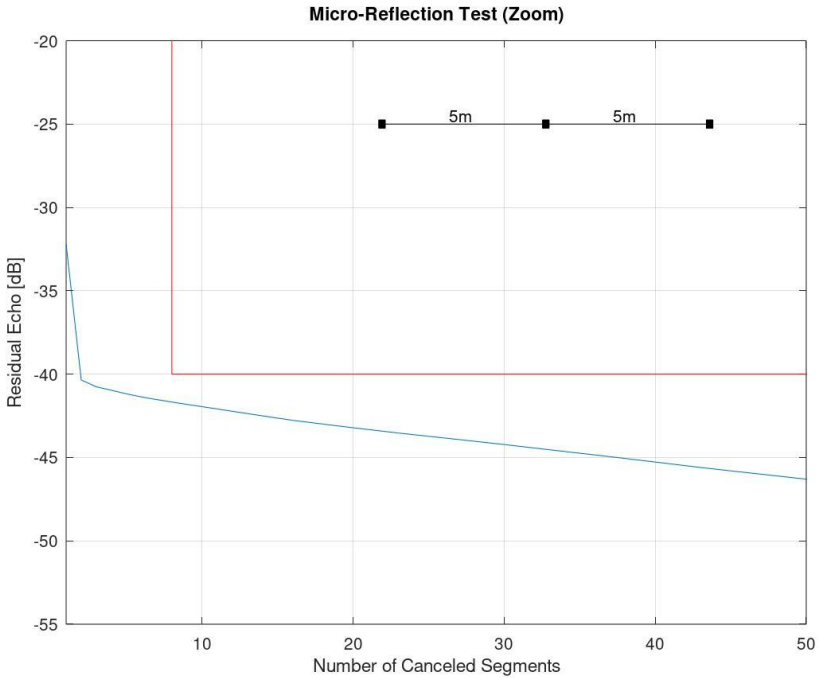
Channel 8


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

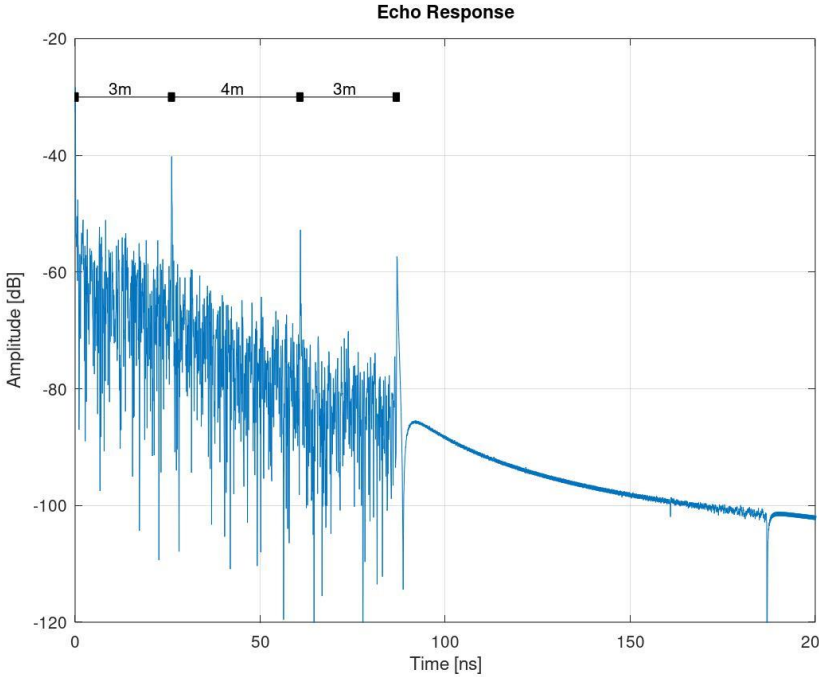

Micro-Reflection Test (Zoom)
10m
-20
-25
-30
-35
-40
-45
-50
-55
Residual Echo [dB]
10
20
30
40
50
Number of Canceled Segments

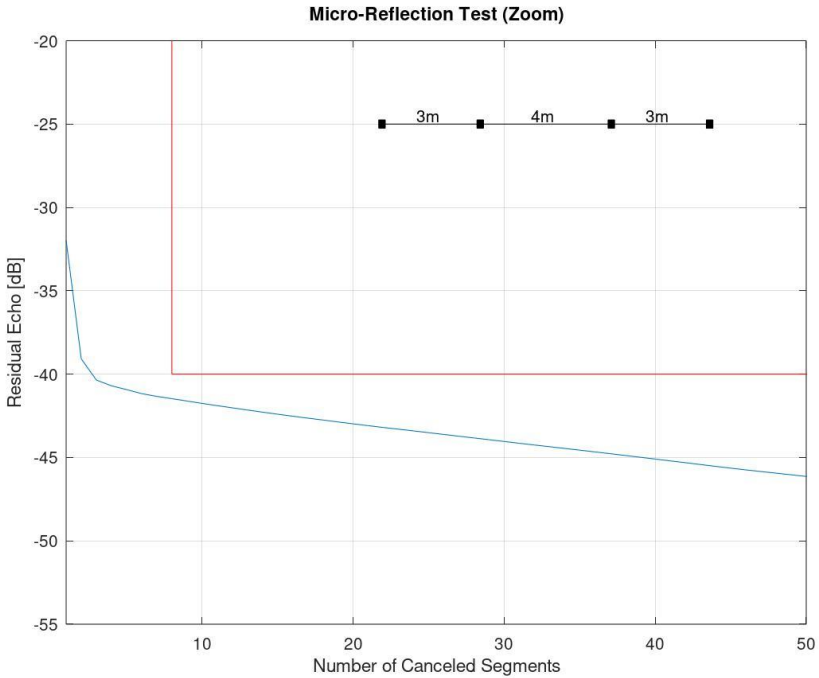
Channel 9


Echo Response
5m
5m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
20
Time [ns]

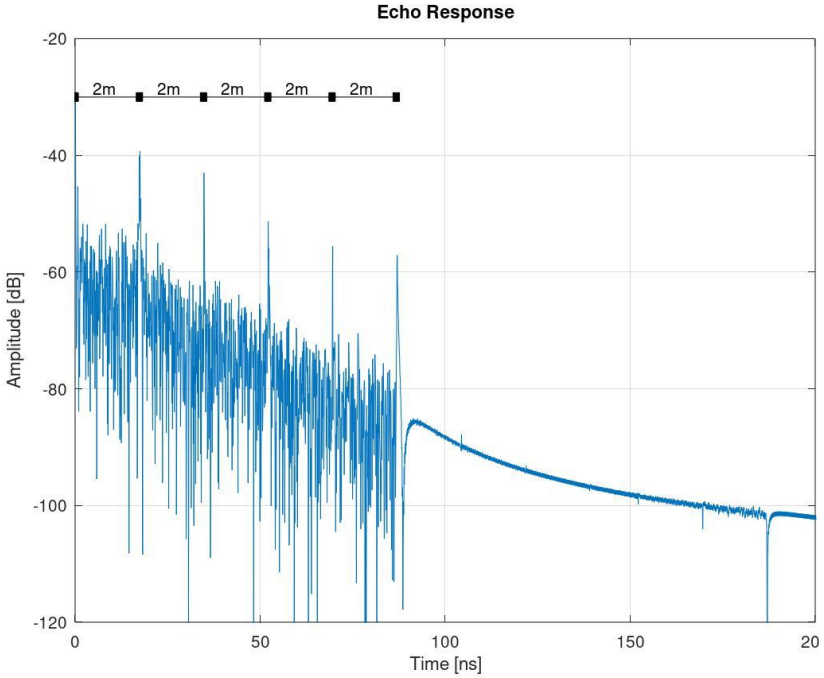

Micro-Reflection Test (Zoom)
5m
5m
-20
-25
-30
-35
-40
-45
-50
-55
Residual Echo [dB]
10
20
30
40
50
Number of Canceled Segments

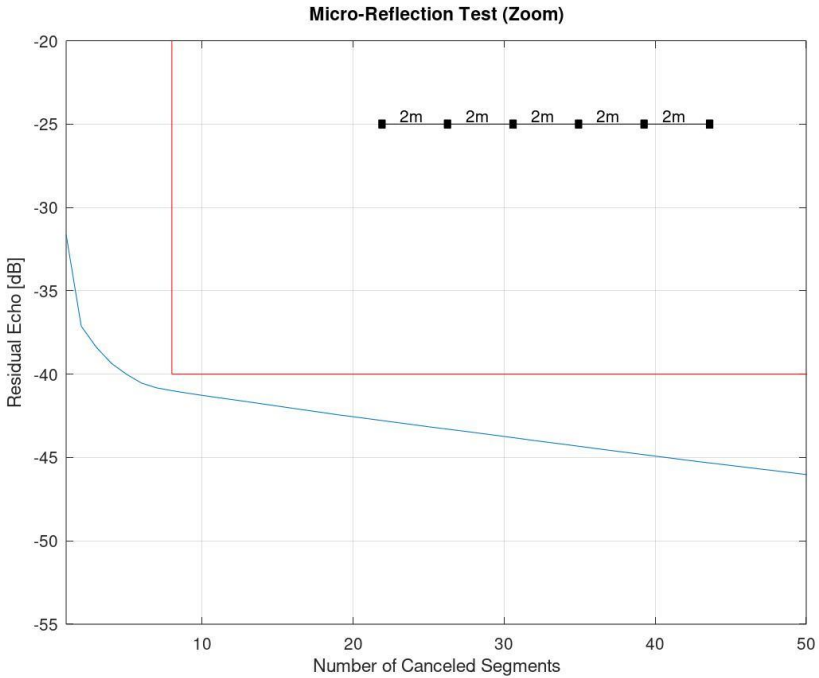
Channel 10


Echo Response
3m
4m
3m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
20
Time [ns]

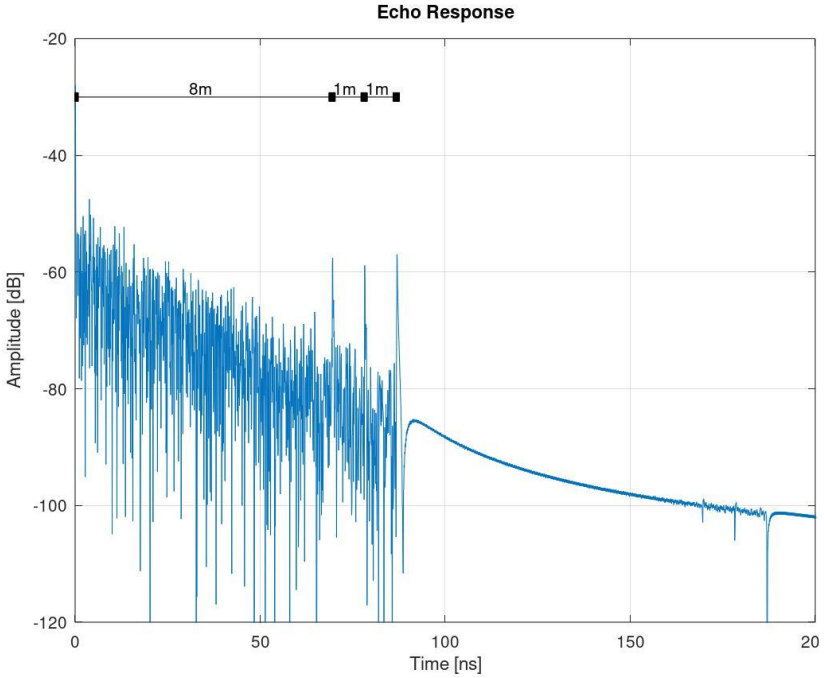

Micro-Reflection Test (Zoom)
3m
4m
3m
-20
-25
-30
-35
-40
-45
-50
-55
Residual Echo [dB]
10
20
30
40
50
Number of Canceled Segments

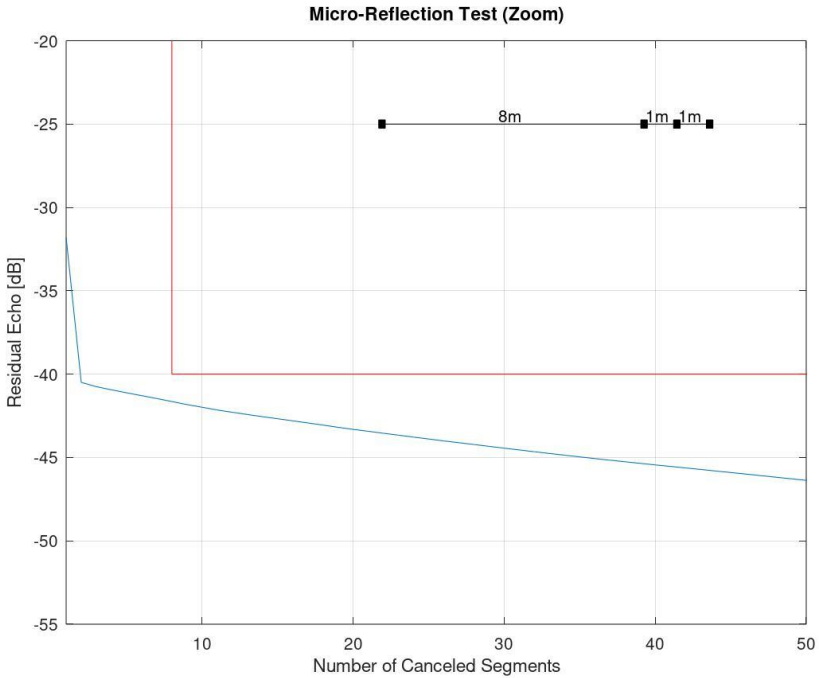
Channel 11


Echo Response
2m
2m
2m
2m
2m
-20
-40
-60
-80
-100
-120
Amplitude [dB]
0
50
100
150
20
Time [ns]

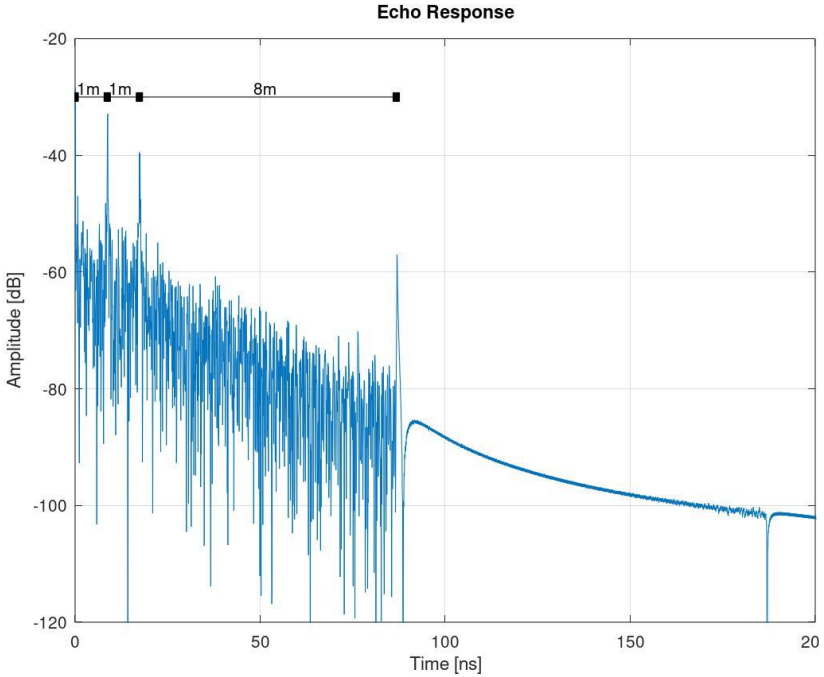

Micro-Reflection Test (Zoom)
2m
2m
2m
2m
2m
-20
-25
-30
-35
-40
-45
-50
-55
Residual Echo [dB]
10
20
30
40
50
Number of Canceled Segments

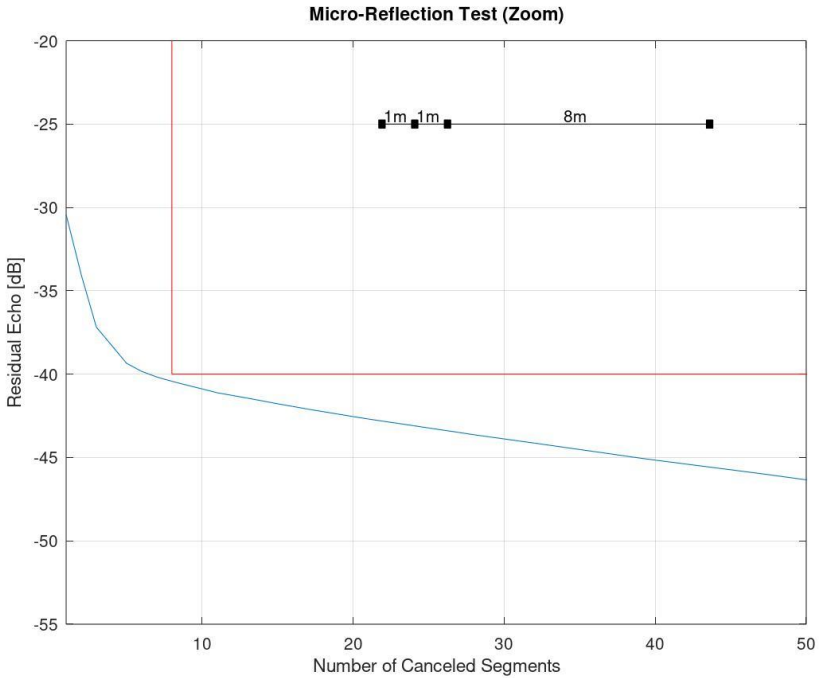
Channel 12


Echo Response
8m
1m
1m
Amplitude [dB]
Time [ns]
-20
-40
-60
-80
-100
-120
0
50
100
150
20

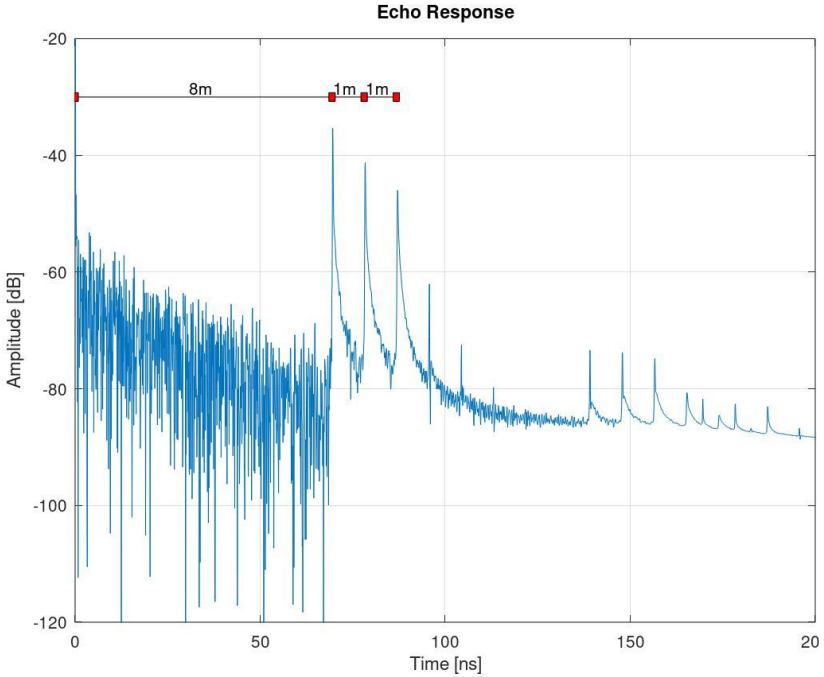

Micro-Reflection Test (Zoom)
8m
1m
1m
Residual Echo [dB]
Number of Canceled Segments
-20
-25
-30
-35
-40
-45
-50
-55
10
20
30
40
50

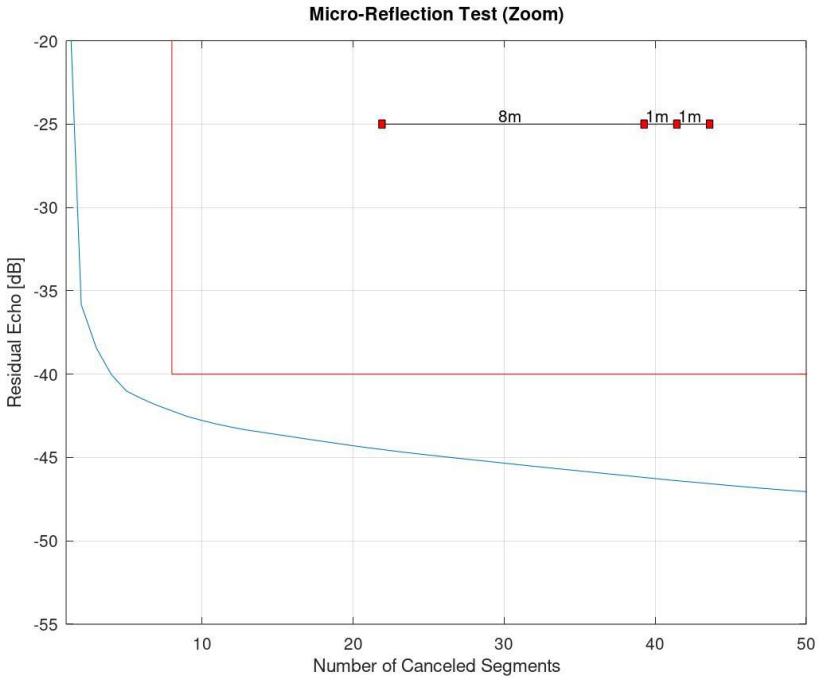
Channel 13


Echo Response
1m
1m
8m
Amplitude [dB]
Time [ns]
-20
-40
-60
-80
-100
-120
0
50
100
150
20

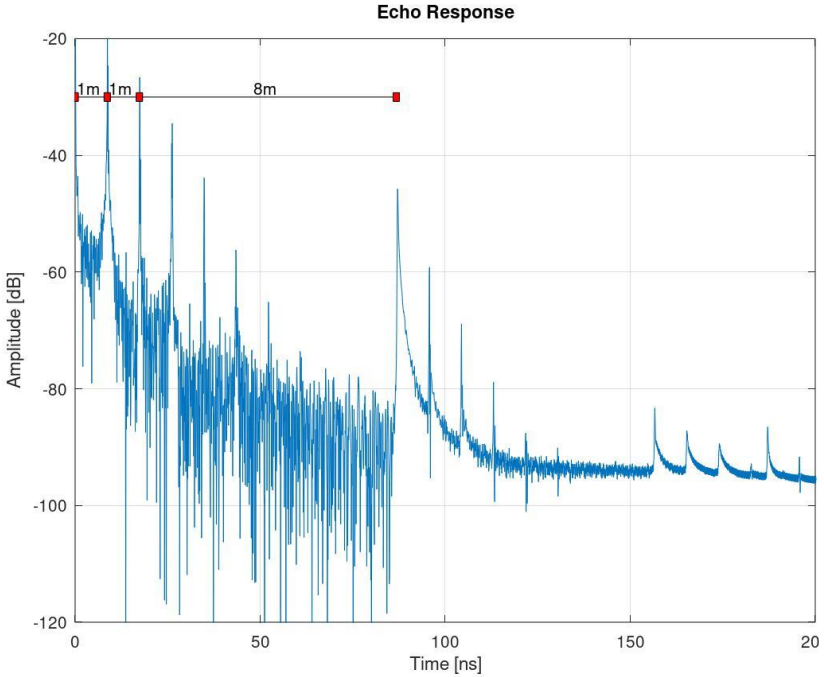

Micro-Reflection Test (Zoom)
1m
1m
8m
Residual Echo [dB]
Number of Canceled Segments
-20
-25
-30
-35
-40
-45
-50
-55
10
20
30
40
50

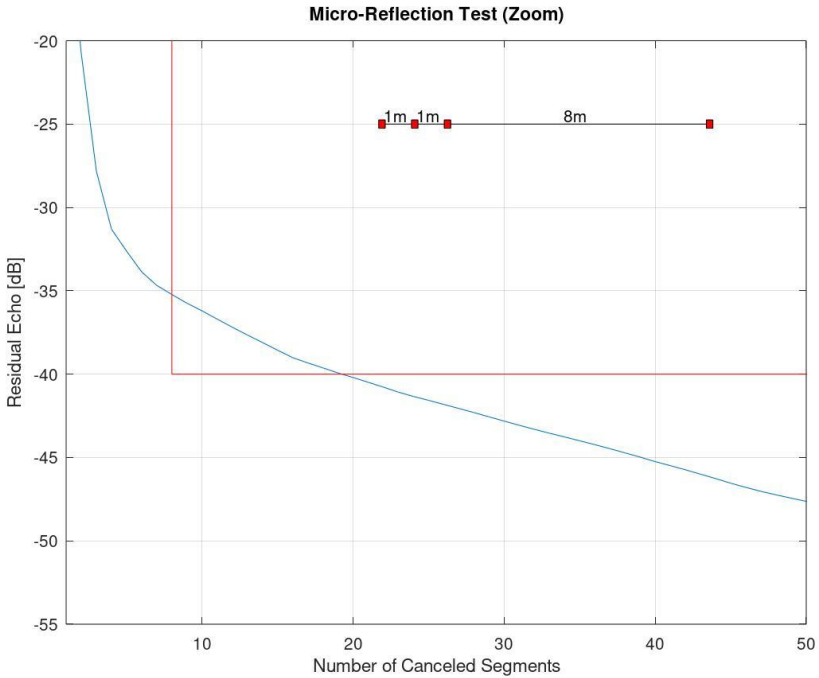
Channel 14


Echo Response
8m
1m
1m
Amplitude [dB]
Time [ns]
-20
-40
-60
-80
-100
-120
0
50
100
150
20


Micro-Reflection Test (Zoom)
8m
1m
1m
Residual Echo [dB]
Number of Canceled Segments
-20
-25
-30
-35
-40
-45
-50
-55
10
20
30
40
50

Channel 15


Echo Response
1m
1m
8m
Amplitude [dB]
Time [ns]
-20
-40
-60
-80
-100
-120
0
50
100
150
20


Micro-Reflection Test (Zoom)
1m
1m
8m
Residual Echo [dB]
Number of Canceled Segments
-20
-25
-30
-35
-40
-45
-50
-55
10
20
30
40
50

Conclusion

The micro-reflection mask is both practical and useful way to limit the echo

Initial values for the mask are reasonable, but need more validation with real cables

We have initial description of how the micro-reflections can be calculated from S-parameters

Essential technology, done right™