

IEEE P802.3ak 10GBASE-CX4 Link Analysis

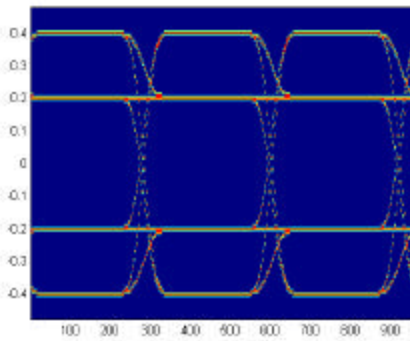
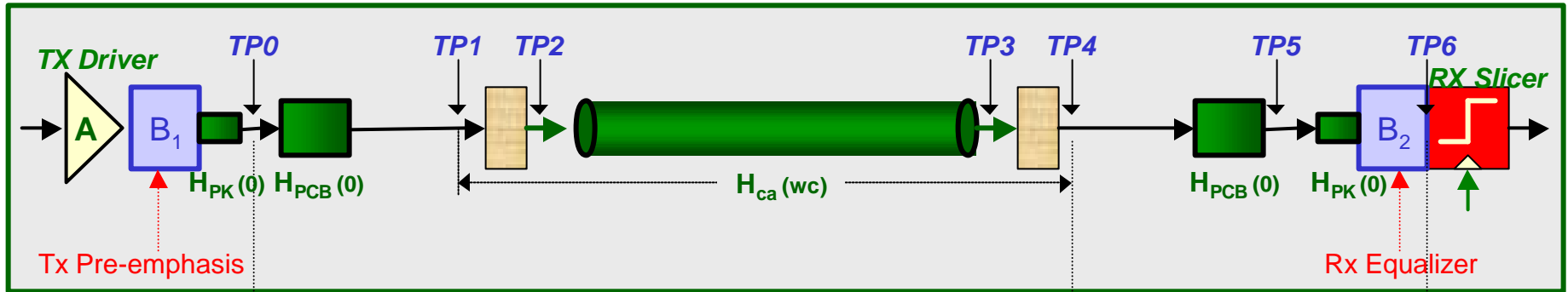


Howard Baumer & Aaron Buchwald
19 May, 2003

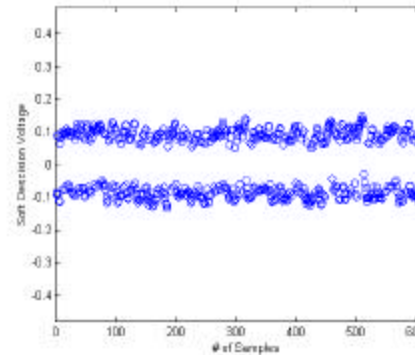
10GBASE-CX4 Link Analysis Outline

- **Link Model Definition**
- Cable Specifications v.s. Measurements
- Transceiver Specifications v.s. Measurements
- Link Simulations
- Summary / Recommendations

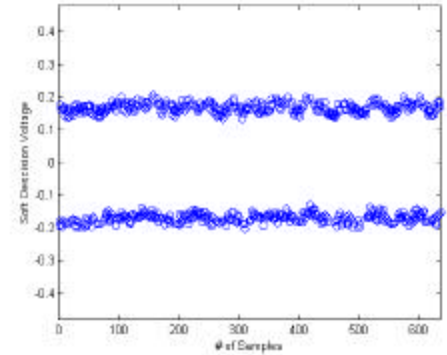
Link Model



Eye = 400mVpp
Margin = 400mVpp



Eye = 81mVpp
Margin = 39mVpp



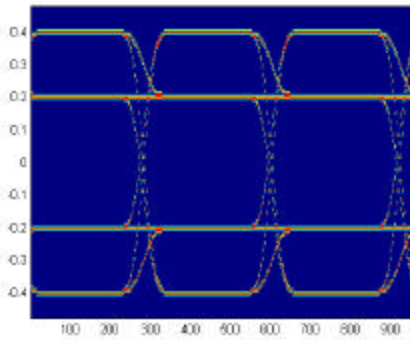
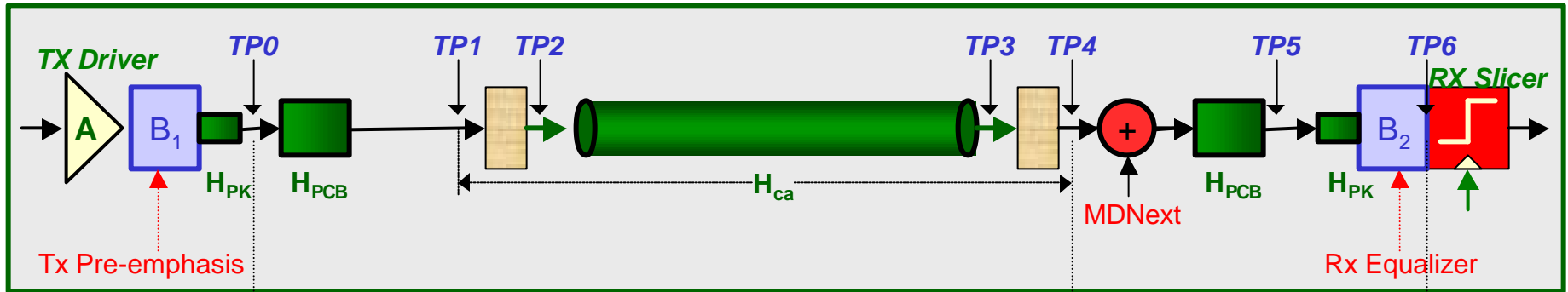
Eye = 265mVpp
Margin = 222mVpp



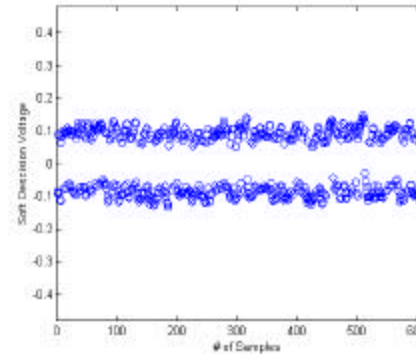
• Typical Eye Diagrams for Nominal Pre-emphasis = 50%

10GBASE-CX4

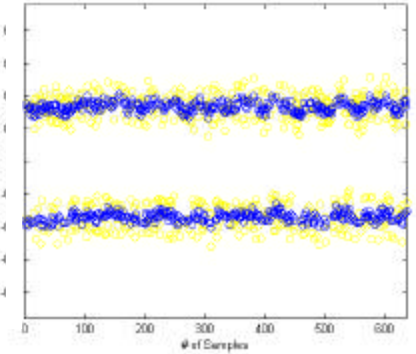
Link Model, + MDNext



**Eye = 400mVpp
Margin = 400mVpp**



**Eye = 81mVpp
Margin = 39mVpp**

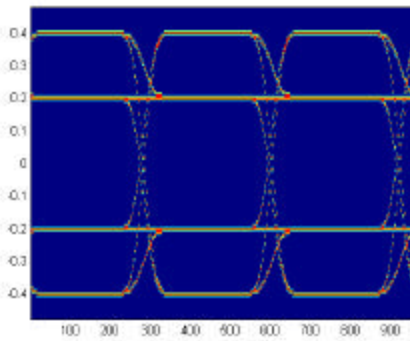
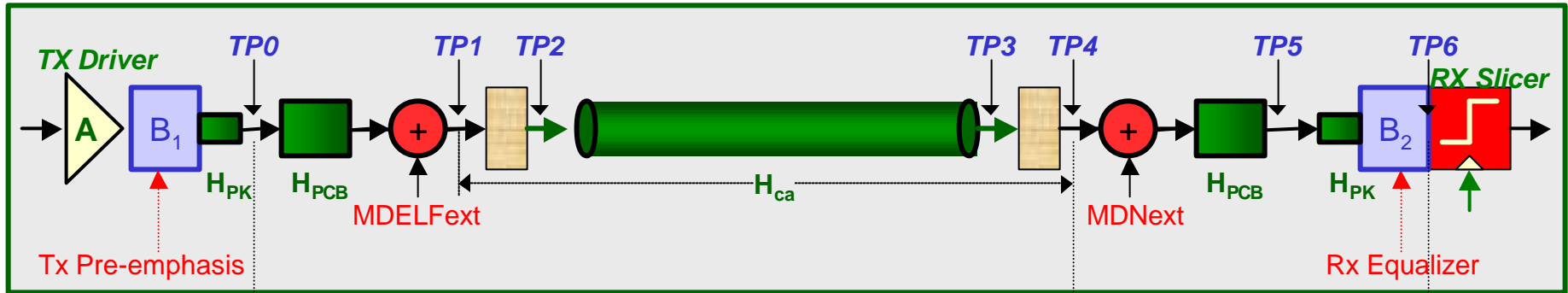


**Eye = 168mVpp
Margin = 112mVpp**

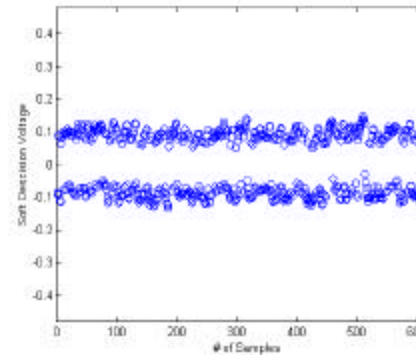
• Typical Eye Diagrams for Nominal Pre-emphasis = 50%



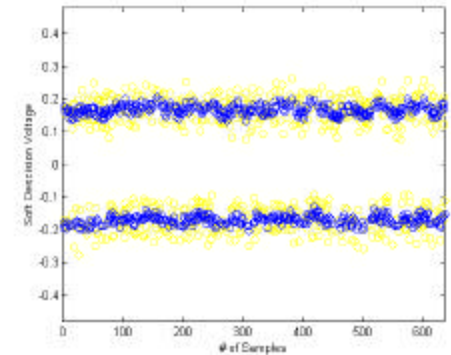
Link Model + MDELFext



Eye = 400mVpp
Margin = 400mVpp



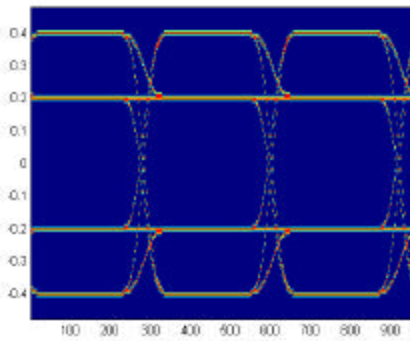
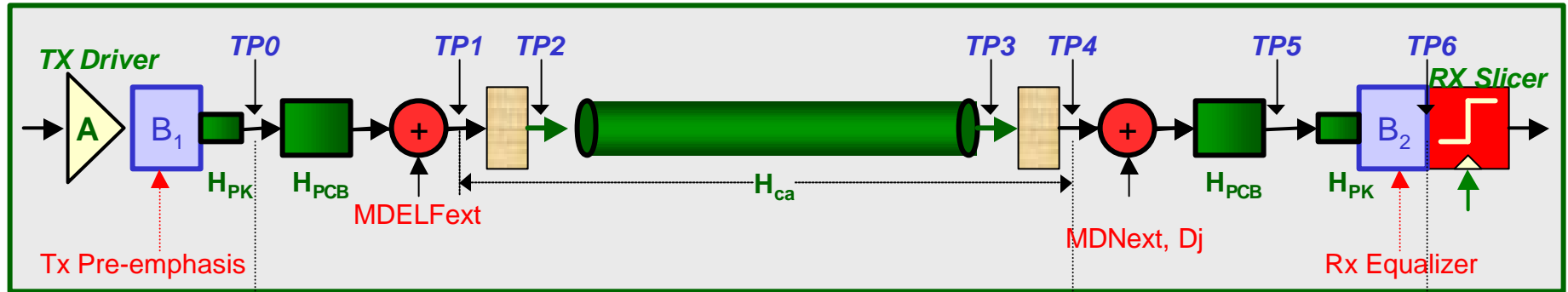
Eye = 81mVpp
Margin = 39mVpp



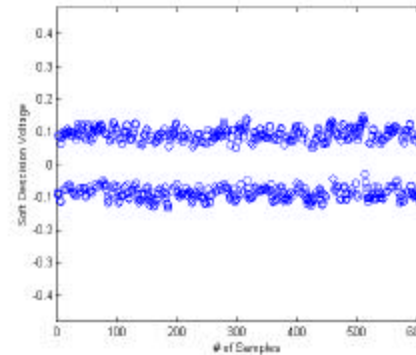
Eye = 170mVpp
Margin = 44mVpp

• Typical Eye Diagrams for Nominal Pre-emphasis = 50%

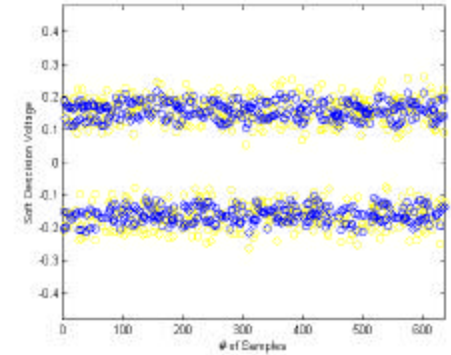
Link Model + Dj



Eye = 400mVpp
Margin = 400mVpp



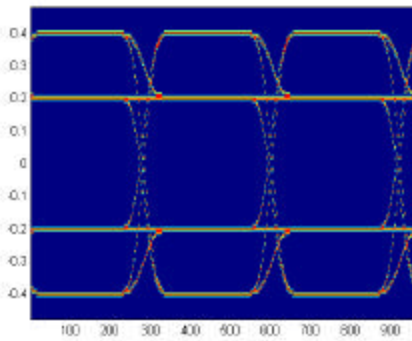
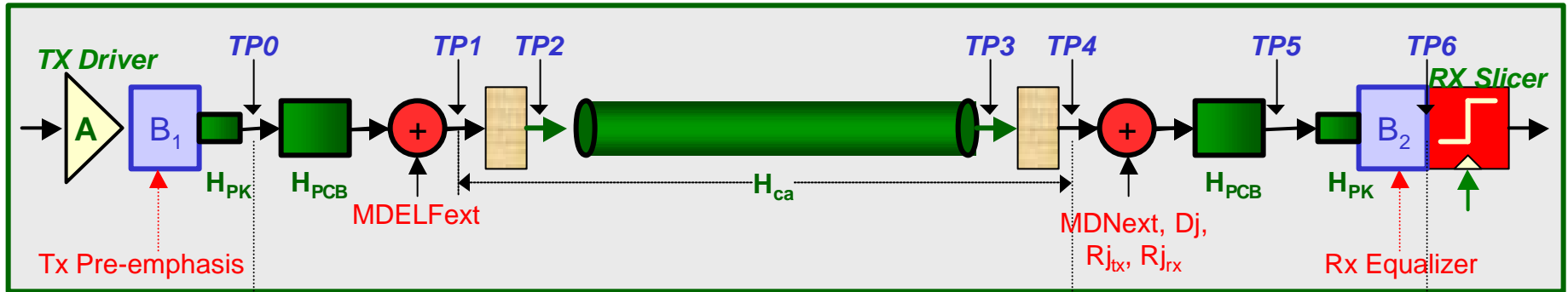
Eye = 81mVpp
Margin = 39mVpp



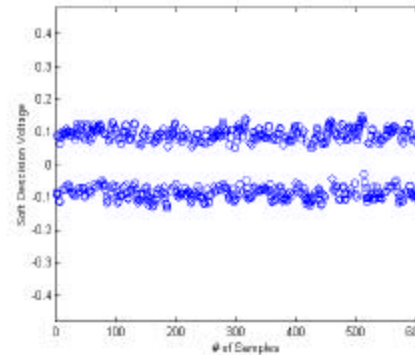
Eye = 130mVpp
Margin = 23mVpp

• Typical Eye Diagrams for Nominal Pre-emphasis = 50%

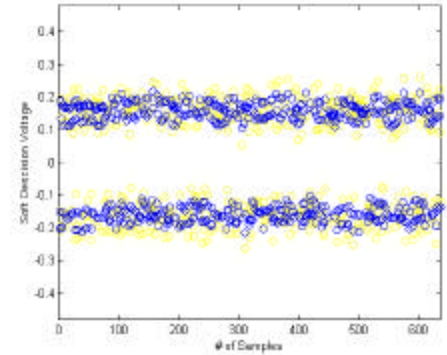
Link Model + Rj



**Eye = 400mVpp
Margin = 400mVpp**



**Eye = 81mVpp
Margin = 39mVpp**

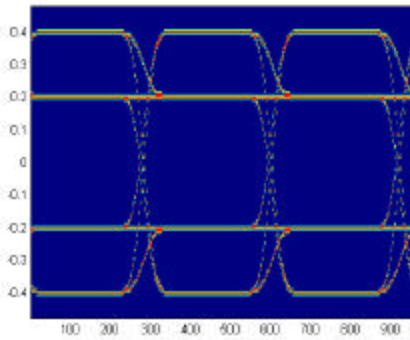
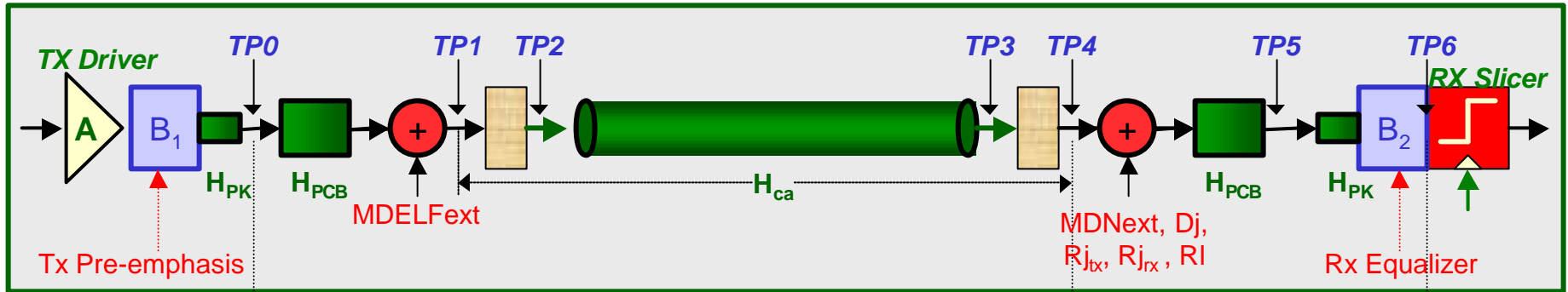


**Eye = 130mVpp
Margin = 7mVpp**

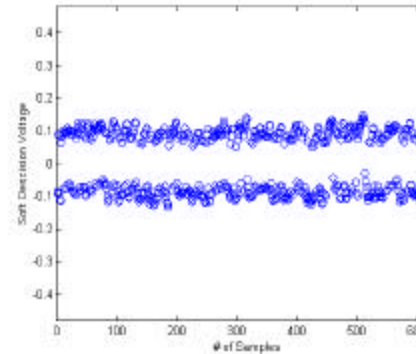
• Typical Eye Diagrams for Nominal Pre-emphasis = 50%



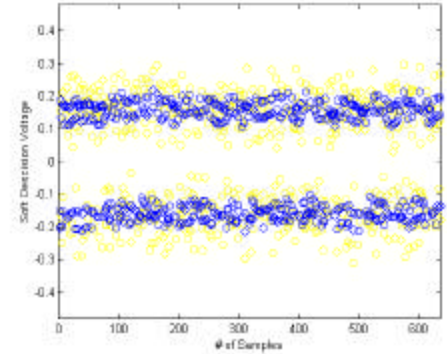
Link Model, + Return Loss



**Eye = 400mVpp
Margin = 400mVpp**



**Eye = 81mVpp
Margin = 39mVpp**

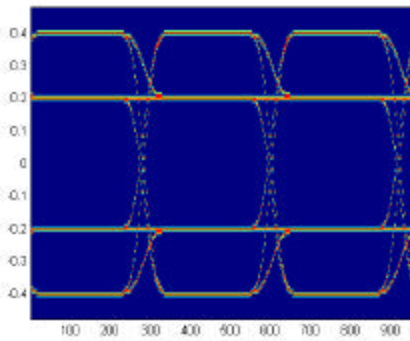
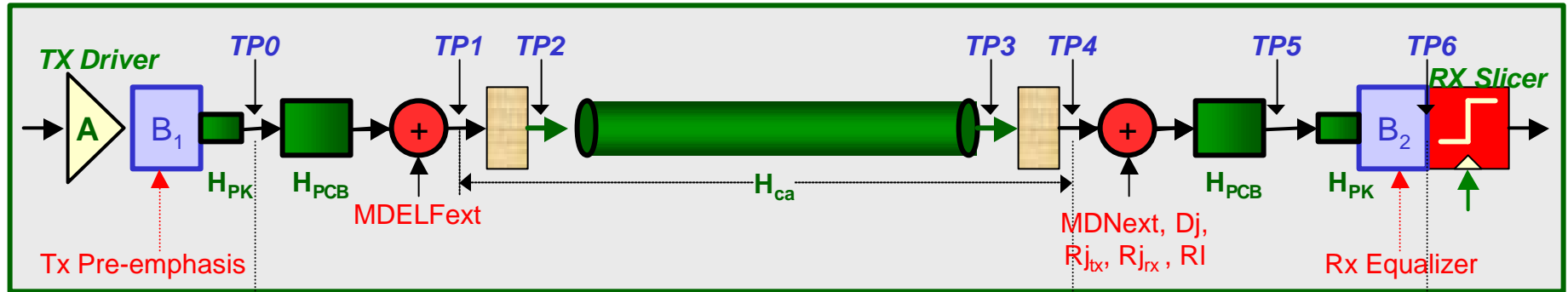


**Eye = 0mVpp
Margin = -107mVpp**

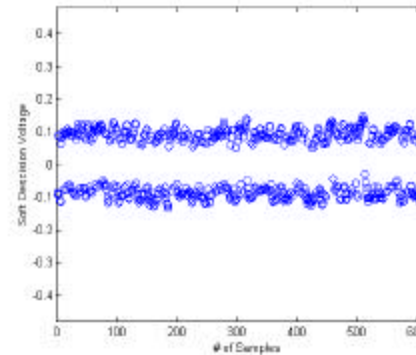
• Typical Eye Diagrams for Nominal Pre-emphasis = 50%



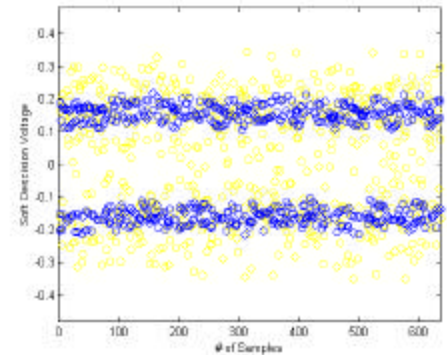
Link Model, + Max V(xtalk)



Eye = 400mVpp
Margin = 400mVpp



Eye = 81mVpp
Margin = 39mVpp



Eye = 0mVpp
Margin = -258mVpp

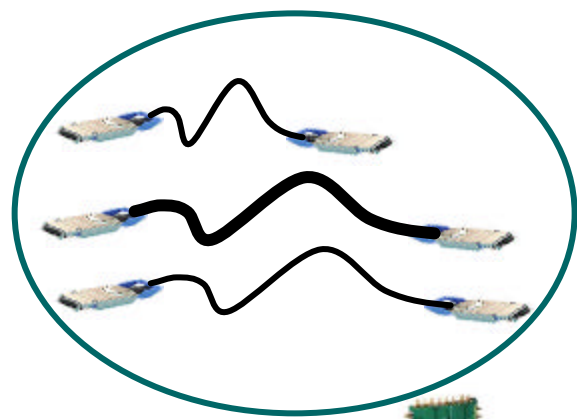
• Typical Eye Diagrams for Nominal Pre-emphasis = 50%



10GBASE-CX4 Link Analysis Outline

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Modeling Method



Channel

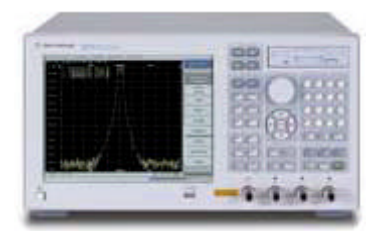
Data



Step Response

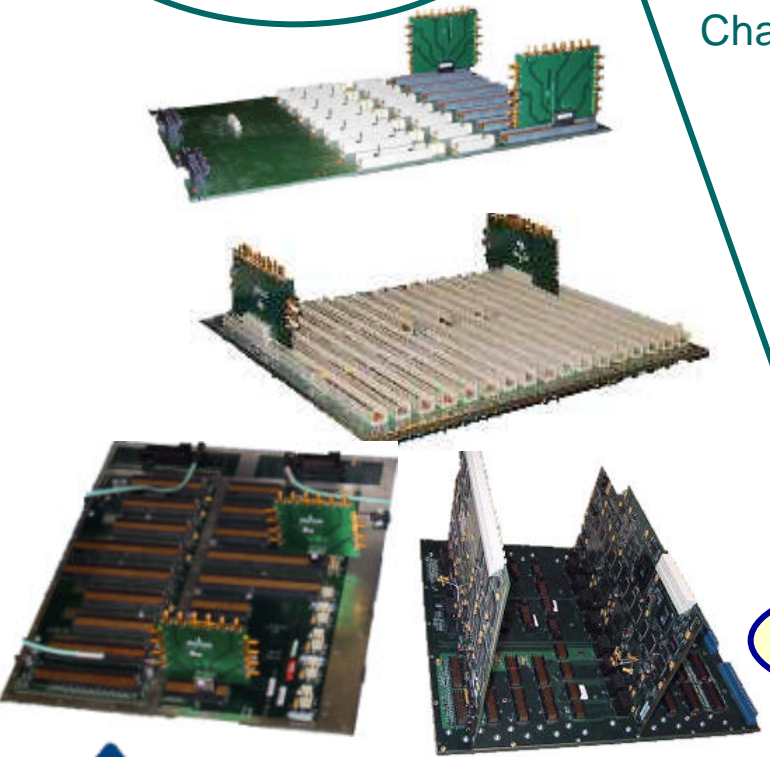


PRBS Modulation



8-GHz 4-Port Network Analyzer

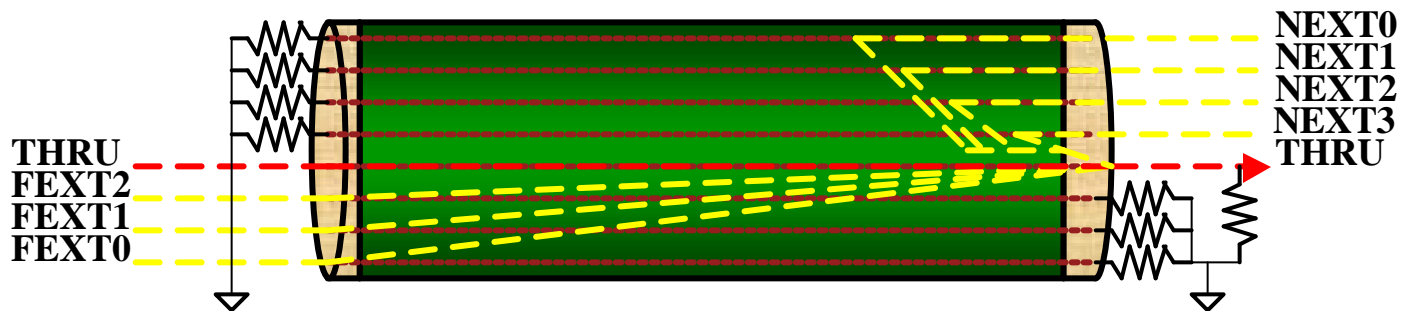
Analyze



- Confirm correlation in data gathering methods before generating model

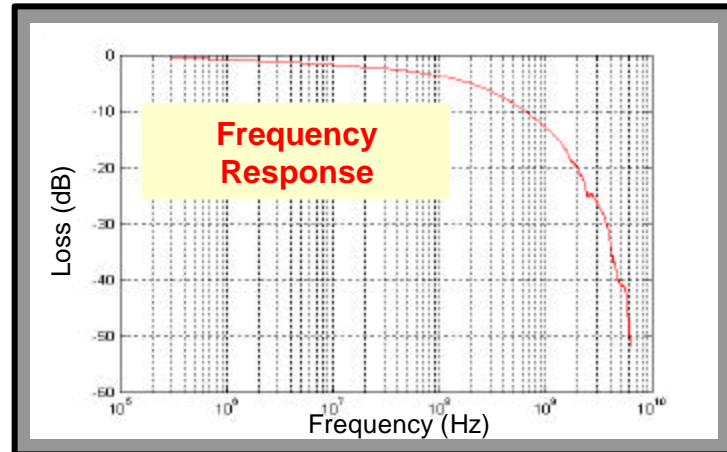
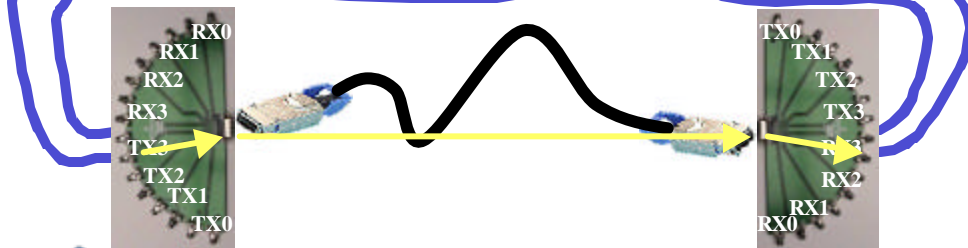
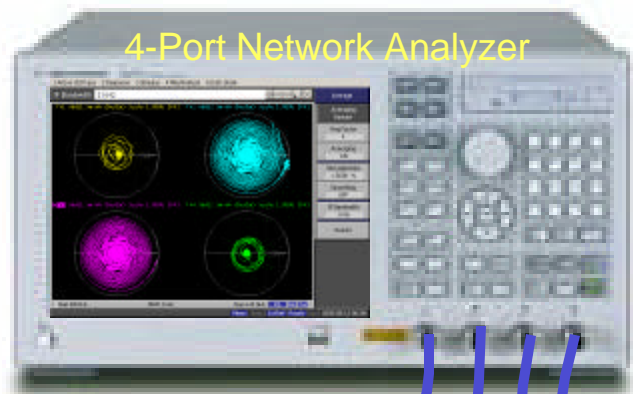


Path Definitions



Thru Setup

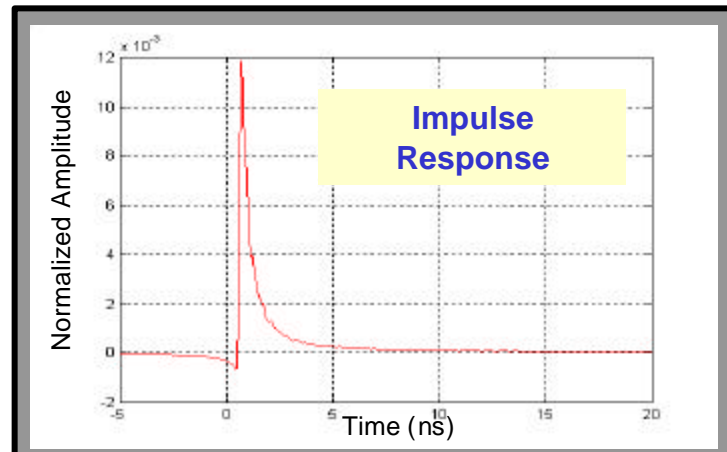
4-Port swept frequency response measured directly
Impulse response obtained by performing an IFFT



MATLAB

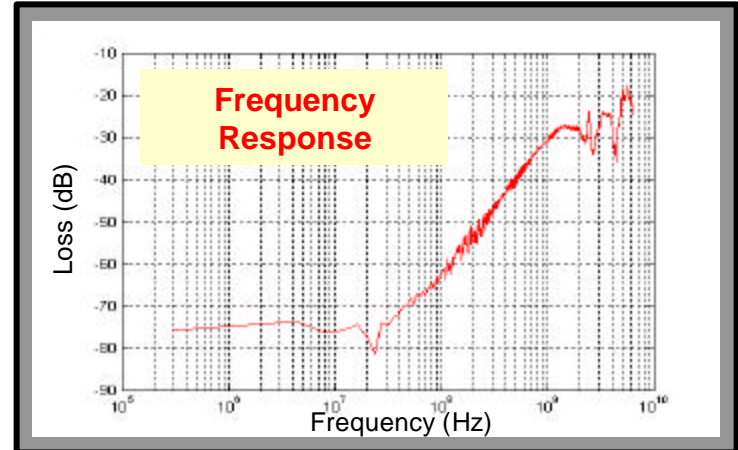
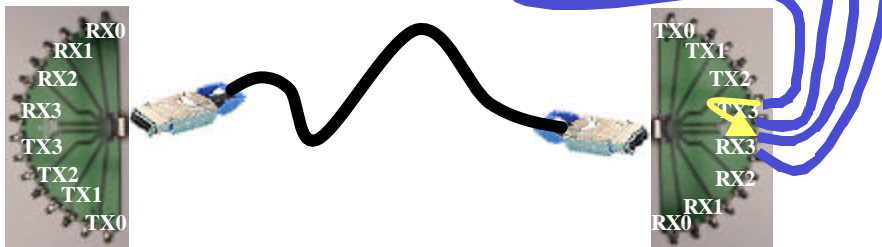
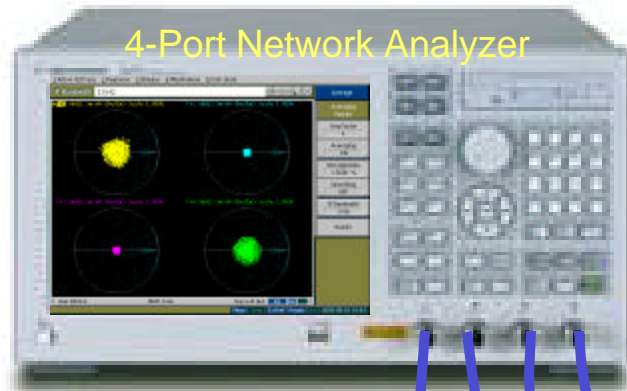


IFFT



Next Setup

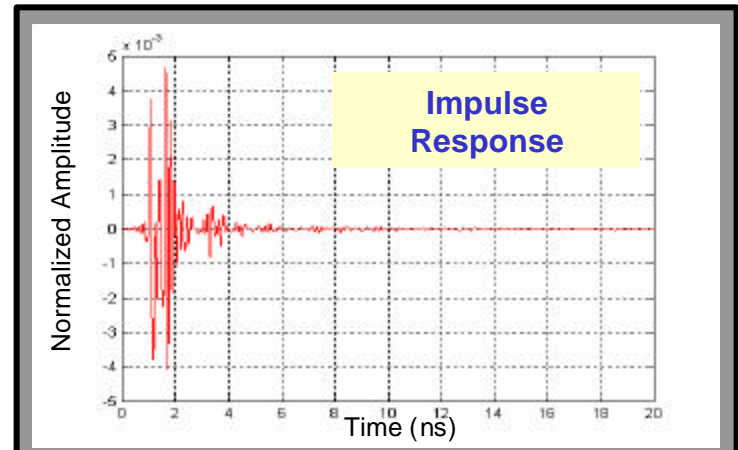
4-Port swept frequency response measured directly
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MATLAB

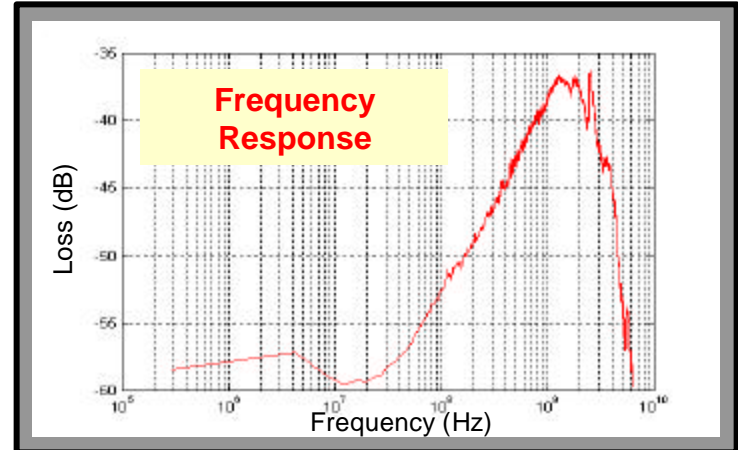
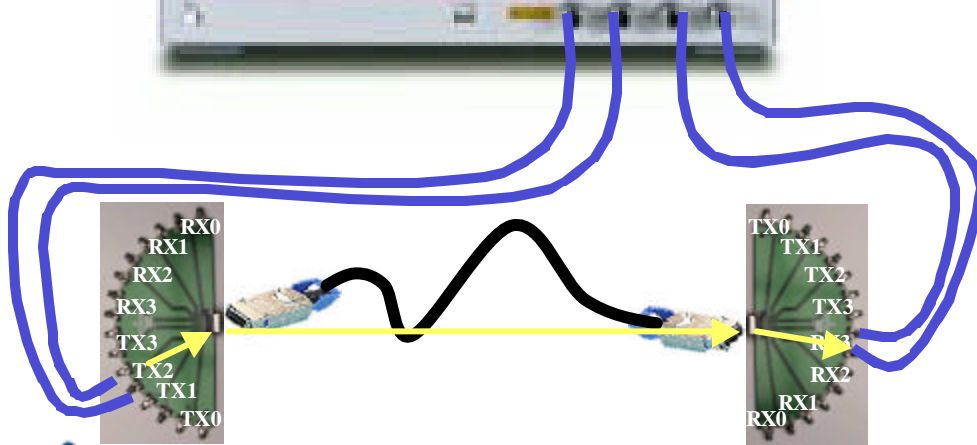
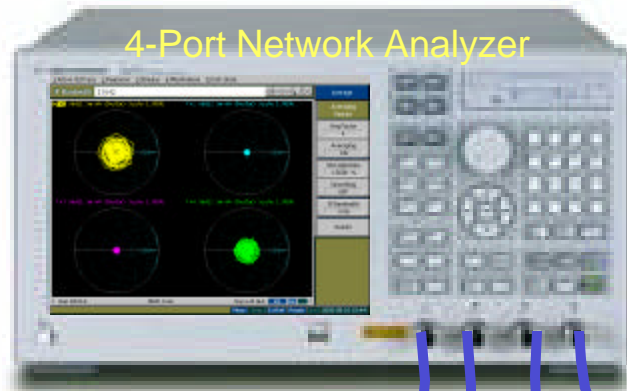


IFFT



Fext Setup

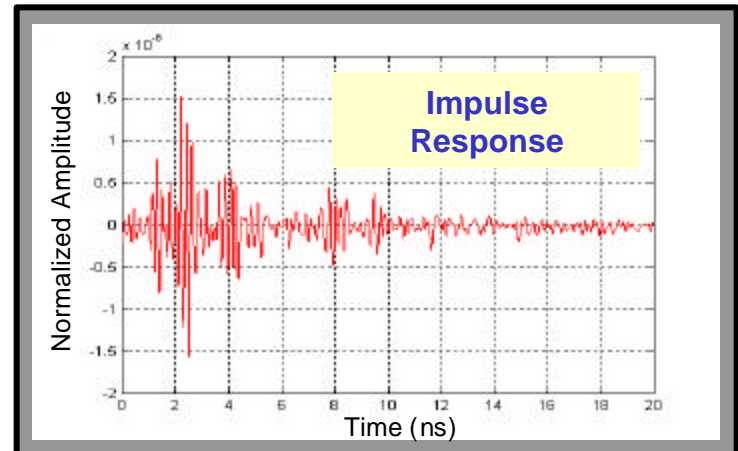
4-Port swept frequency response measured directly
Impulse response obtained by performing an IFFT



MATLAB

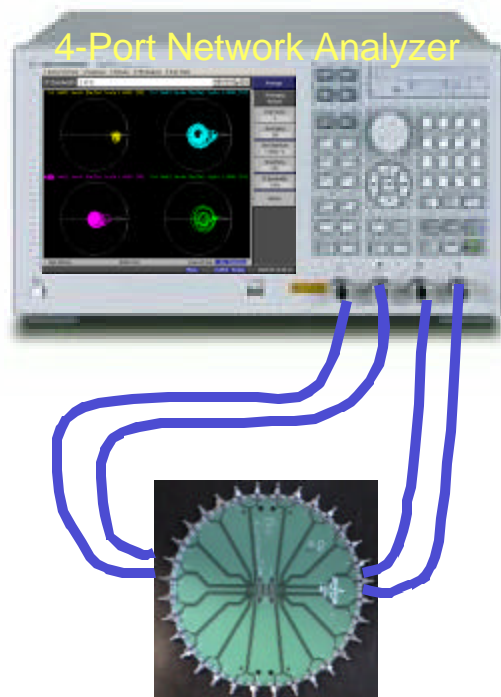


IFFT

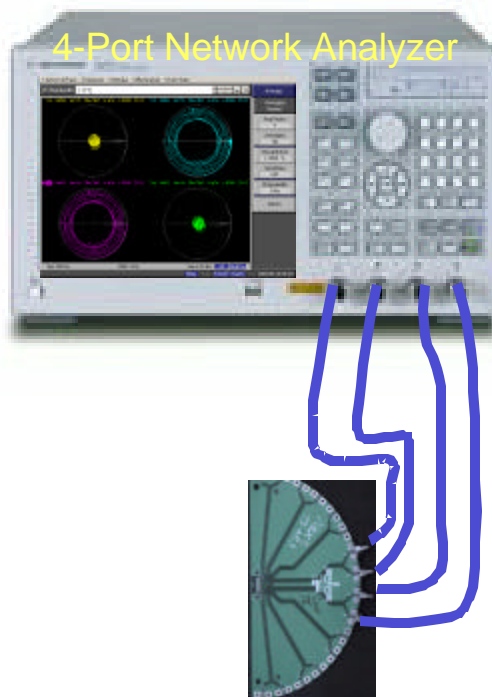


Calibration

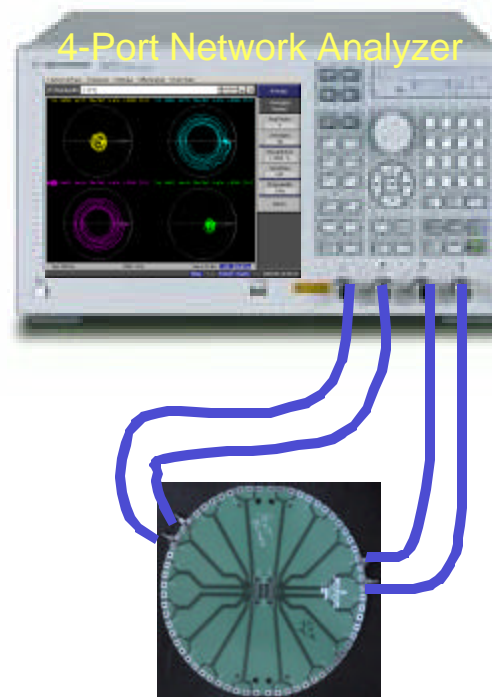
Replica board, w/o connectors, built to calibrate out the effects of PCB traces and SMAs



Through Calibration



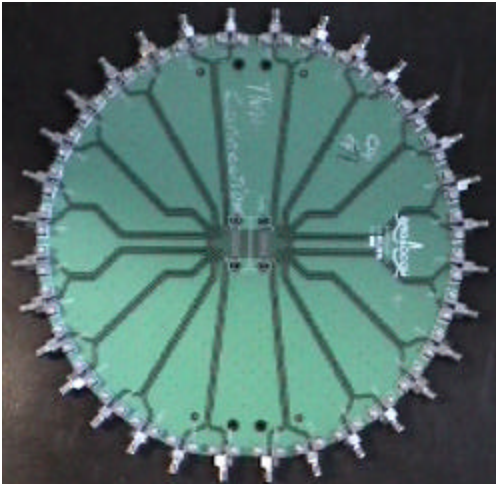
Next Calibration



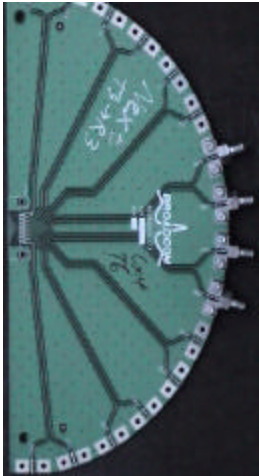
Fext Calibration

Calibration Cards

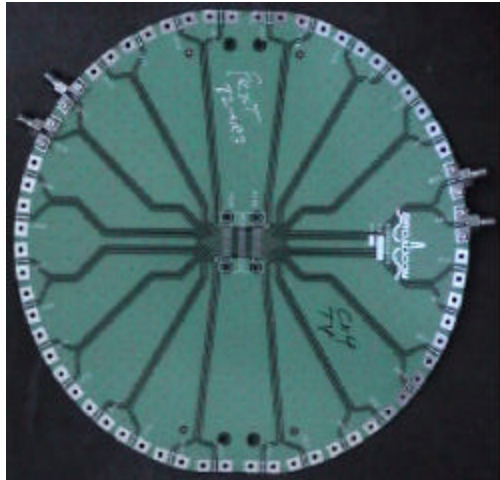
Replica board, w/o connectors, built to calibrate out the affects of PCB traces and SMAs



Through Calibration



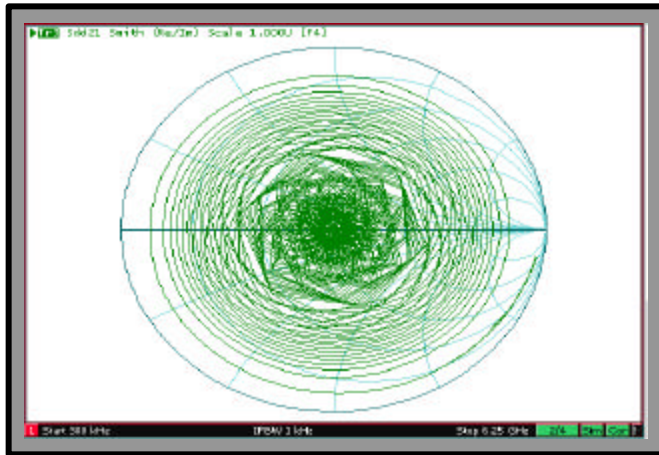
Next Calibration



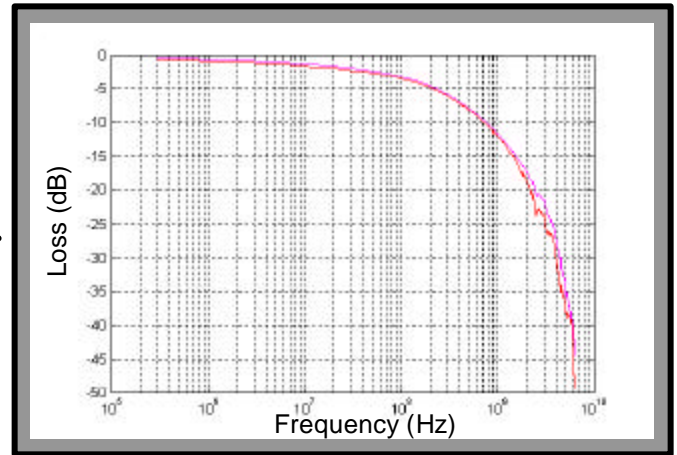
Fext Calibration



15m Cable Assembly S21

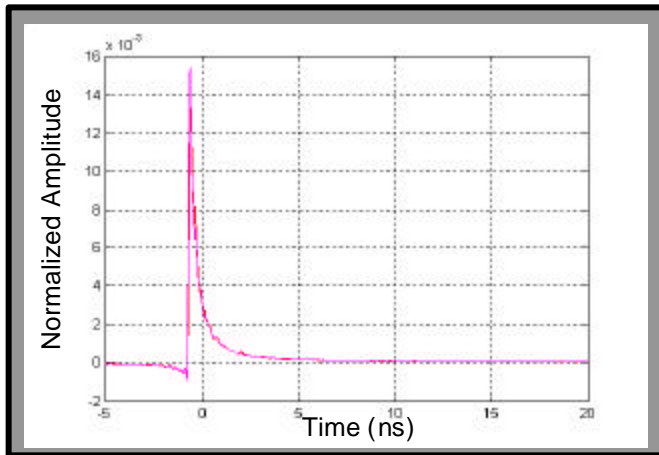


MATLAB
rect 2 polar



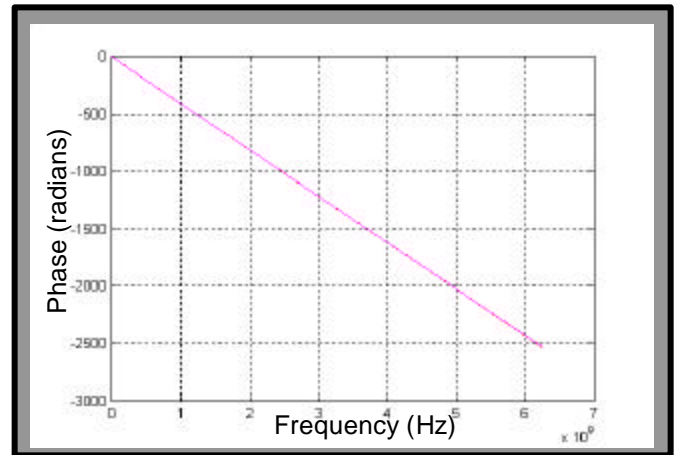
Magnitude Response

MATLAB IFFT



Impulse Response

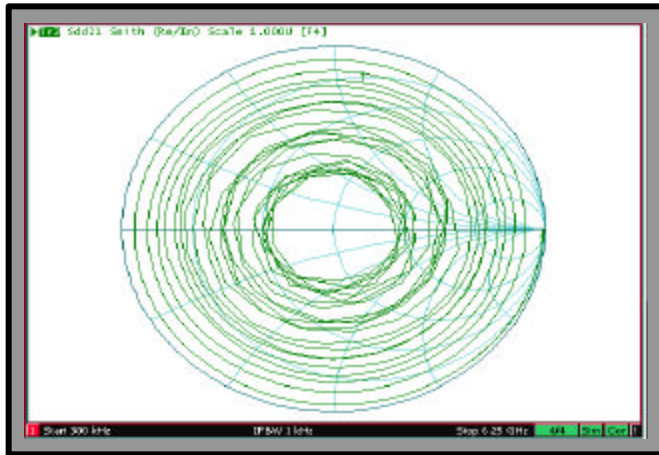
MATLAB
rect 2 phase



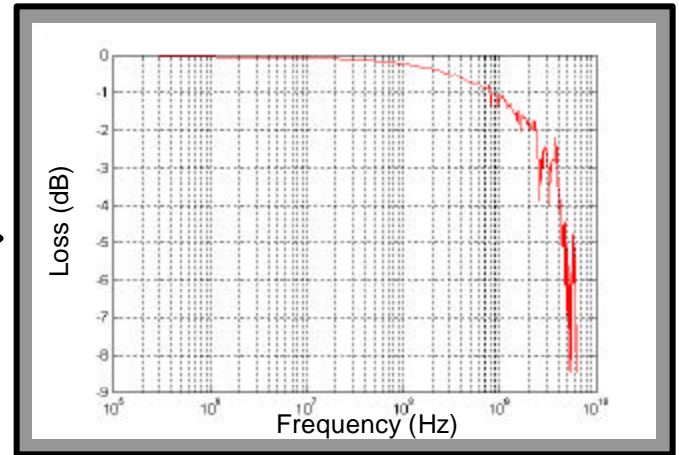
Phase Response



0.5m Cable Assembly S21

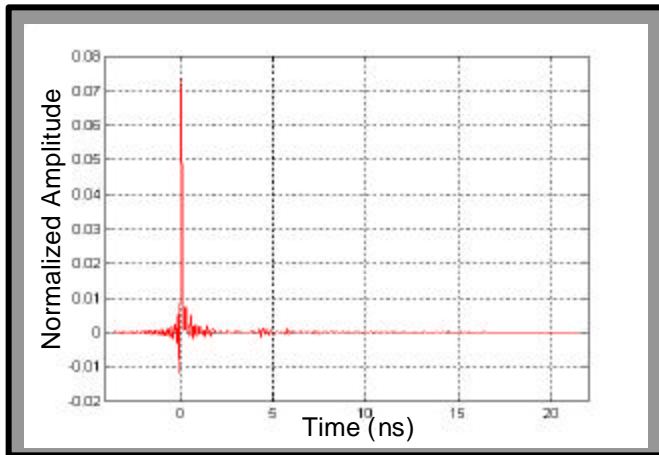


MATLAB
rect 2 polar

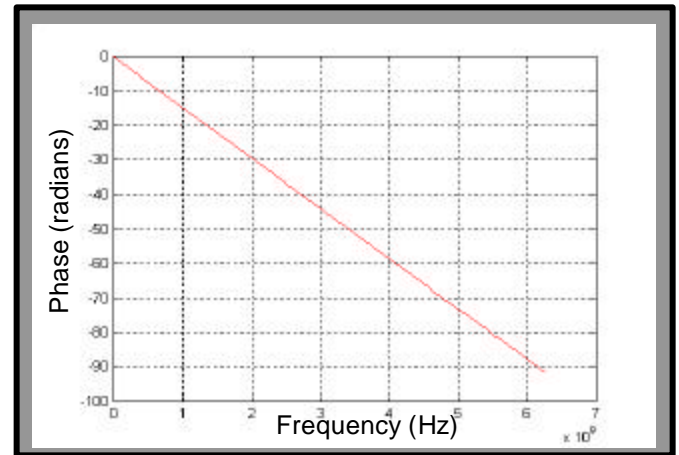
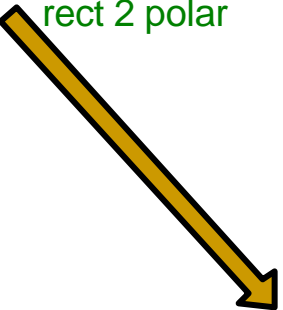


Magnitude Response

MATLAB IFFT



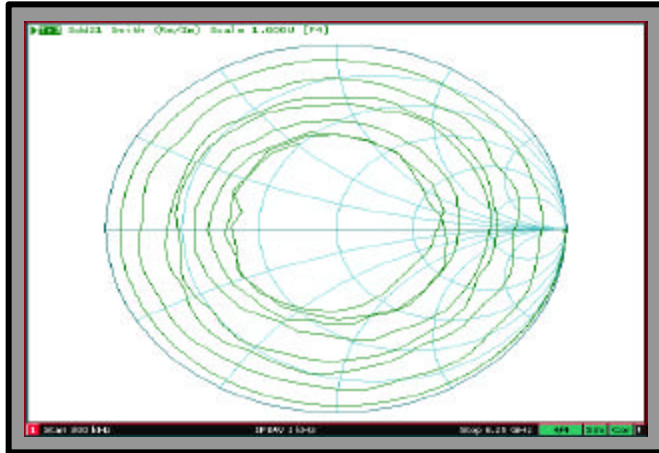
Impulse Response



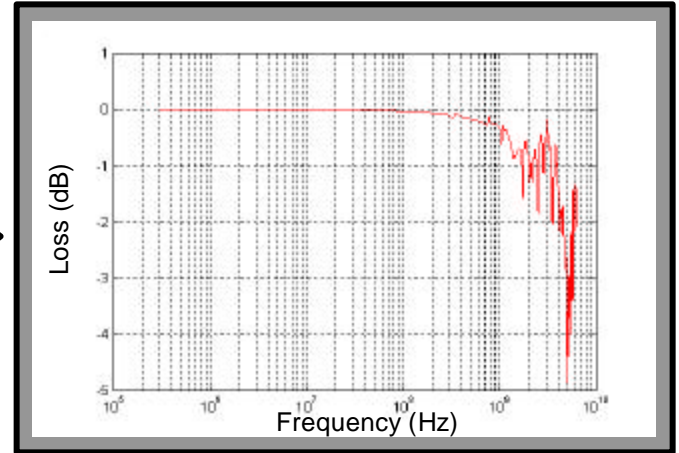
Phase Response



Connector S21

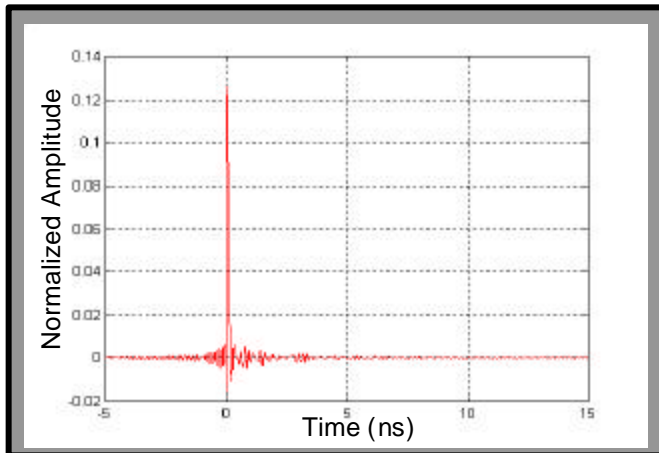


MATLAB
rect 2 polar

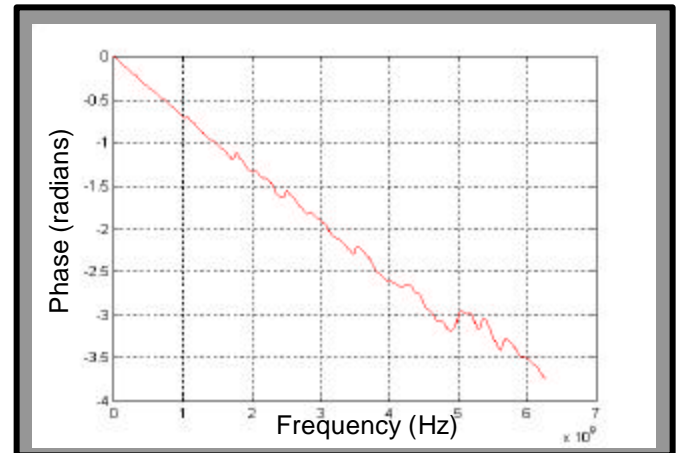
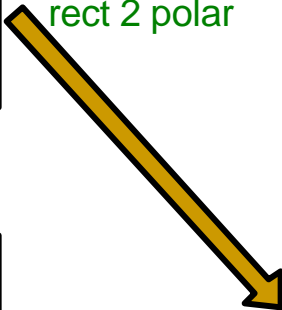


Magnitude Response

MATLAB IFFT



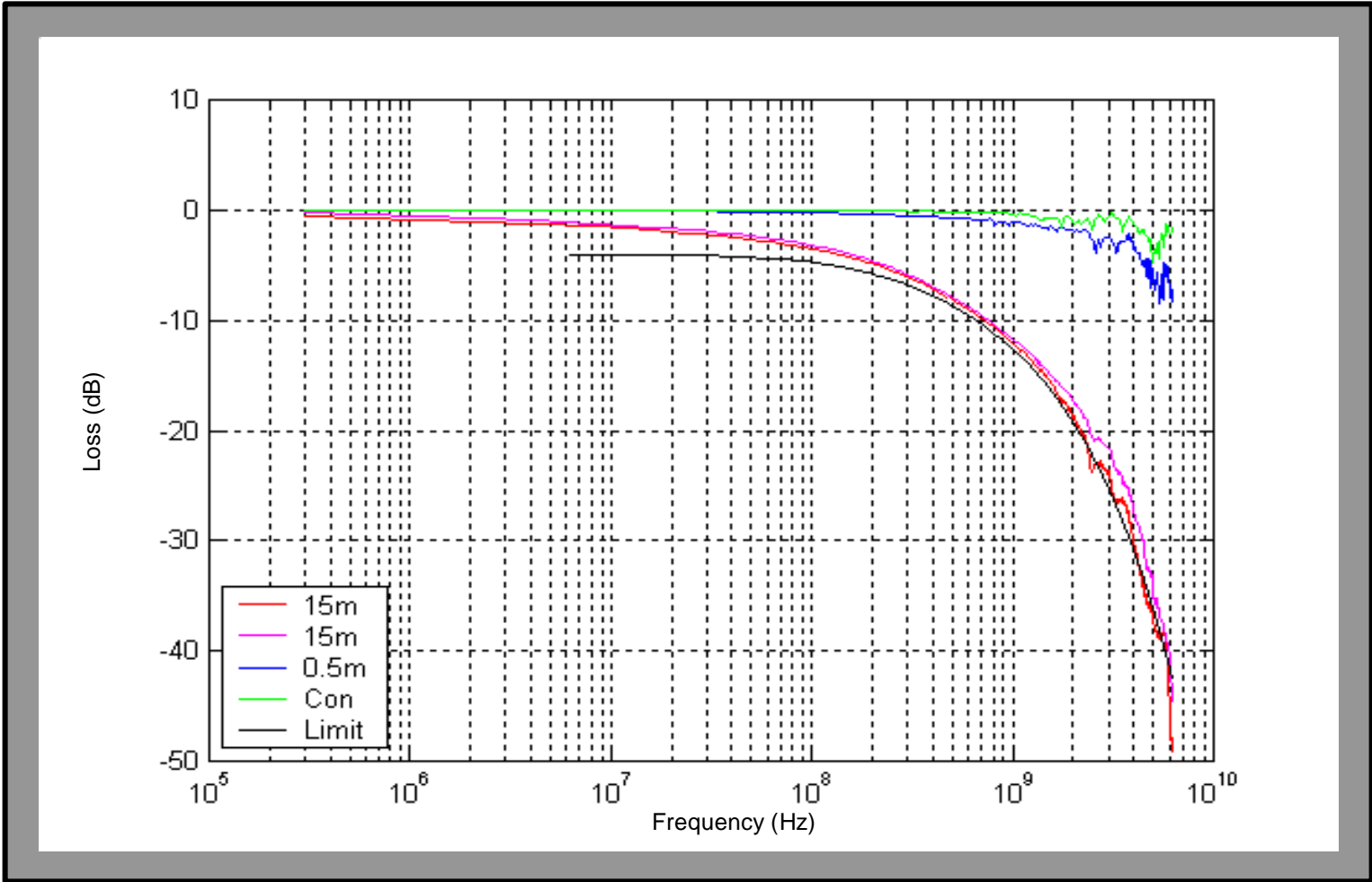
Impulse Response



Phase Response



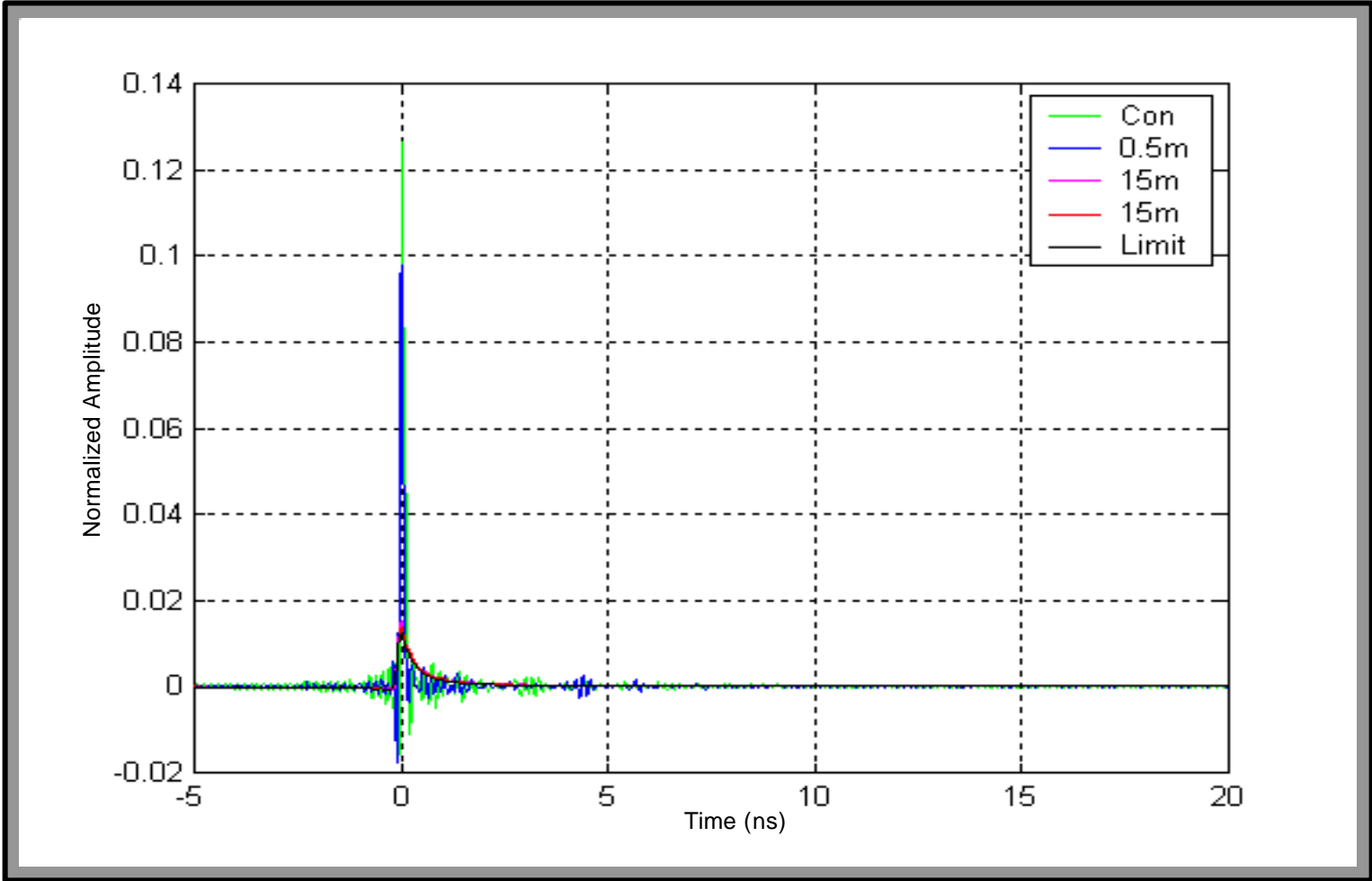
Cable Assembly Insertion Loss Model



Magnitude Response



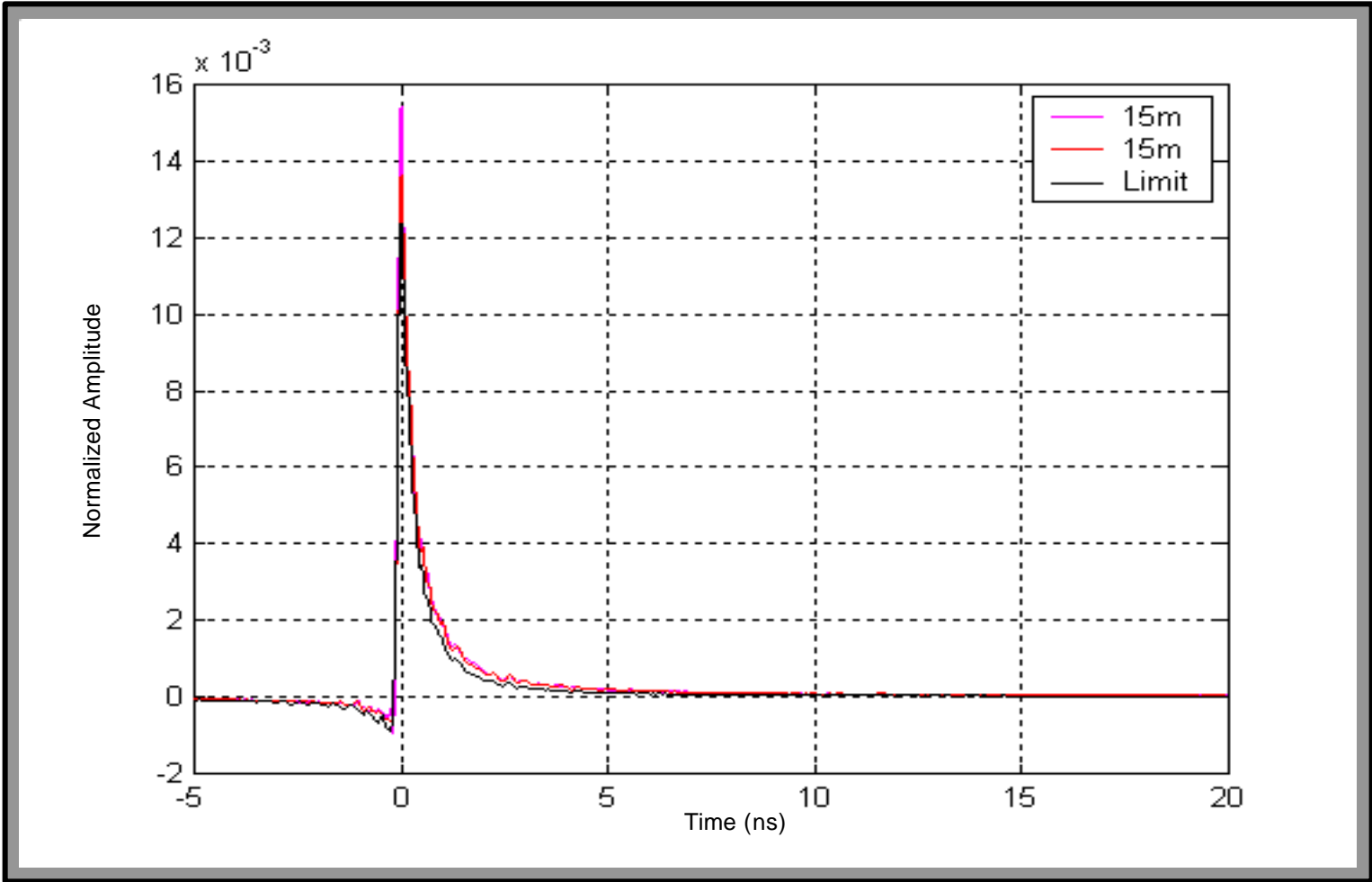
Cable Assembly Insertion Loss Model



Inpulse Response



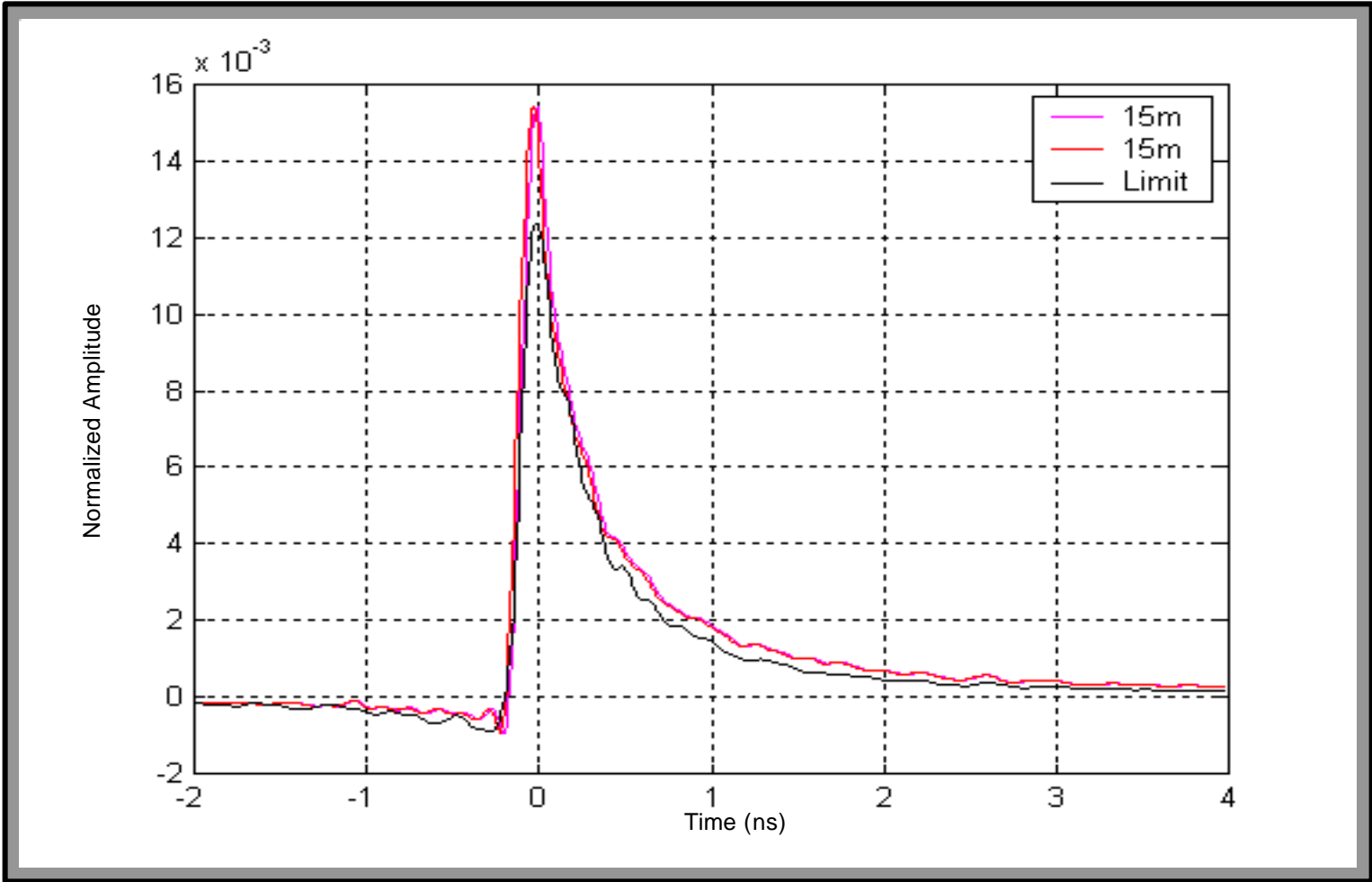
Cable Assembly Insertion Loss Model



Inpulse Response



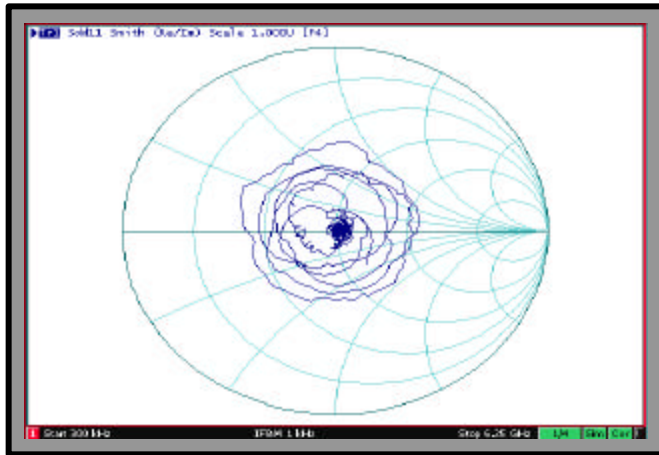
Cable Assembly Insertion Loss Model



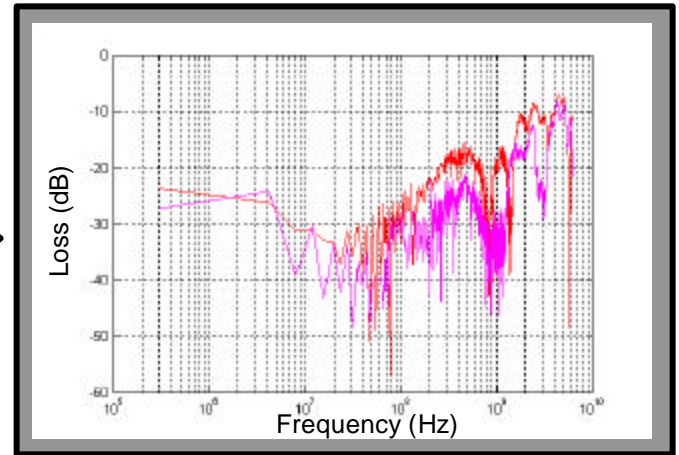
Inpulse Response



15m Cable Assembly S11

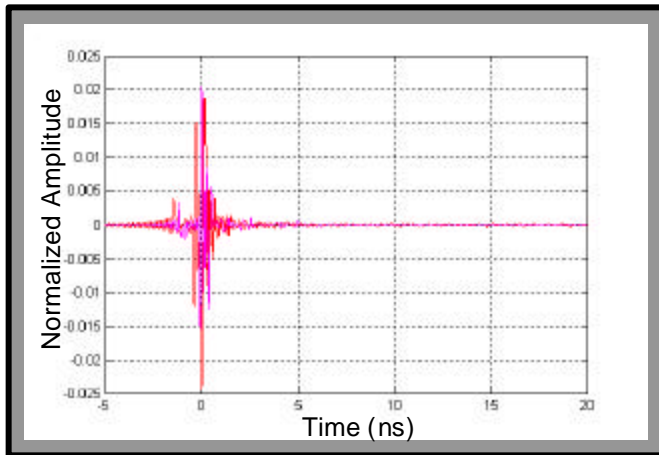


MATLAB
rect 2 polar

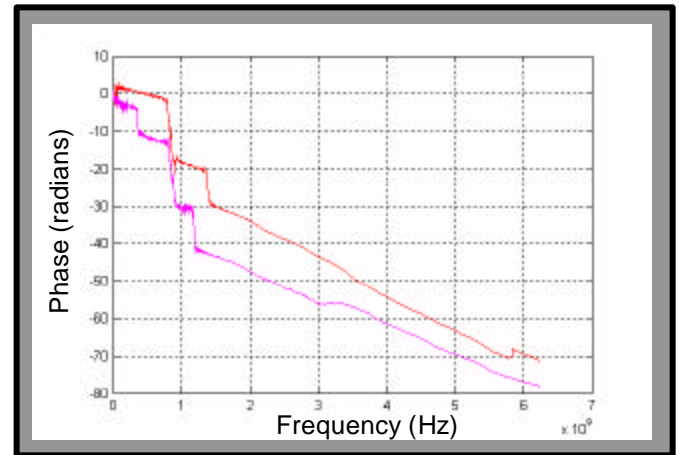
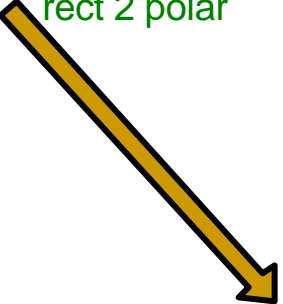


Magnitude Response

MATLAB IFFT



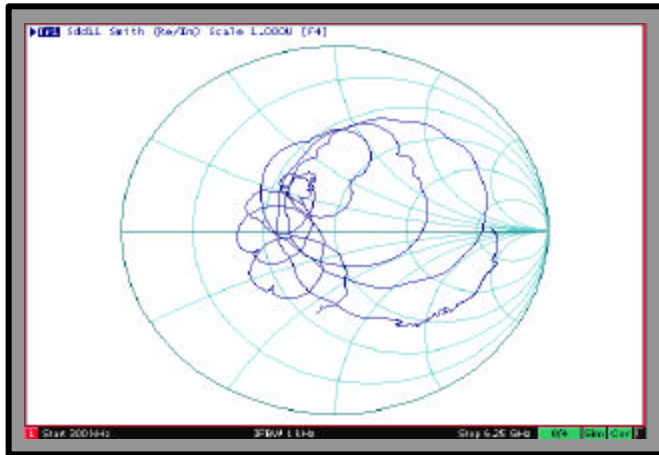
Impulse Response



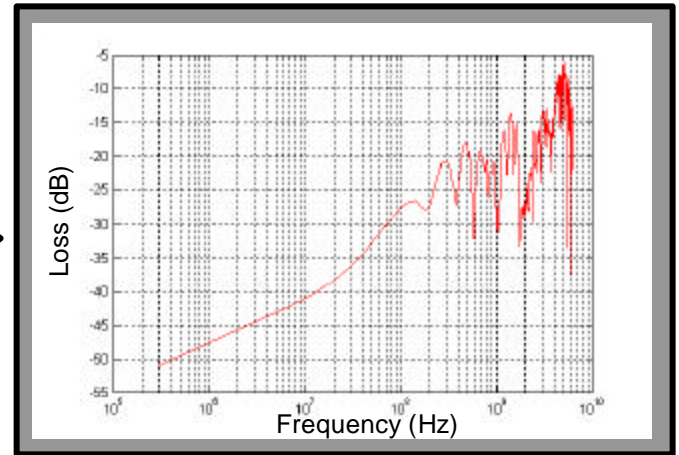
Phase Response



0.5m Cable Assembly S11

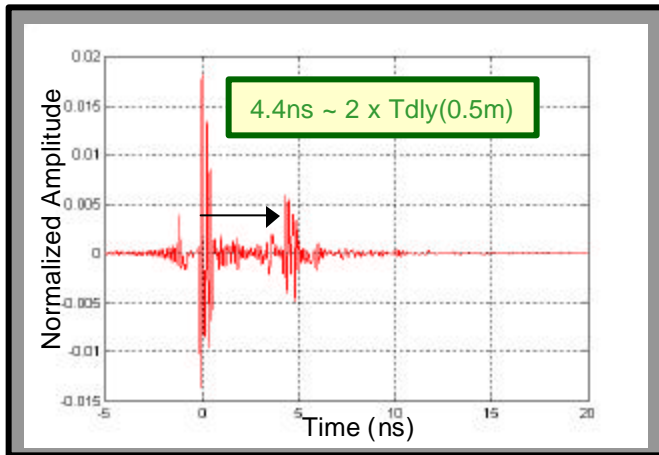


MATLAB
rect 2 polar

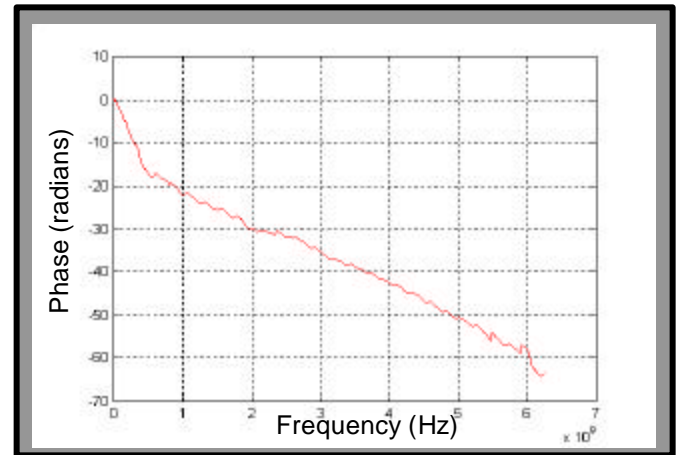
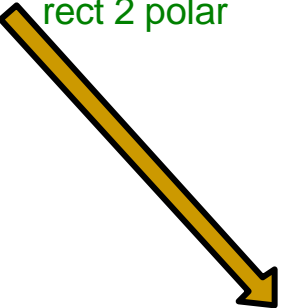


Magnitude Response

MATLAB IFFT



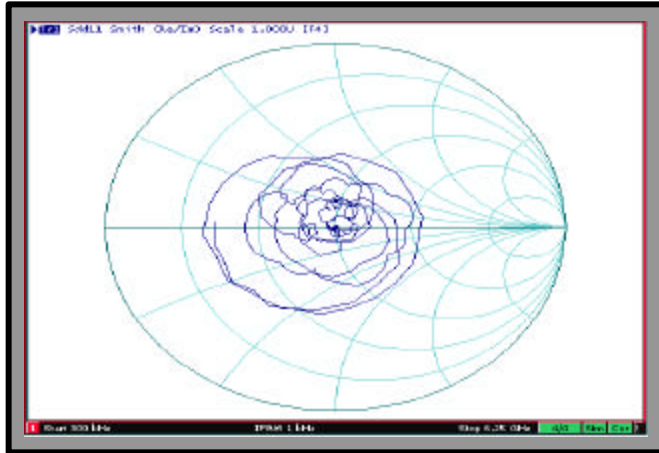
Impulse Response



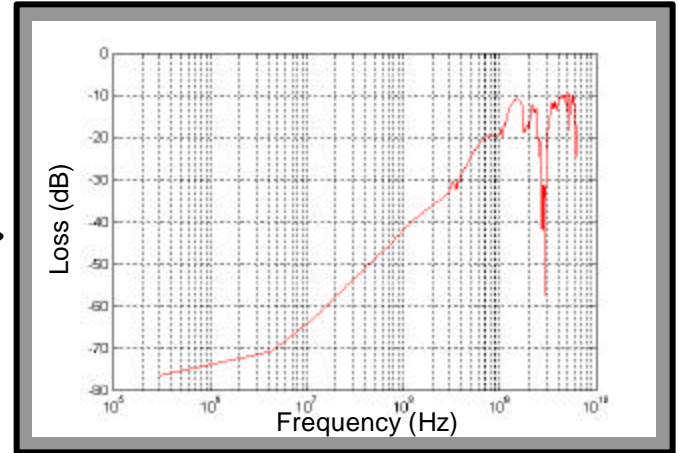
Phase Response



Connector S11

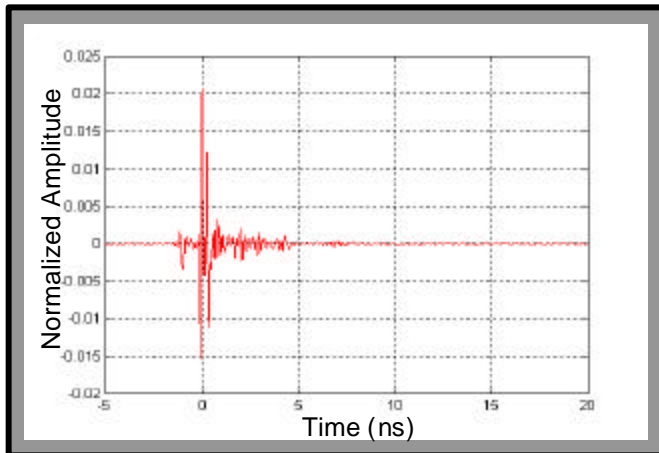


MATLAB
rect 2 polar

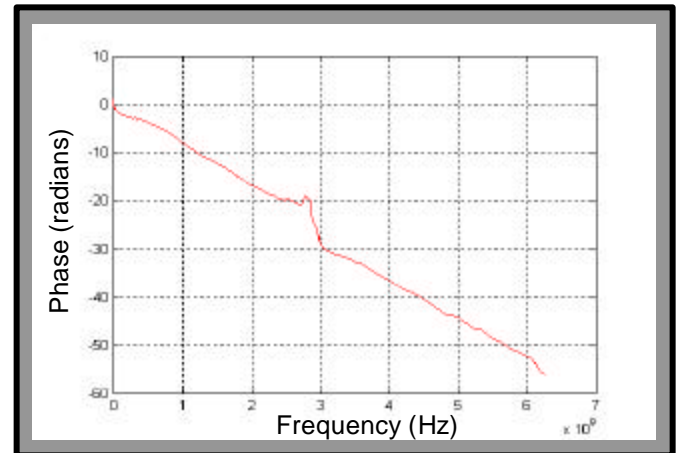
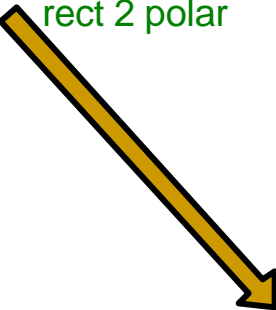


Magnitude Response

MATLAB IFFT



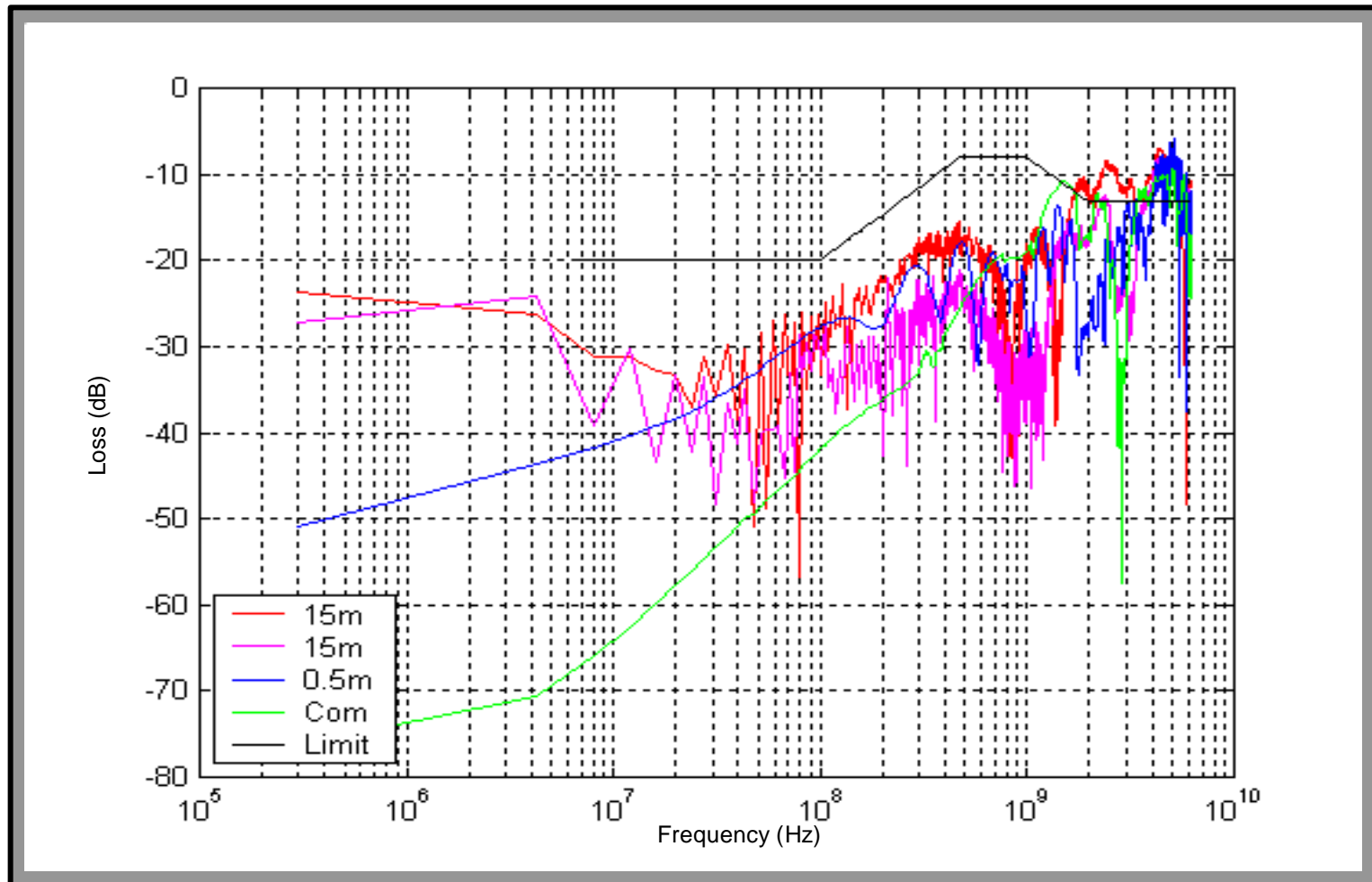
Impulse Response



Phase Response



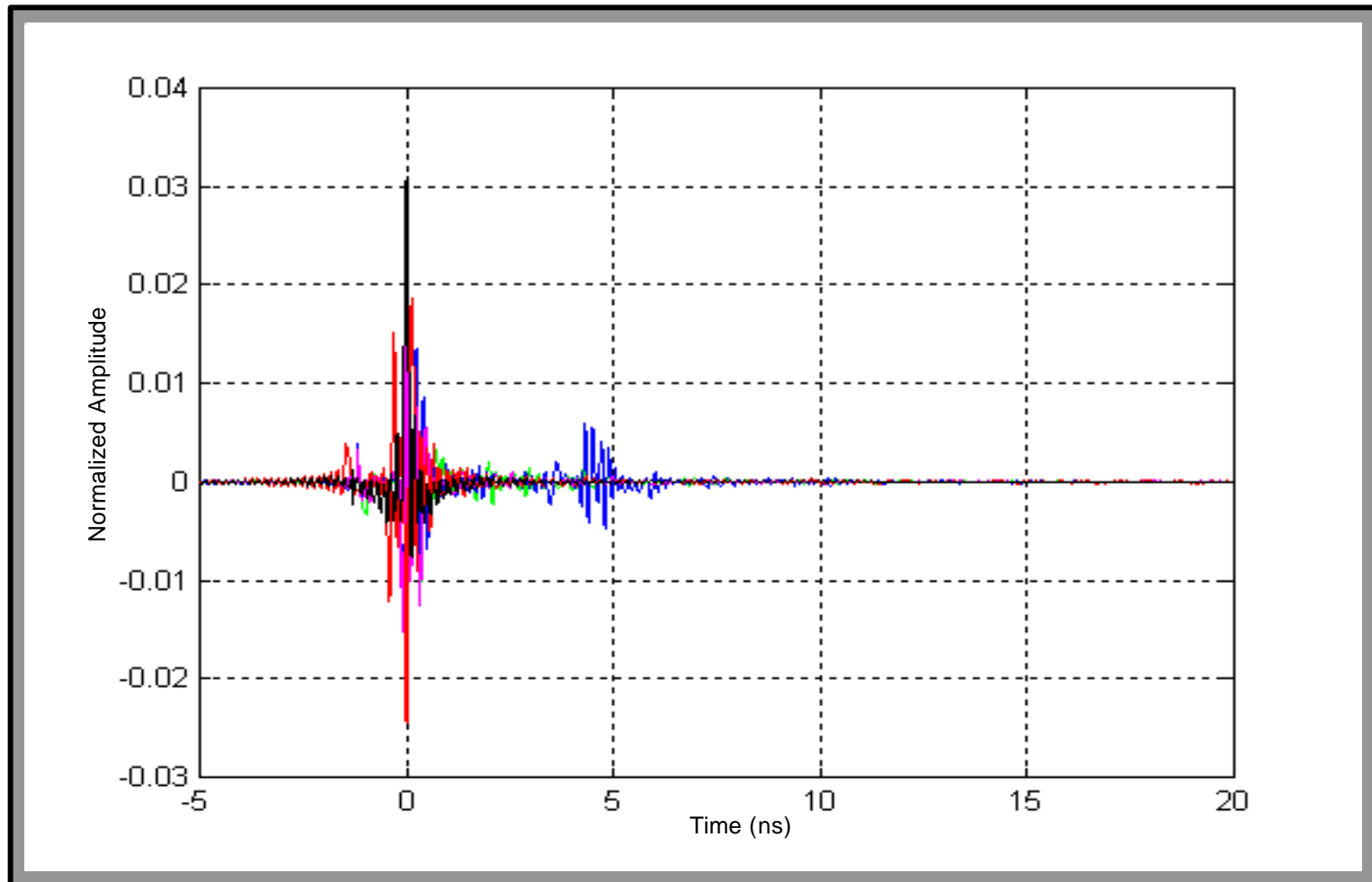
Cable Assembly Return Loss Model



Magnitude Response

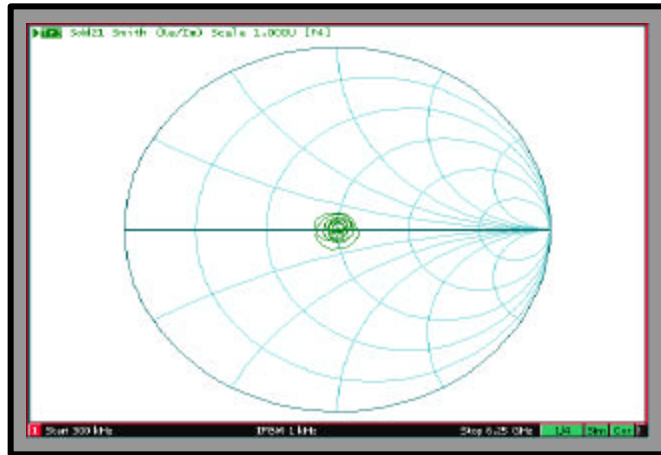


Cable Assembly Return Loss Model

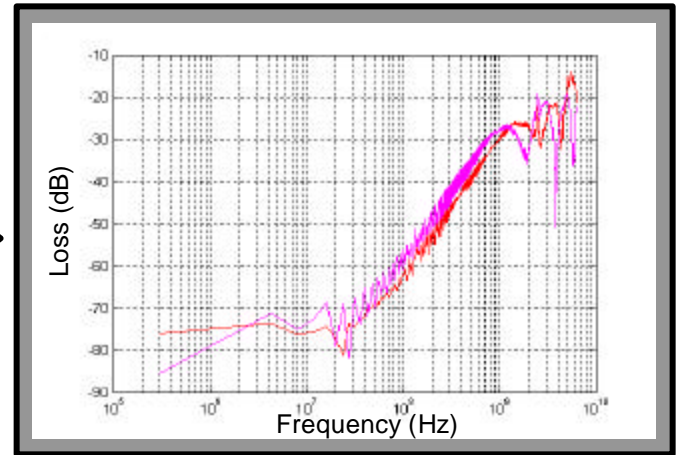


Impulse Response

15m Cable Assembly Next

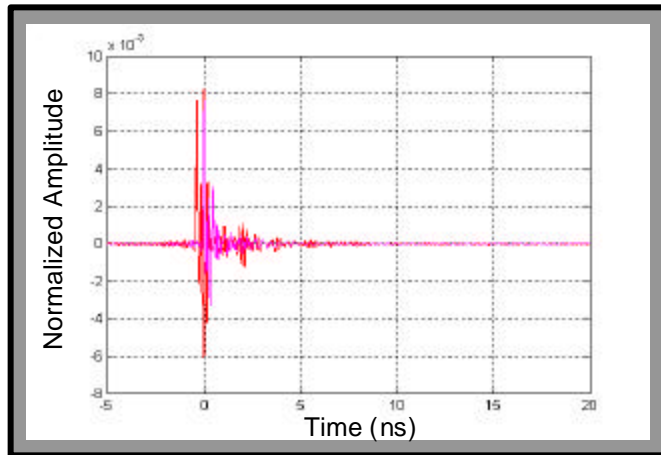


MATLAB
rect 2 polar

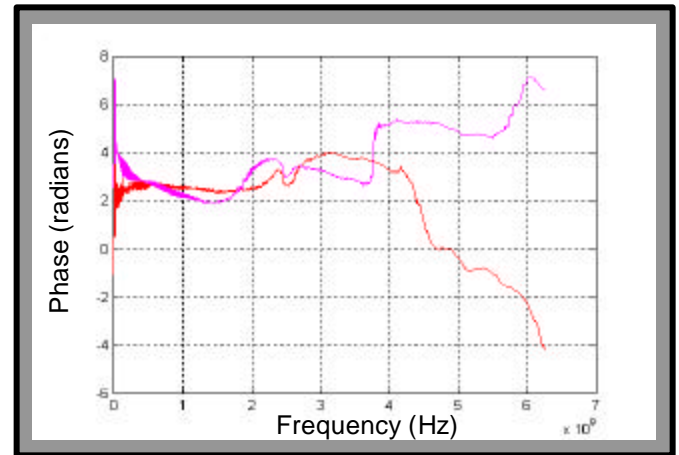
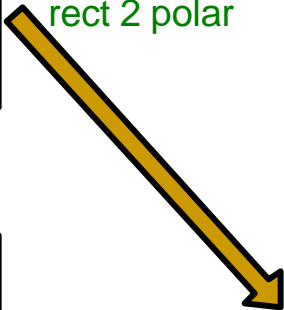


Magnitude Response

MATLAB IFFT



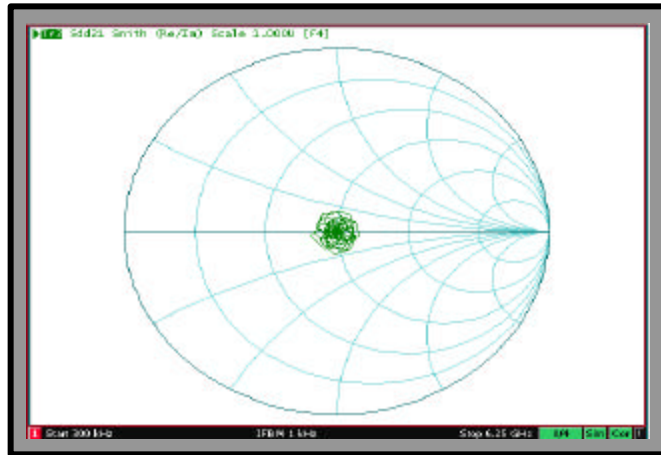
Impulse Response



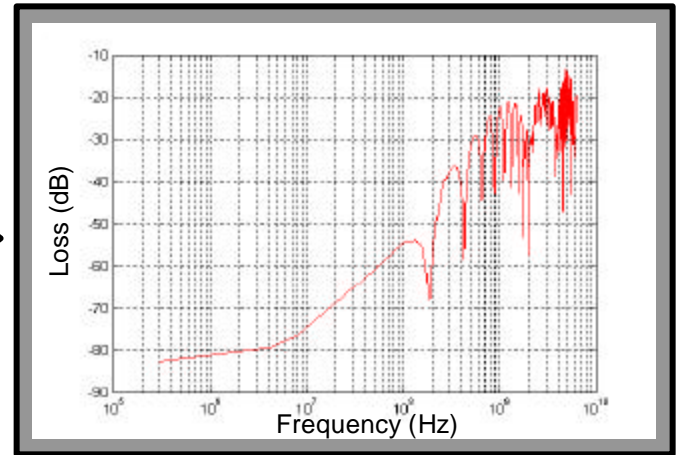
Phase Response



0.5m Cable Assembly Next

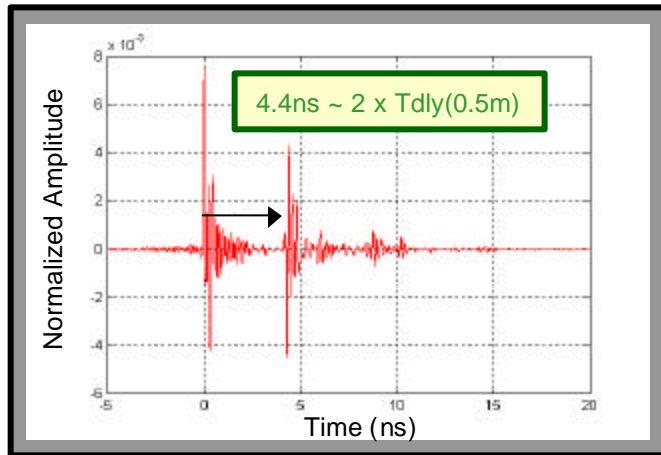


MATLAB
rect 2 polar



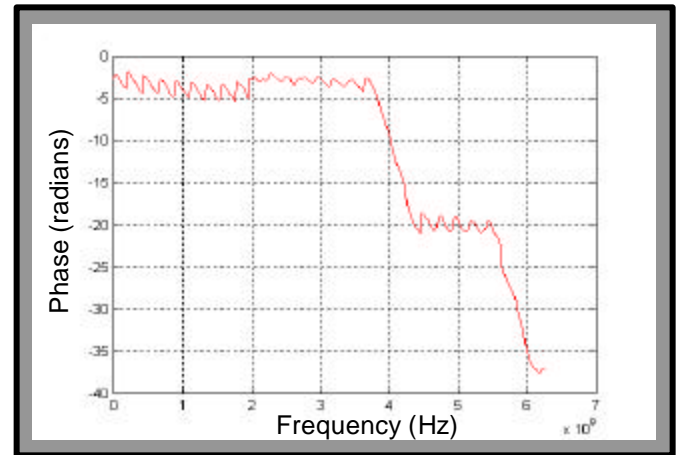
Magnitude Response

MATLAB IFFT



Impulse Response

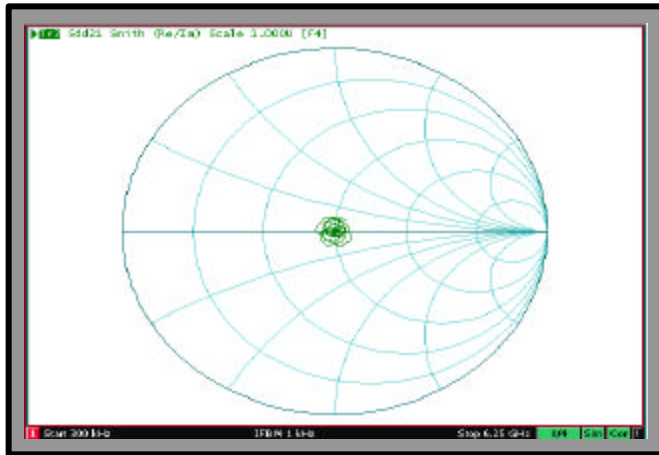
MATLAB
rect 2 phase



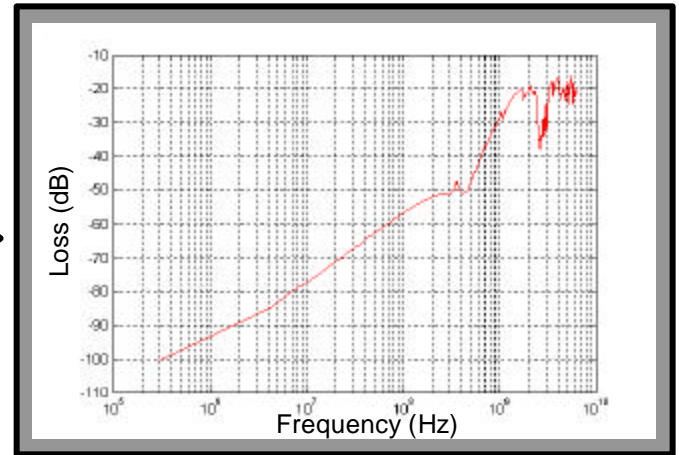
Phase Response



Connector Next

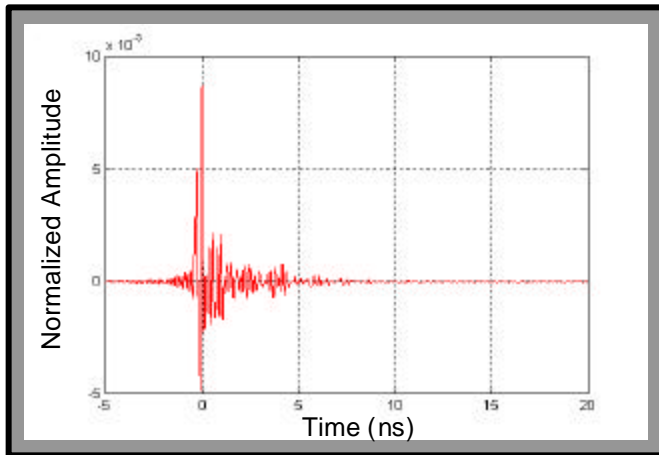


MATLAB
rect 2 polar

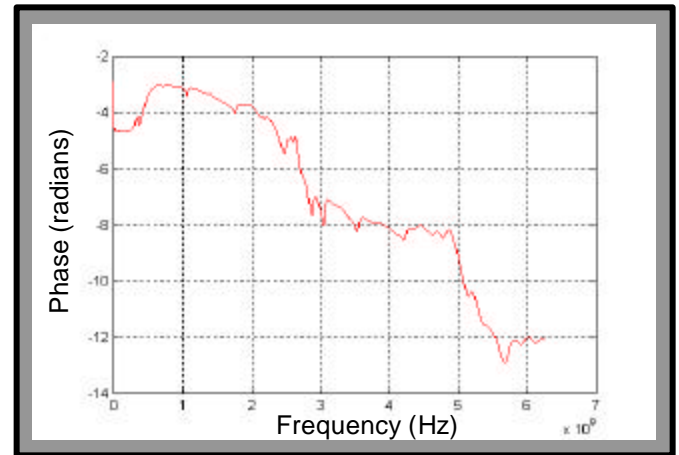
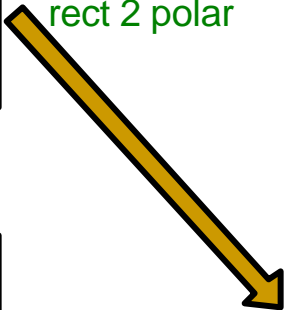


Magnitude Response

MATLAB IFFT



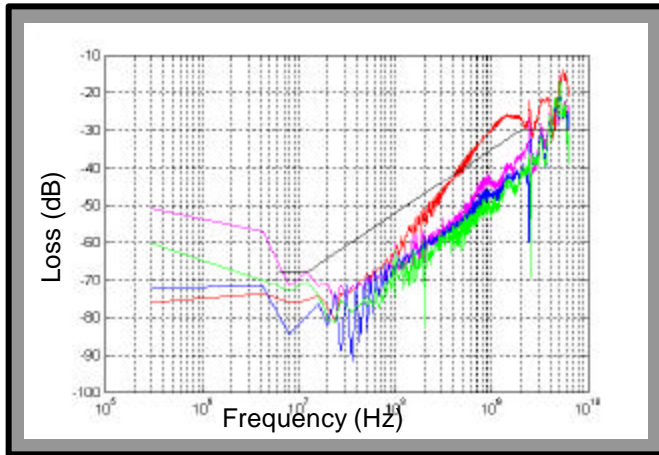
Impulse Response



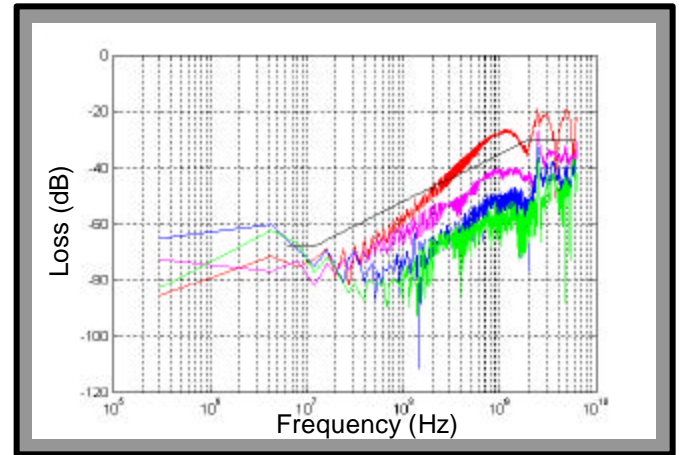
Phase Response



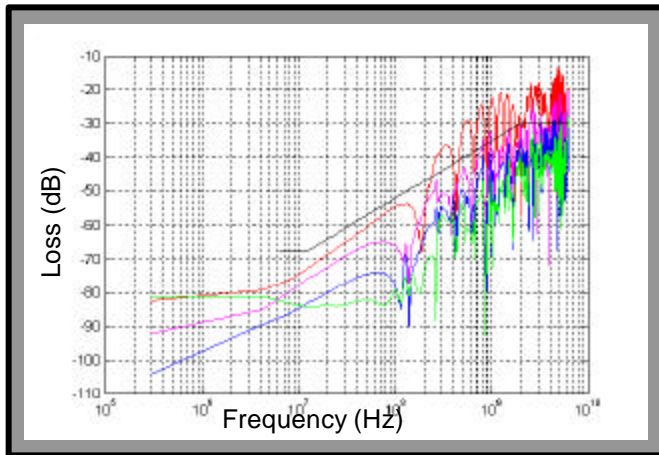
Next Summary



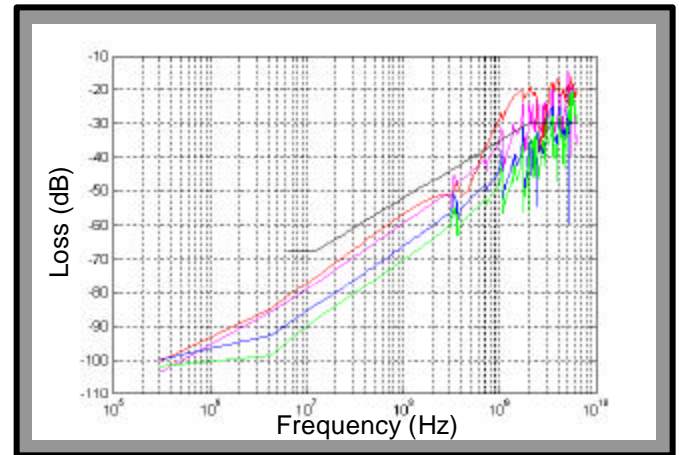
15m Next Response



15m Next Response



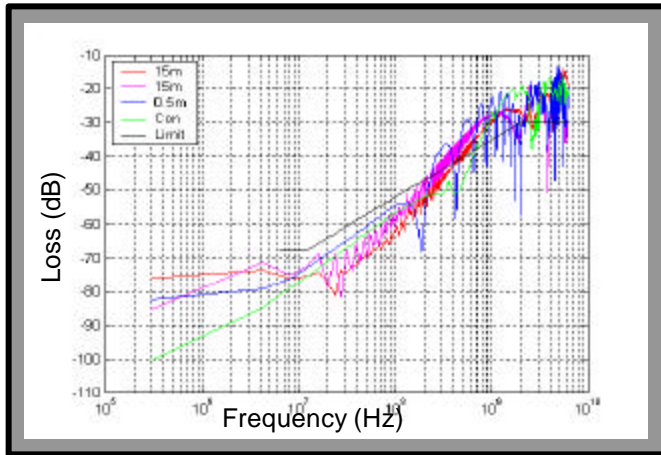
0.5m Next Response



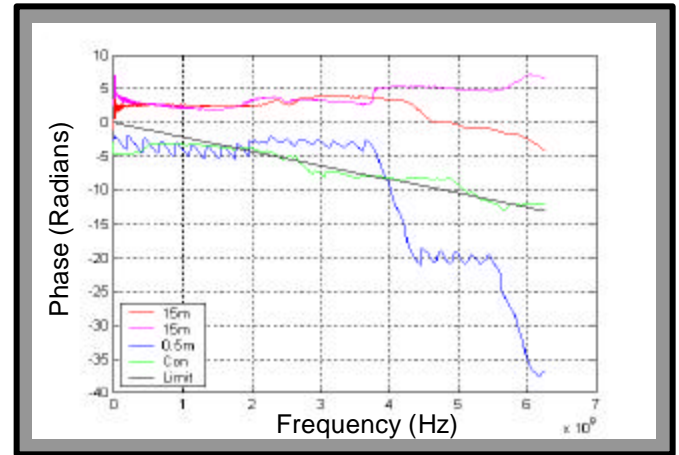
Connector Next Response



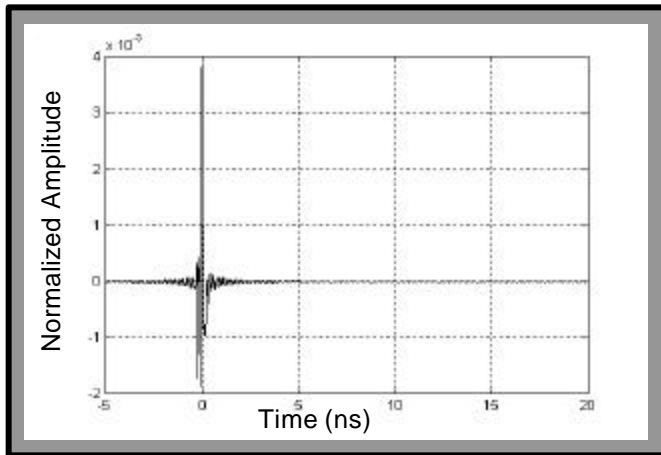
Next Model



Magnitude Response



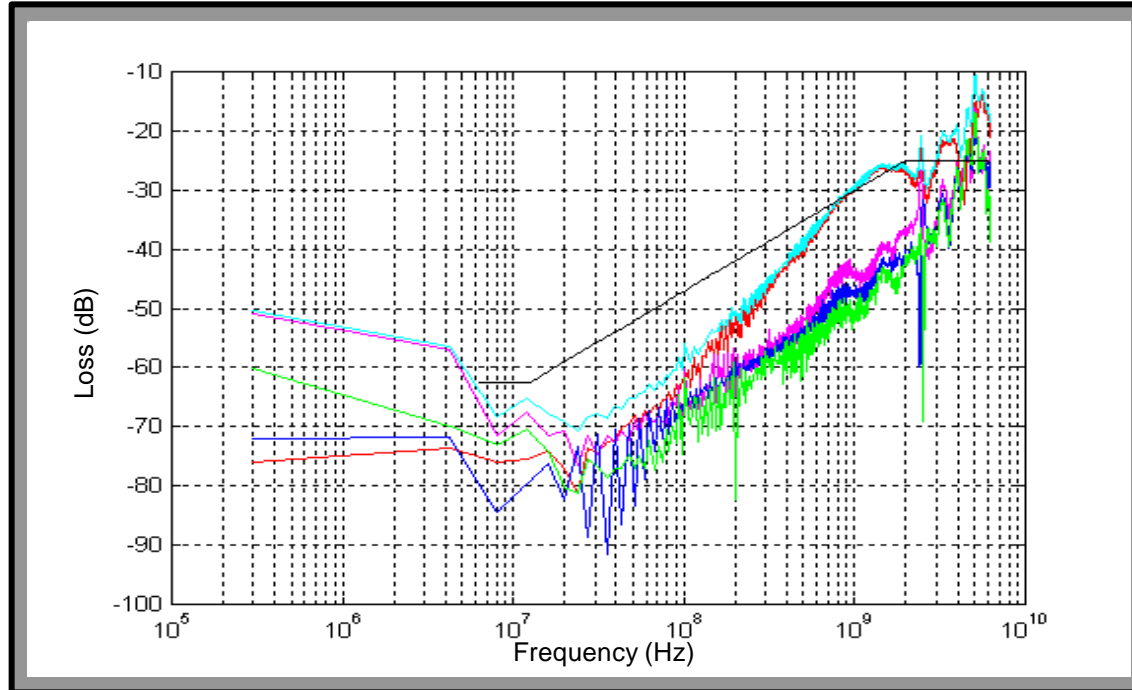
Phase Response



Impulse Response



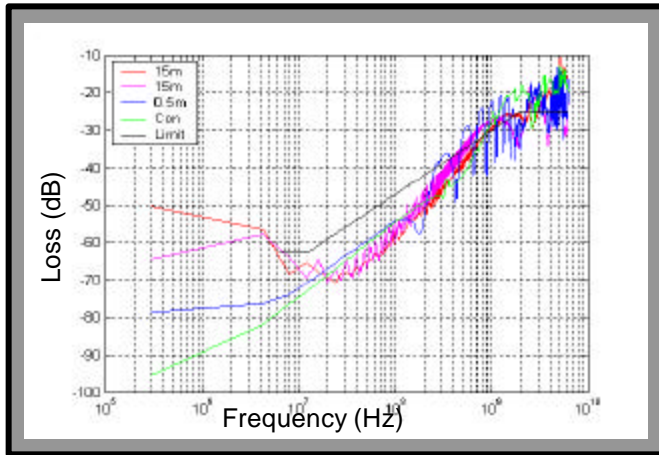
MDNext Calculation (15m)



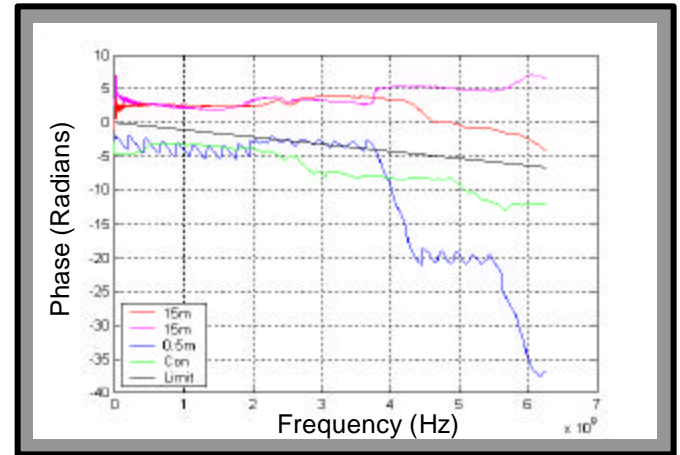
Limit $\leq 25 - 17 \times \log_{10}(\text{Freq}/2000)$

MDNext = $10 \times \log_{10}(|\text{Next3}|^2 + |\text{Next2}|^2 + |\text{Next1}|^2 + |\text{Next0}|^2)$

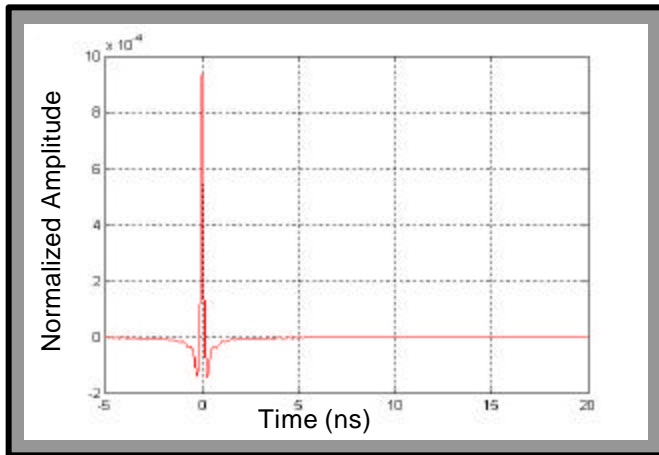
MDNext Model



Magnitude Response



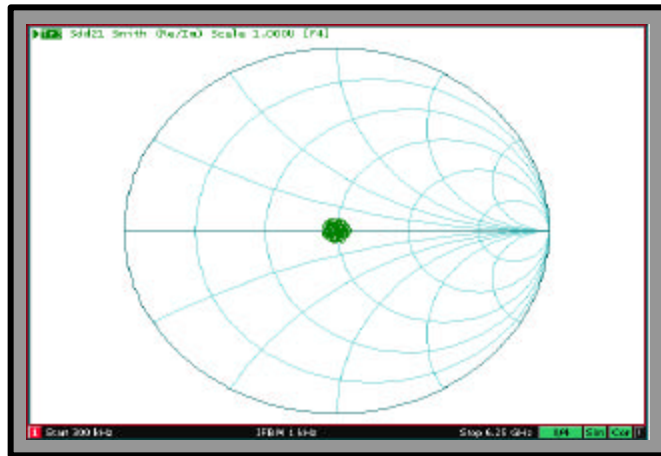
Phase Response



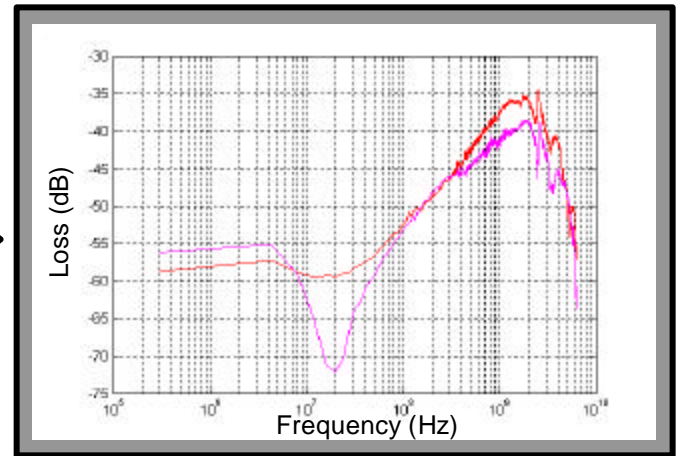
Impulse Response



15m Cable Assembly Fext

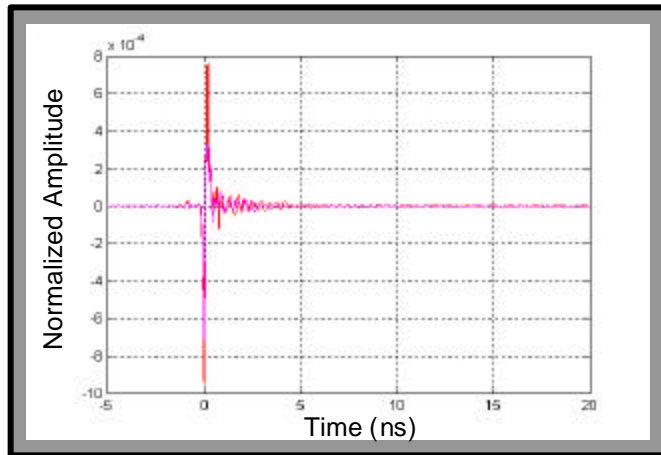


MATLAB
rect 2 polar

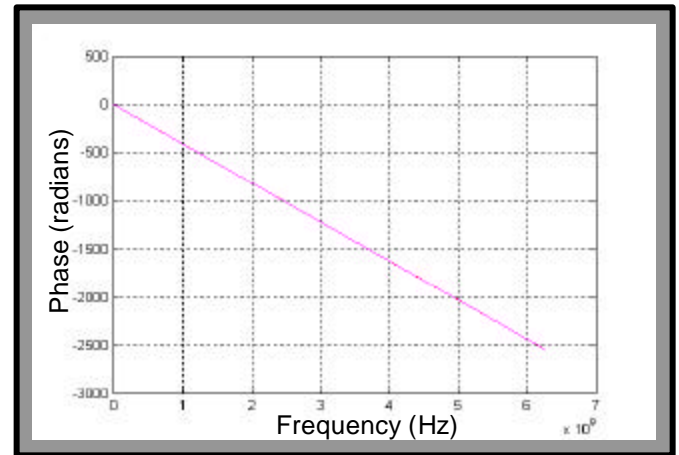


Magnitude Response

MATLAB IFFT



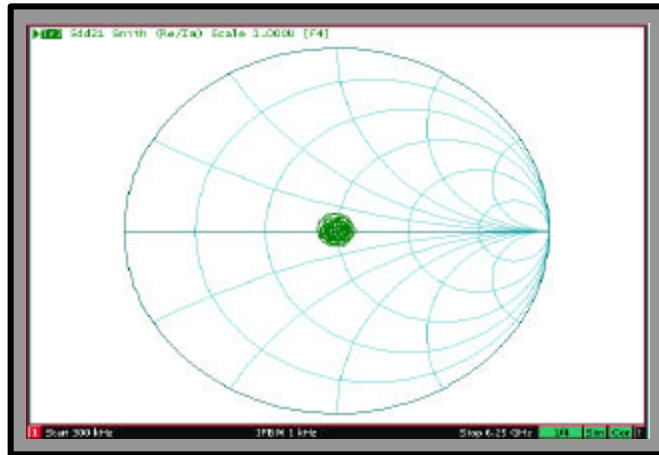
Impulse Response



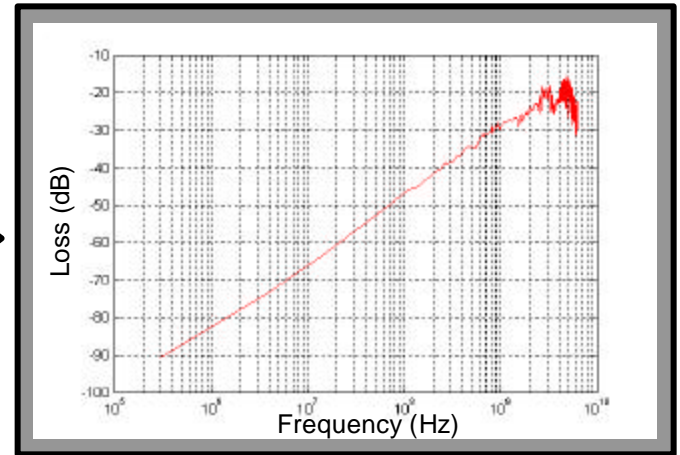
Phase Response



0.5m Cable Assembly Fext

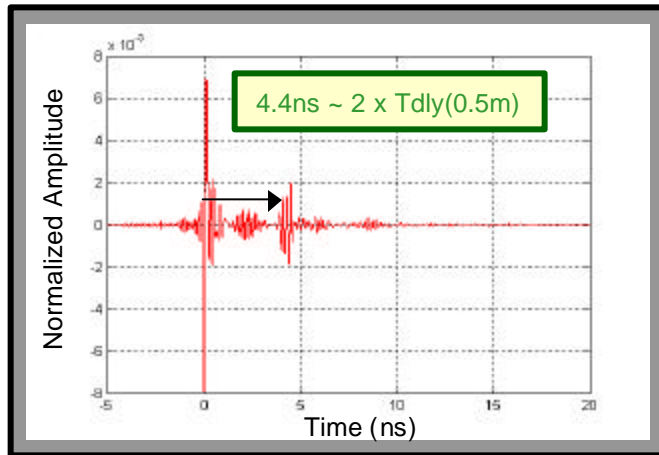


MATLAB
rect 2 polar

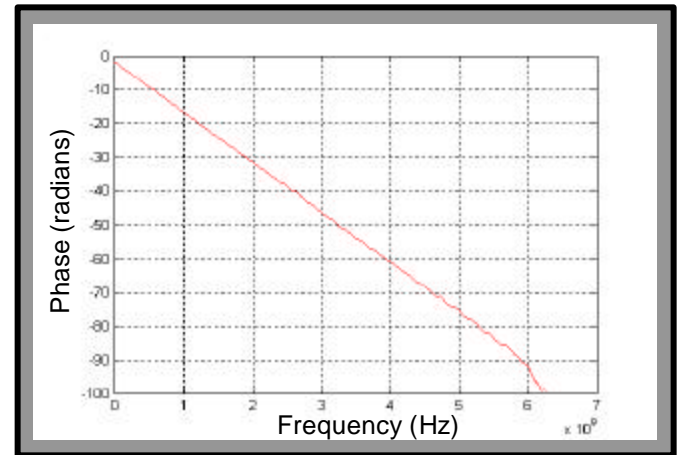
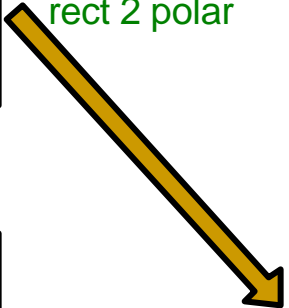


Magnitude Response

MATLAB IFFT



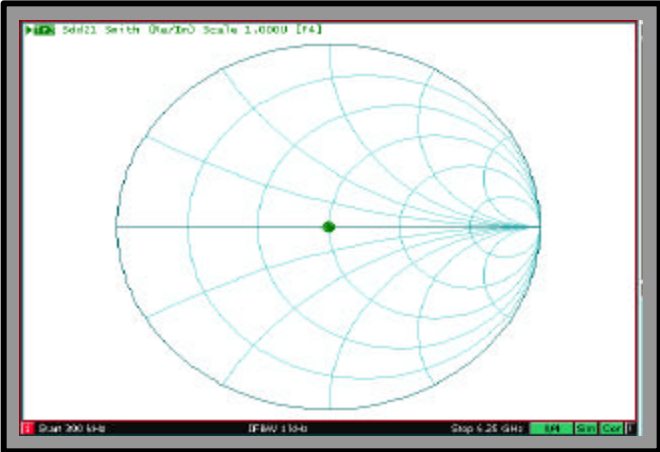
Impulse Response



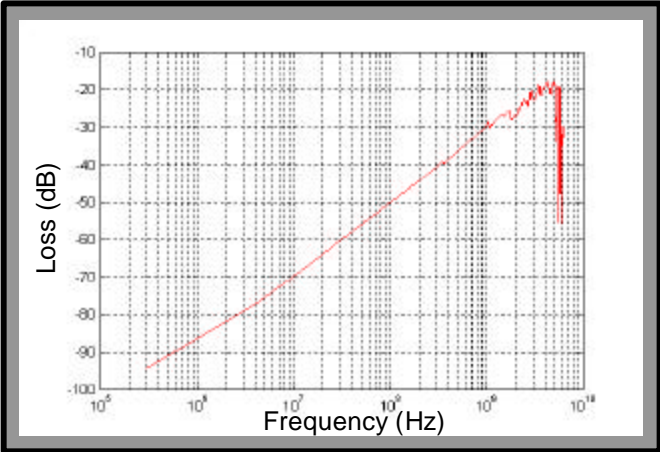
Phase Response



Connector Fext

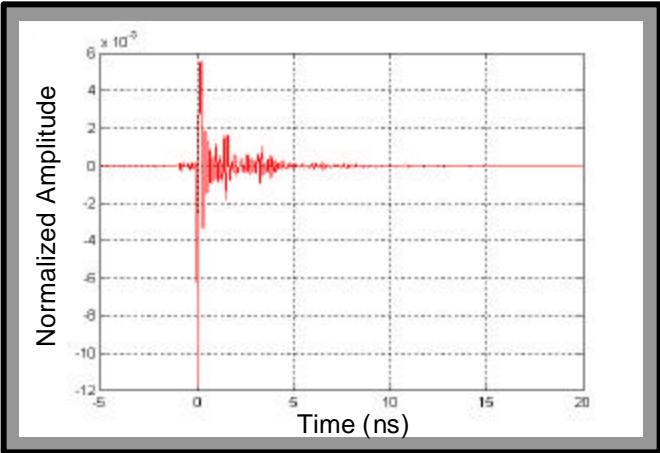


MATLAB
rect 2 polar

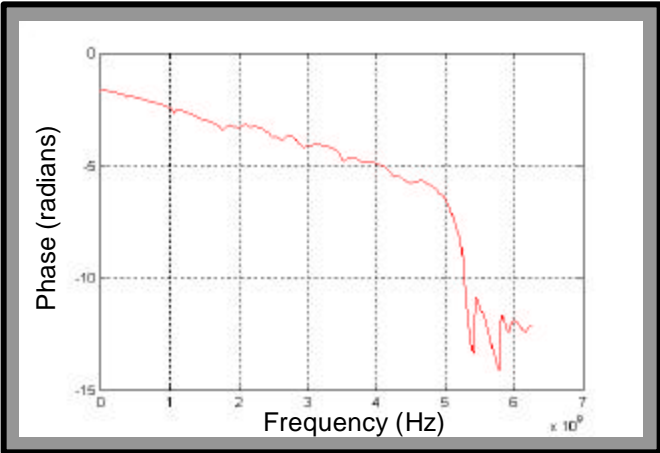
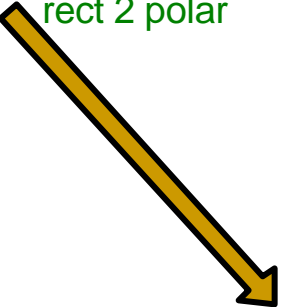


Magnitude Response

MATLAB IFFT



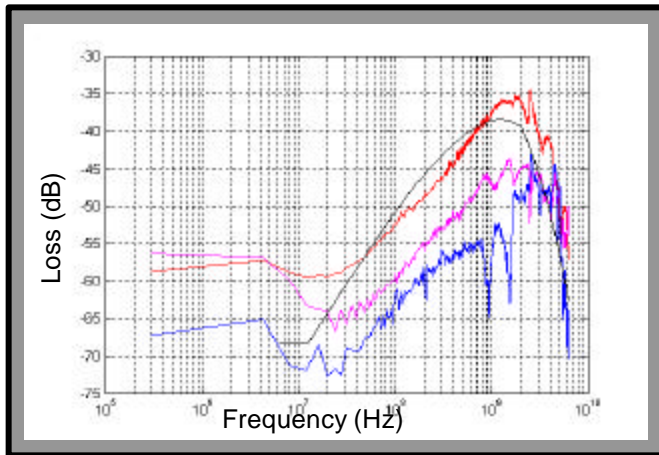
Impulse Response



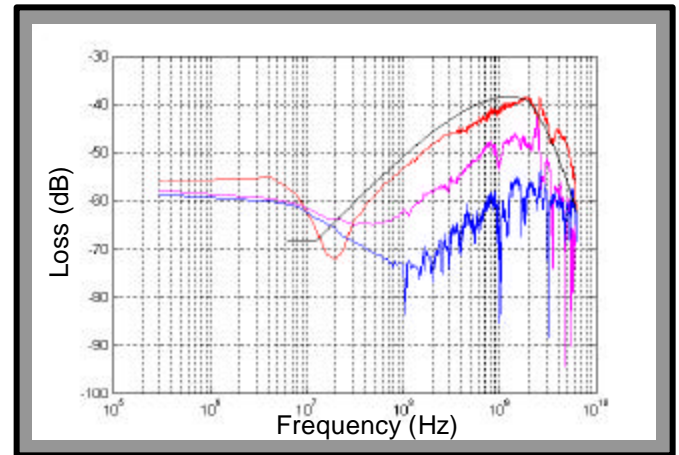
Phase Response



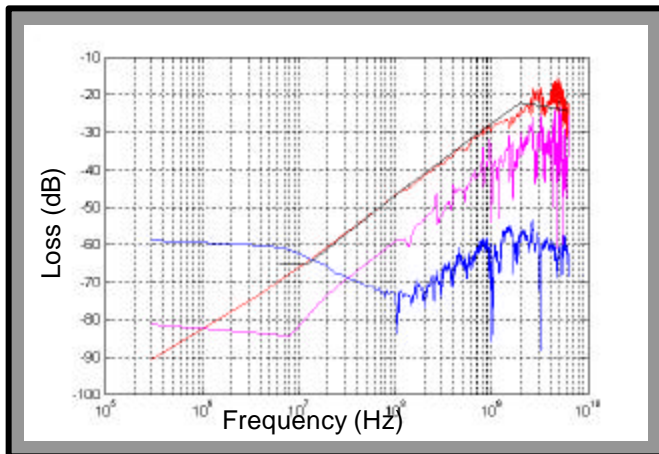
Fext Summary



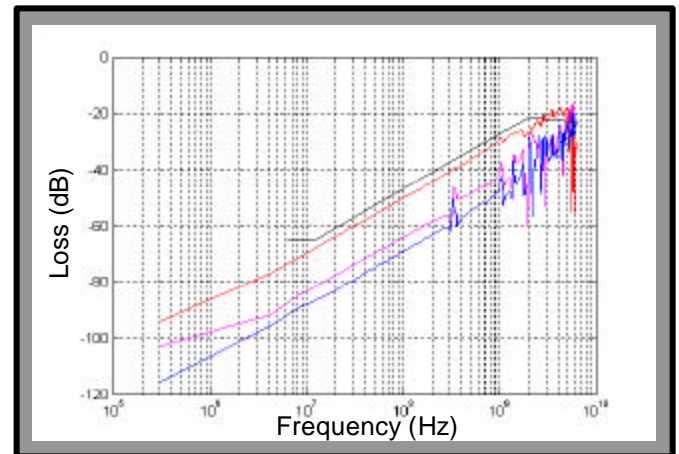
15m Fext Response



15m Fext Response



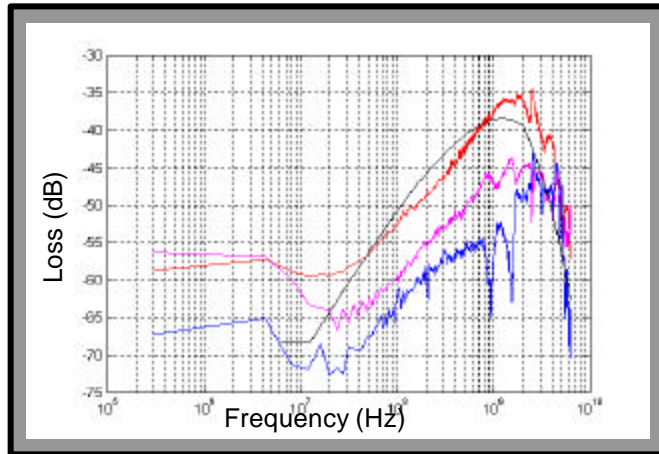
0.5m Fext Response



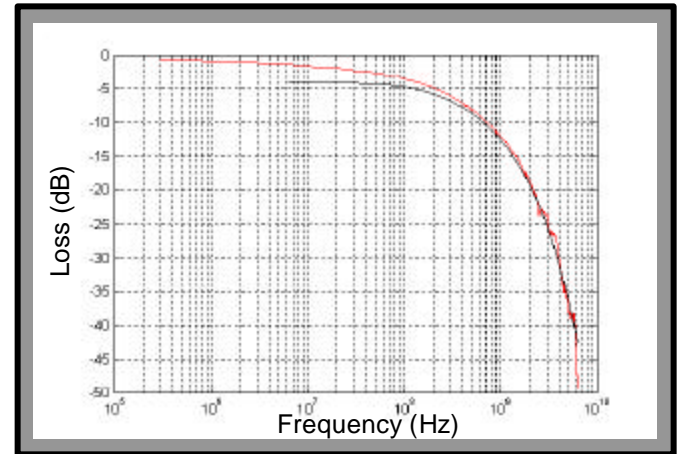
Connector Fext Response



15m ELFext Calculation



Fext Response

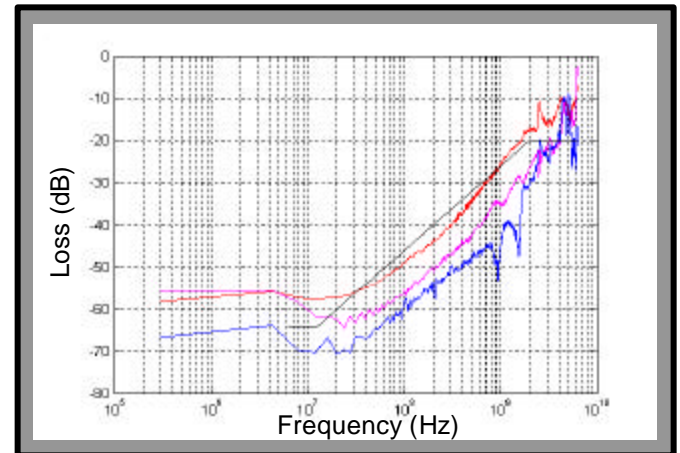


Insertion Loss



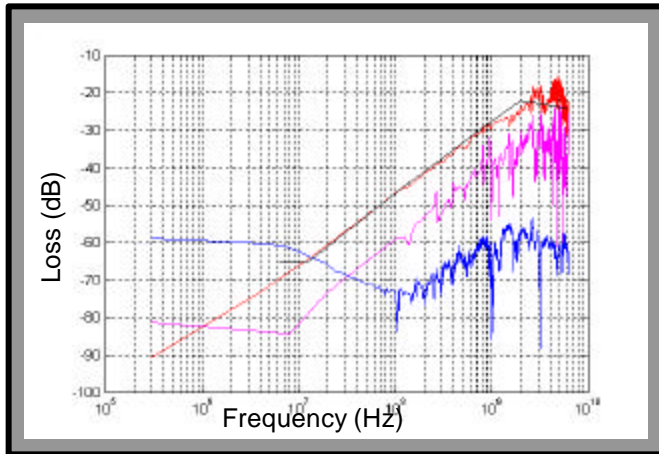
$$\text{ELFext} = \text{Fext} / \text{InsertionLoss}$$

Fext and Insertion Loss as complex numbers in the frequency domain

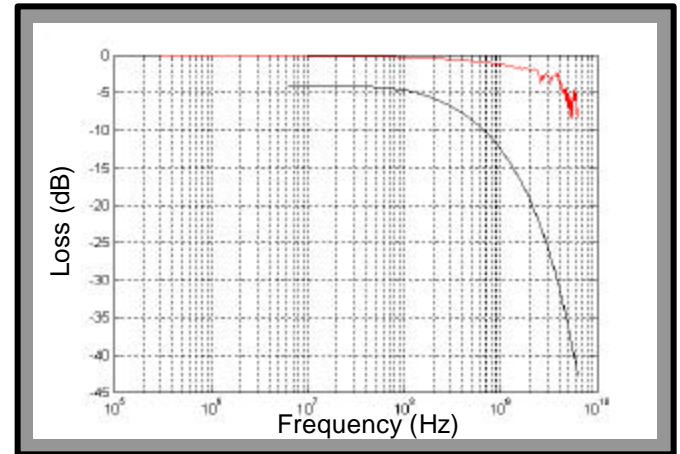


ELFext Response

0.5m ELFext Calculation



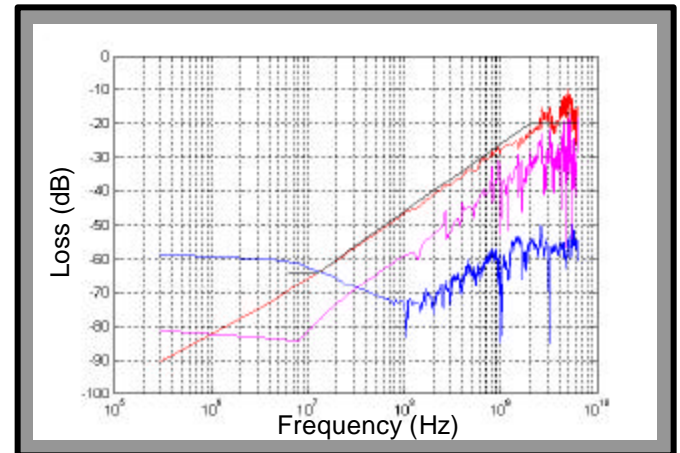
Fext Response



Insertion Loss

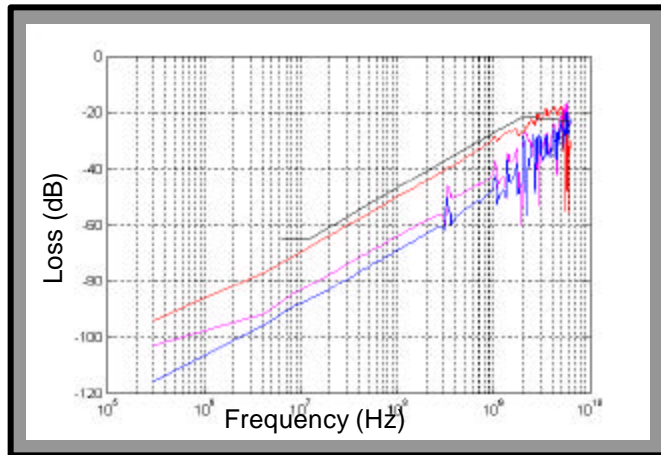
$$\text{ELFext} = \text{Fext} / \text{InsertionLoss}$$

Fext and Insertion Loss as complex numbers in the frequency domain

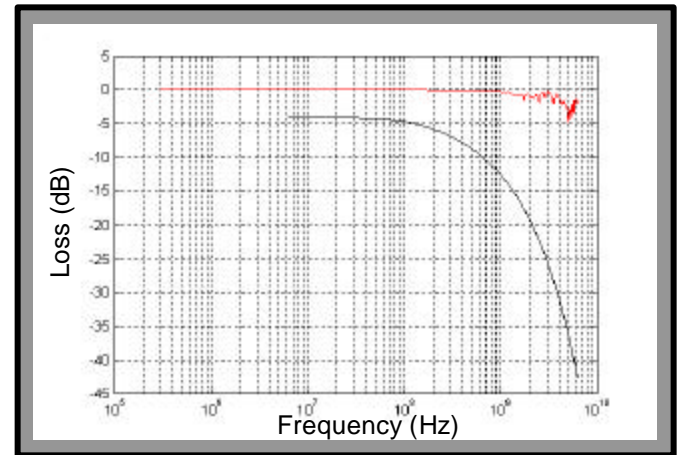


ELFext Response

Connector ELFext Calculation



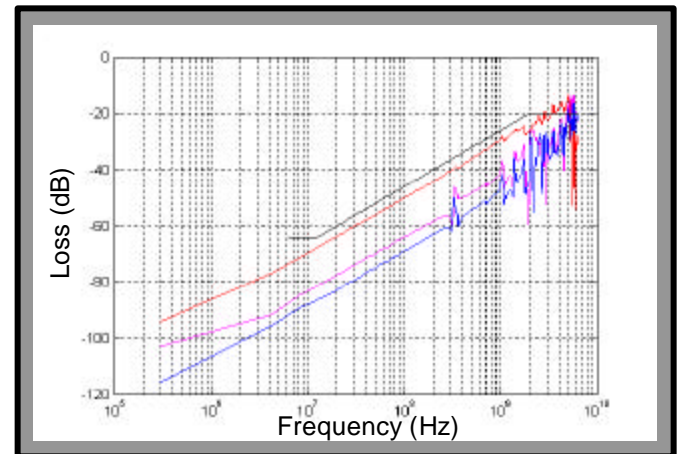
Fext Response



Insertion Loss

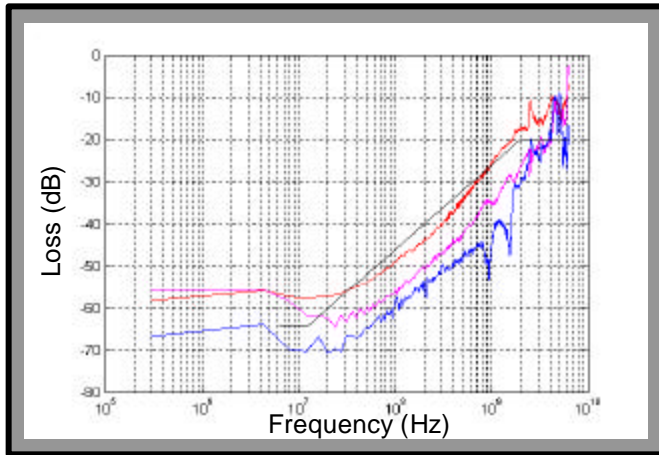


$ELFext = Fext / InsertionLoss$
Fext and Insertion Loss as complex numbers in the frequency domain

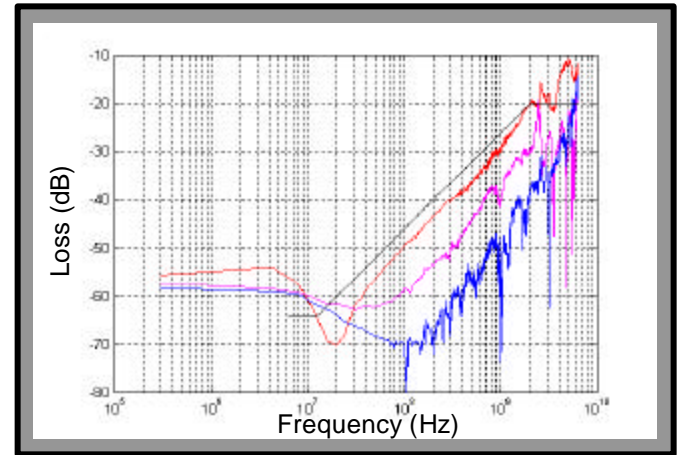


ELFext Response

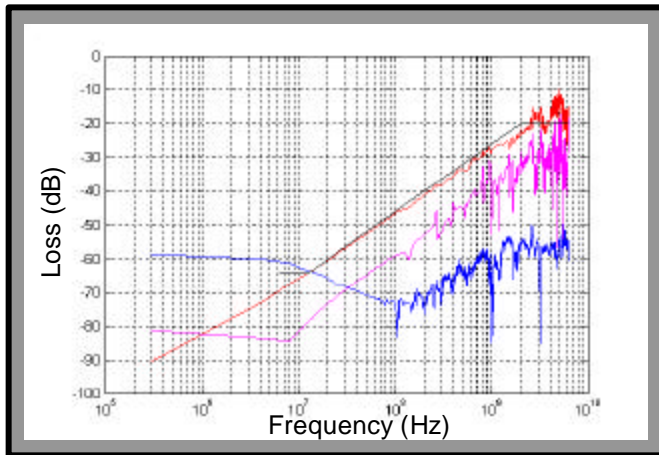
ELFext Summary



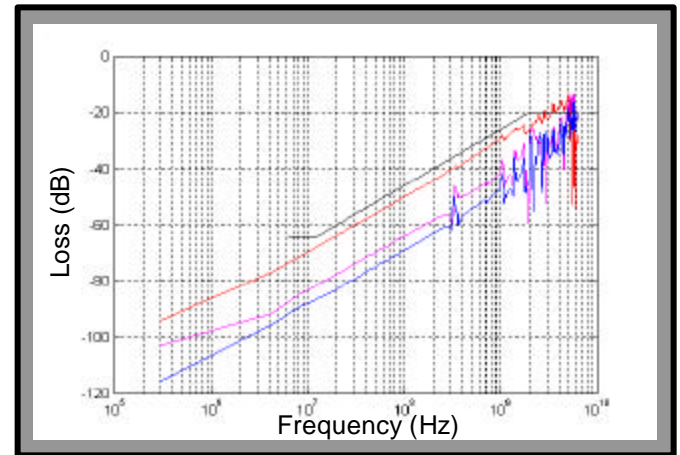
15m ELFext Response



15m ELFext Response



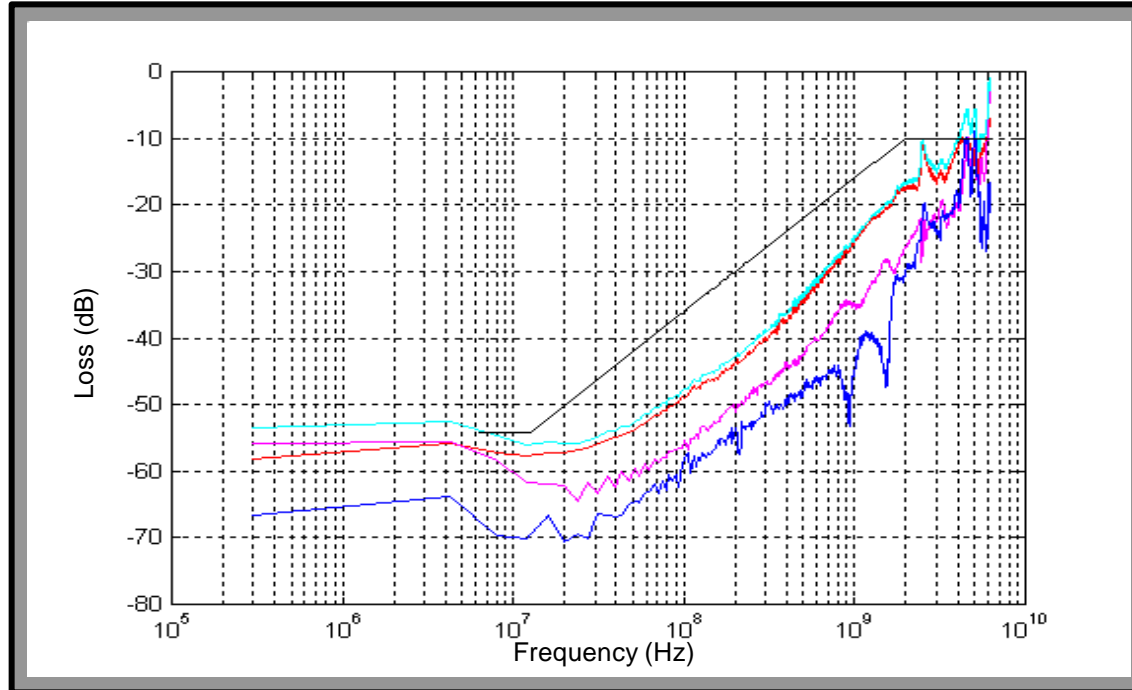
0.5m ELFext Response



Connector ELFext Response



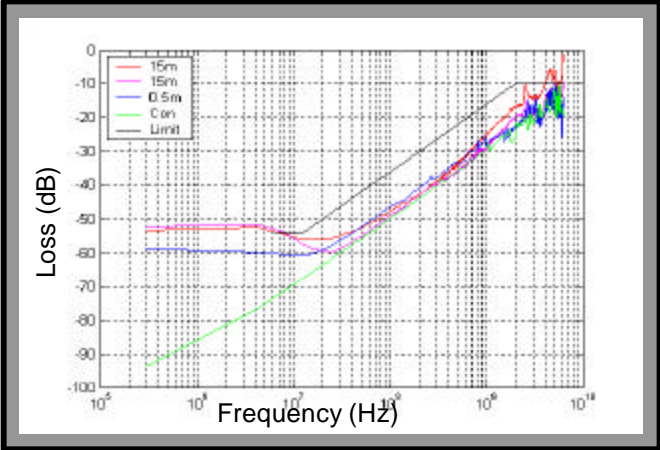
MDEL Fext Calculation (15m)



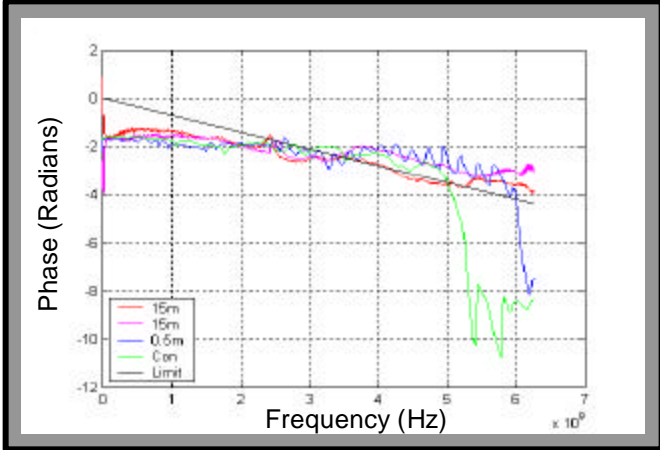
Limit $\leq 18 - 20 \times \log_{10}(\text{Freq}/2000)$

MDEL Fext = $10 \times \log_{10}(|\text{ELFext2}|^2 + |\text{ELFext1}|^2 + |\text{ELFext0}|^2)$

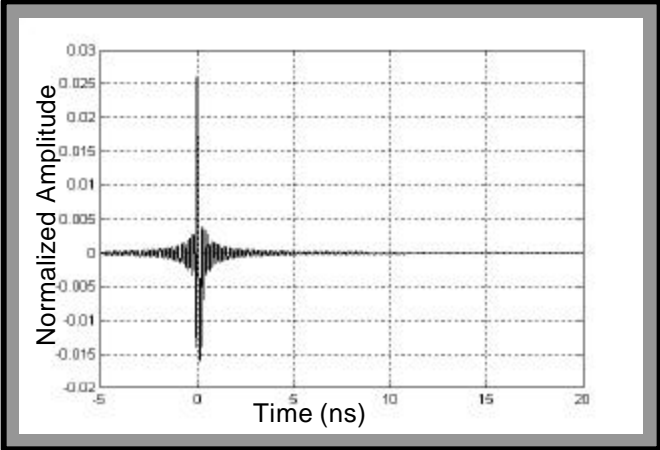
MDELFext Model



Magnitude Response



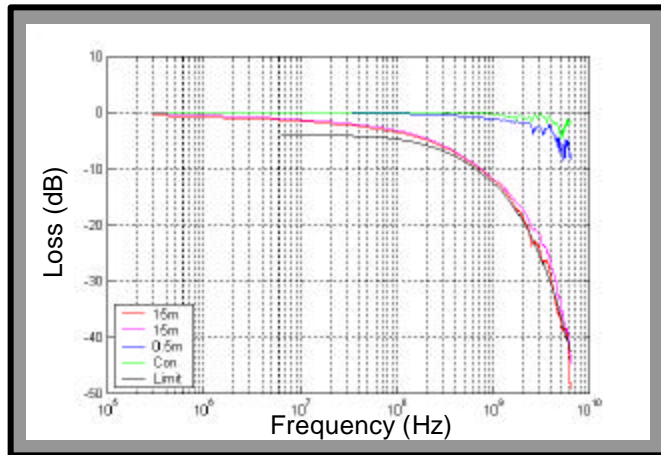
Phase Response



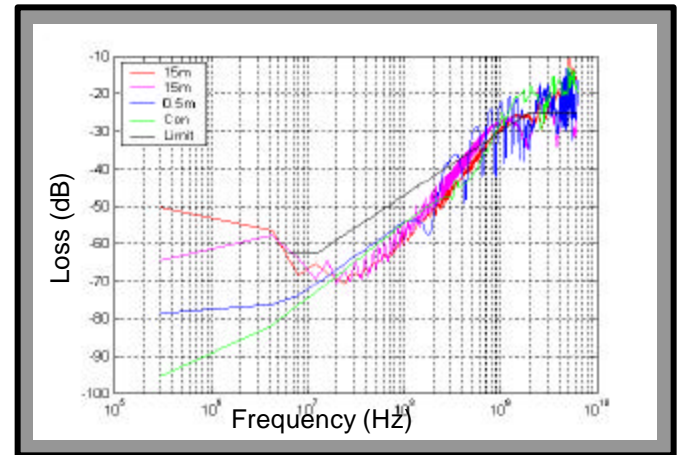
Impulse Response



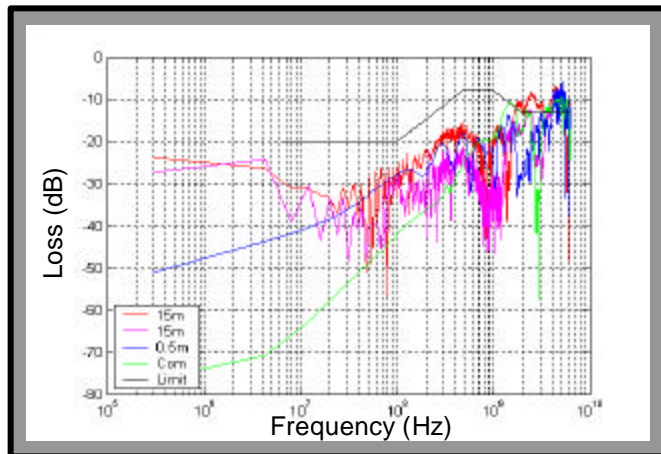
Cable Assembly Summary



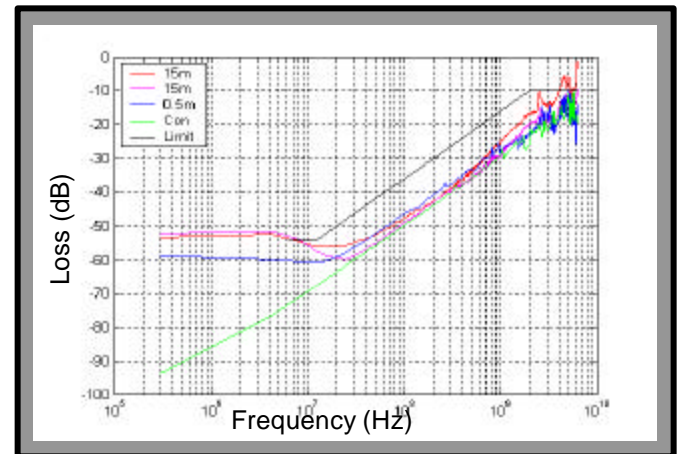
Insertion Loss



MDNext



Return Loss



MDELFext

