PAM4 MODULATION FOR THE 400G ELECTRICAL INTERFACE

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IEEE 802 July 2014 Plenary
San Diego, CA

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- Scott Powell, Clariphy
- Howard Frazier, Broadcom
- Vasu Parthasarathy, Broadcom
- Will Bliss, Broadcom

INTRODUCTION

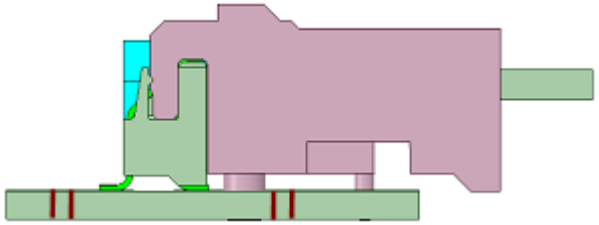
- **Scenario**
  - Data rate: 50Gbps
  - Transcoding: 64/66
  - Signaling: PAM4
  - Signaling rate: 25.78125Gsps
- **Targets**
  - Low power scheme
  - Extendable to higher loss channels
- **Analysis**
  - Uncoded performance (no FEC)

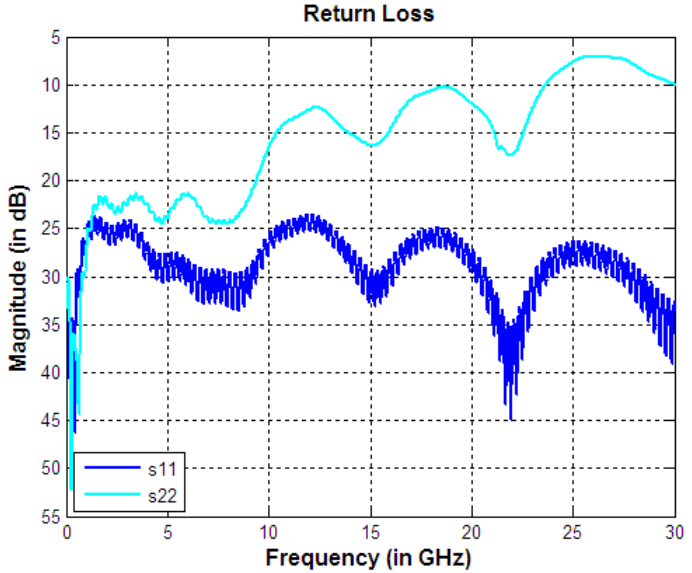
CHANNELS

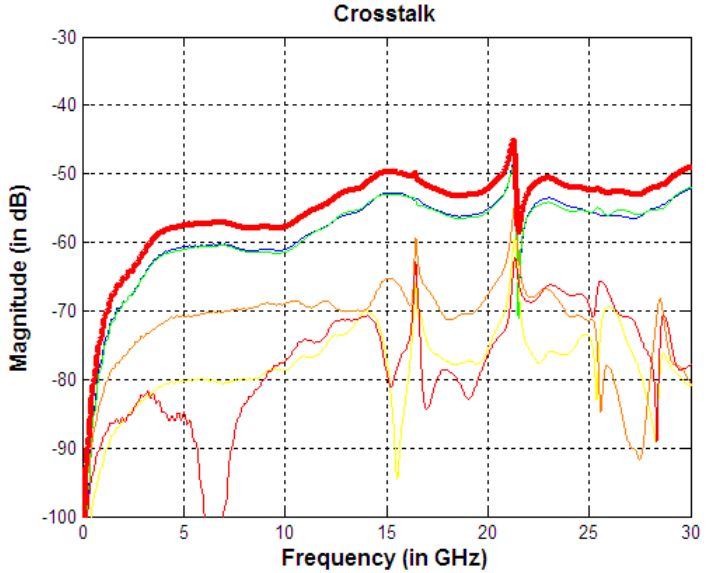
- **Source**
  - OIF 2014.142.00 (56G VSR)
  - Nathan Tracy, TE Connectivity
- **Channel 1**
  - Next generation 28Gbps high density SMT IO
  - IL: 9.2dB loss @14GHz
  - XT: 5 FEXT, 0 NEXT
- **Channel 2**
  - Next generation 28Gbps press-fit stacked IO
  - IL: 9.1dB loss @14GHz
  - XT: 11 FEXT, 0 NEXT

HIGH DENSITY SMT IO CHANNEL

- **Host PCB**
  - 2.86mm thick, 23 Layers(12 GND planes)
  - 2 Layer route out (Layer 10,12)
  - Nelco 4000-13SI Material (Dk=3.32, Loss Tangent=0.010)
  - 8mil stub on signal vias
  - 7.3 dB stripline trace loss added

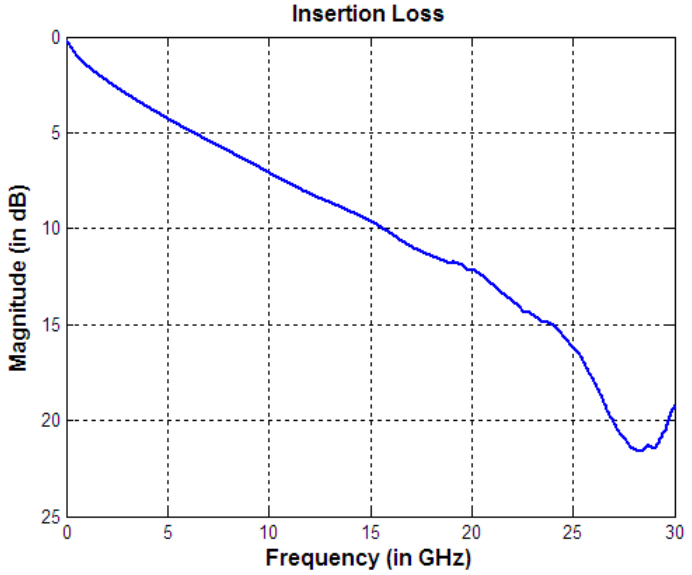




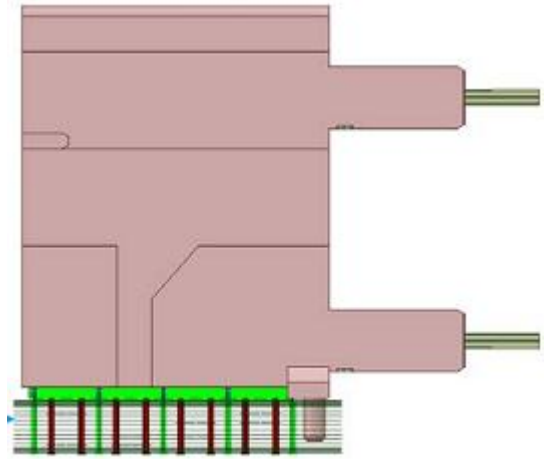


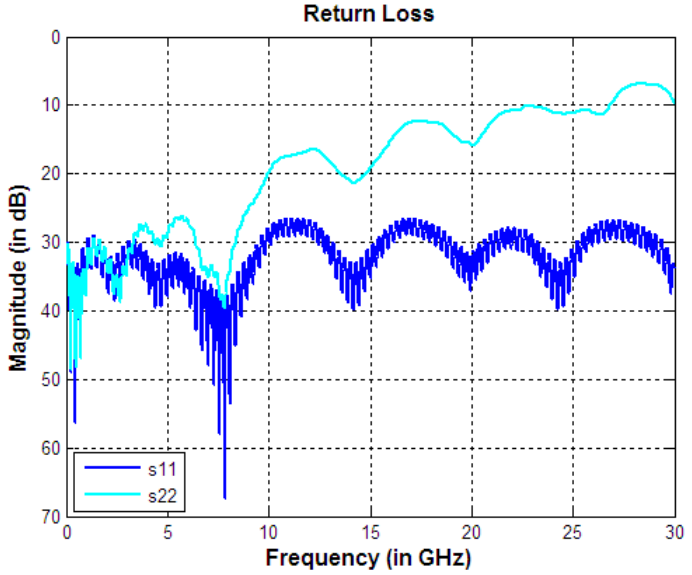
- **Module PCB details**
  - 1mm thick, 6 layer PCB (4 GND Planes)
  - Microstrip trace route-out from 0.35x1.4mm mating pads
  - Nelco 4000-13SI Material (Dk=3.32, Loss Tangent=0.010)
  - 1.2 dB microstrip trace loss added

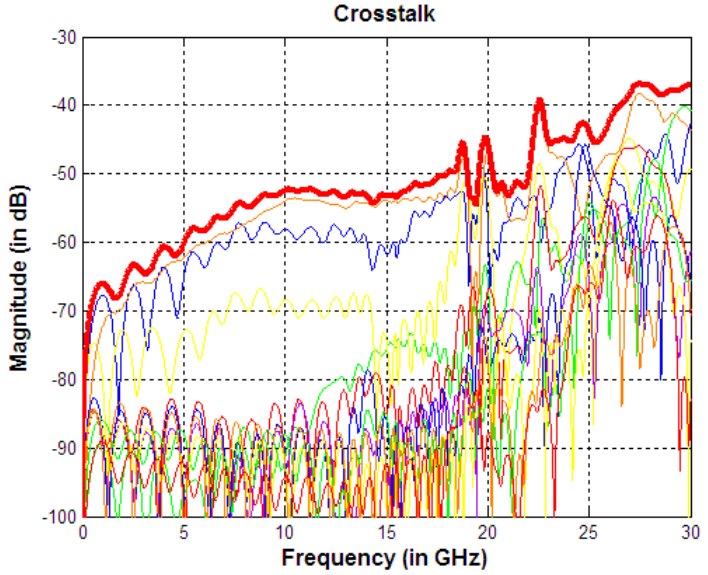
PRESS-FIT STACKED IO CHANNEL



- **Host PCB**
  - 3.425mm thick, 26 Layers (15 GND Planes)
  - 4 Layer route-out (Layers 7, 11, 17, 21)
  - EM-888 Material (Dk=3.8, Loss Tangent=0.012)
  - 8mil stub on signal vias
  - 7.3 dB stripline trace loss added





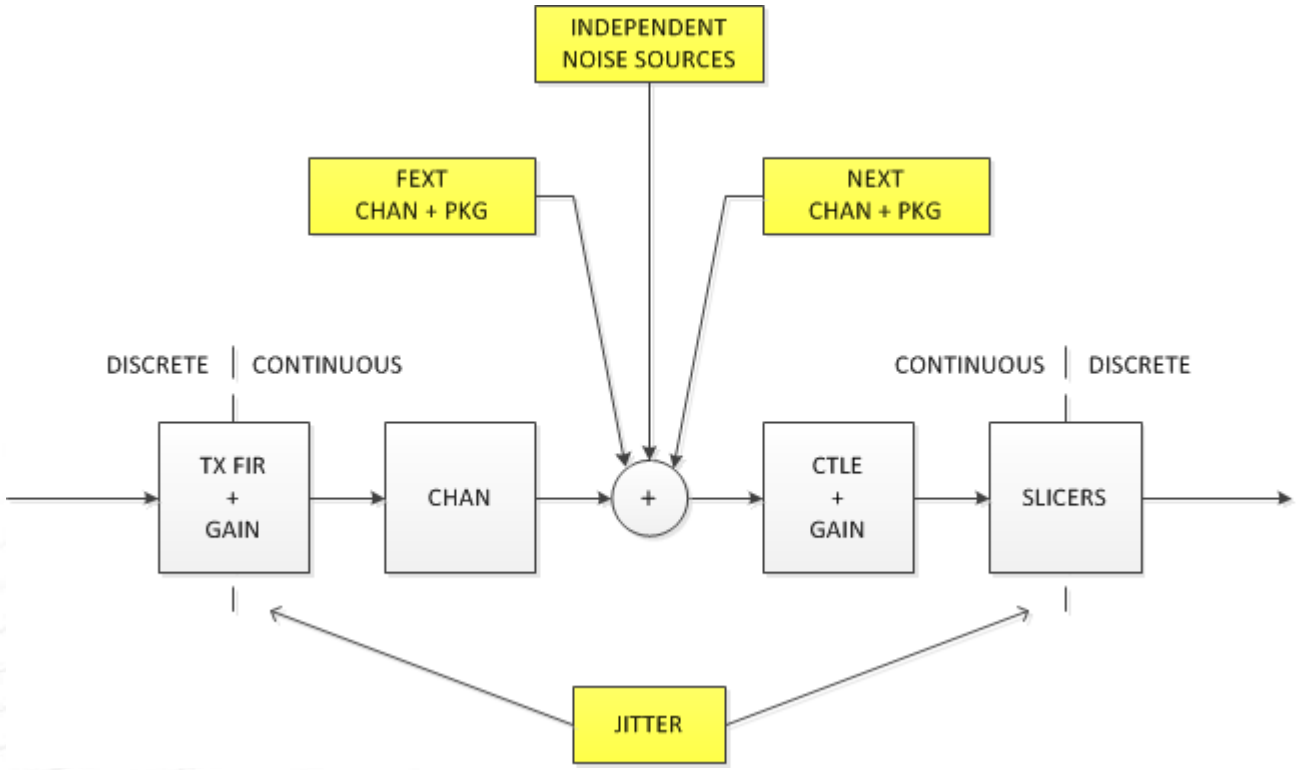


- **Module PCB details**
  - 1mm thick, 6 layer PCB (4 GND Planes)
  - Microstrip trace route-out from 0.35x1.4mm mating pads
  - Nelco 4000-13SI Material (Dk=3.32, Loss Tangent=0.010)
  - 1.2 dB microstrip trace loss added

oif2014.142.00, Nathan Tracy, TE Connectivity, Berlin, May 2014

TRANSCEIVER STRUCTURE

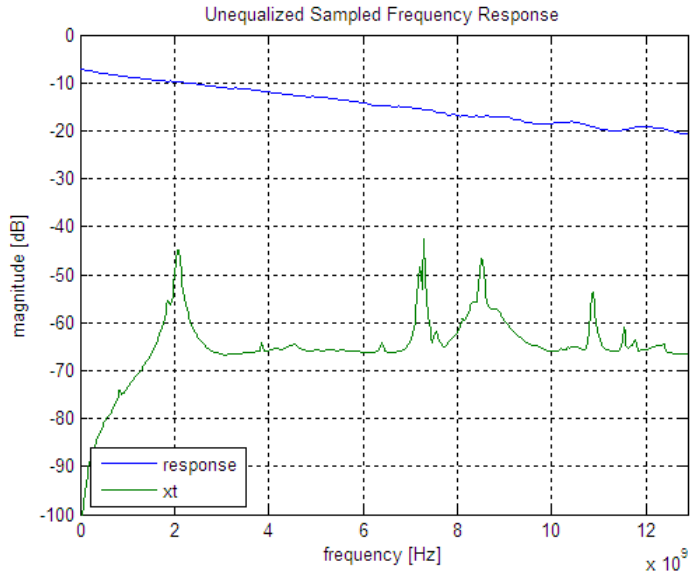
- **Signaling: PAM4**
- **Signaling rate: 25.78125Gsps**
- **No coding**
- **CTLE**
  - 2 real zeros
  - 2 real poles @ 25GHz
- **TXFIR**
  - Option 1: 3 coefs, 1 pre, 1 post
  - Option 2: 5 coefs, 1 pre, 3 post

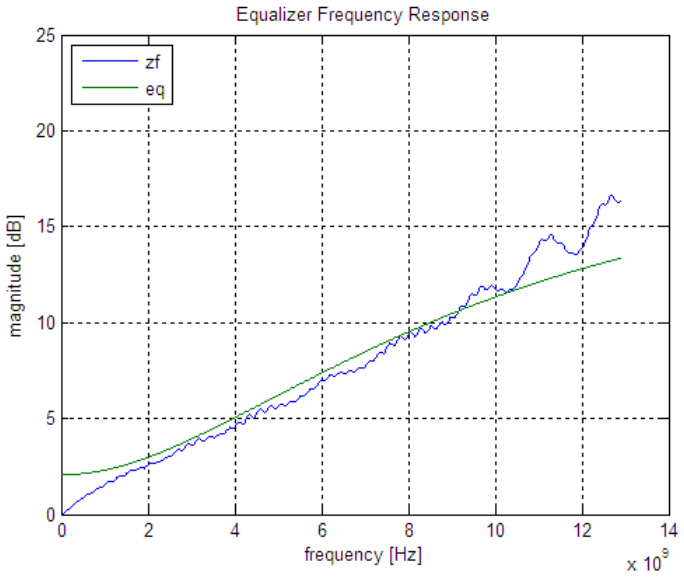


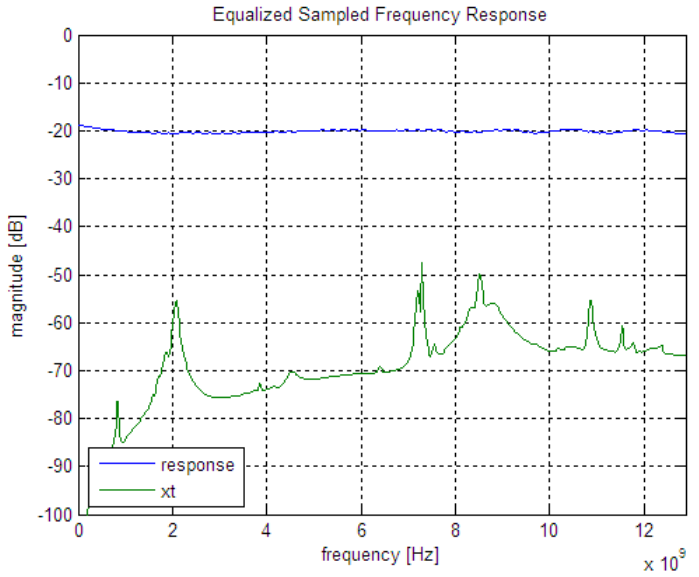
TRANSCEIVER NOISES

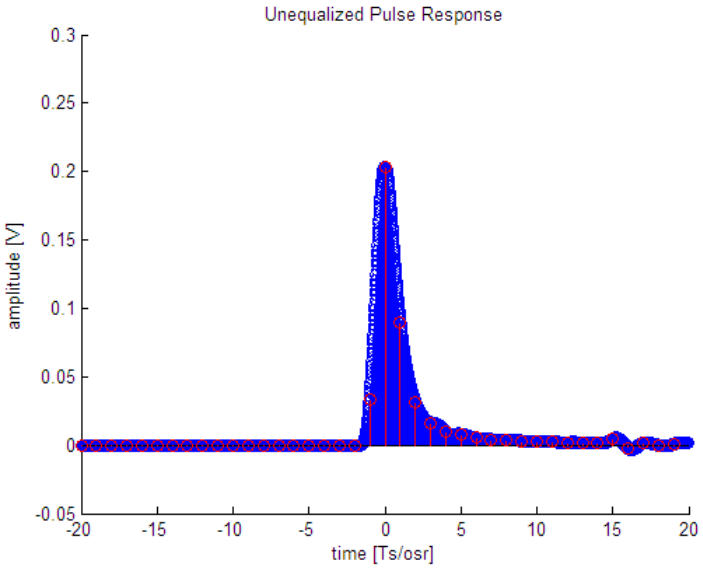
- **Analog IO signal models based on existing 28nm, 25G NRZ design**
- **Package XT models based on existing 28nm, 25G NRZ design**
- **Aggressors assumed filtered by same TX FIR as victim**
- **RX input referred white noise -155dBm/Hz (~1.6mV rms)**
- **Slicer offset ~±2%**
- **Jitter ~0.2UI p2p**
  - TX, RX, and CDR

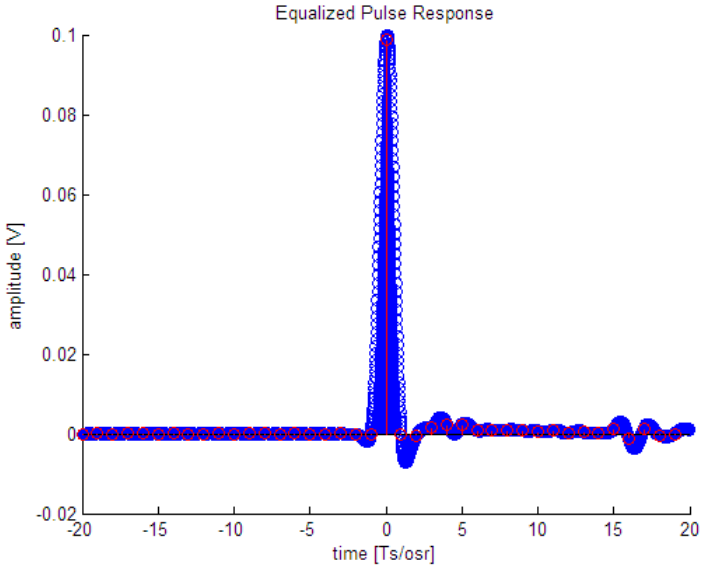
OIF2014.149.01, 9.2DB, 5 FEXT – 3-TAP TX FIR

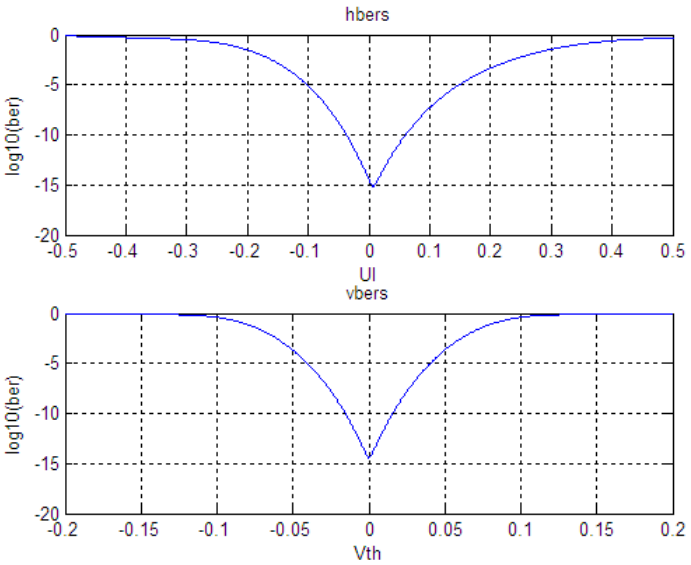






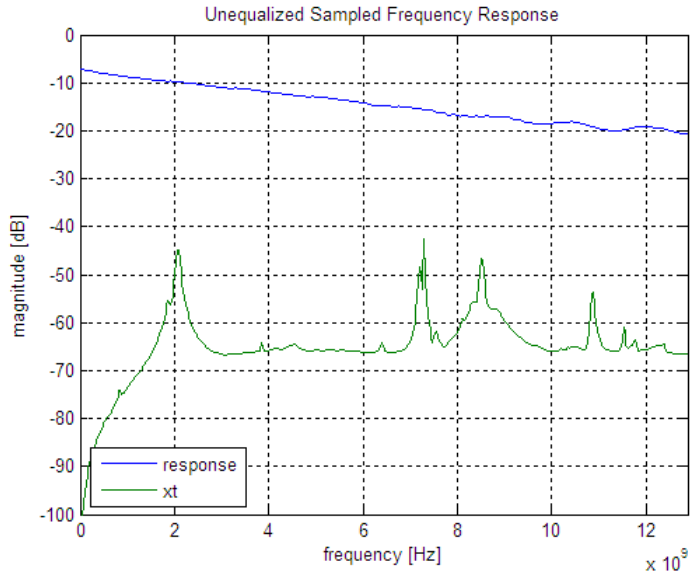


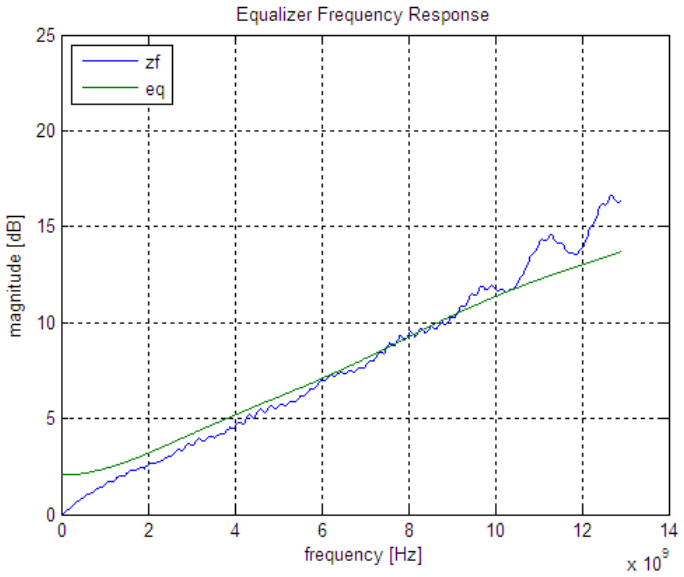


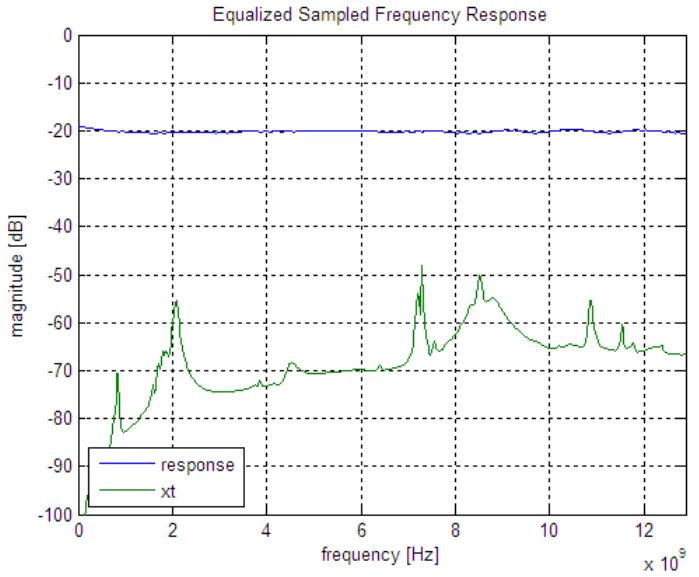


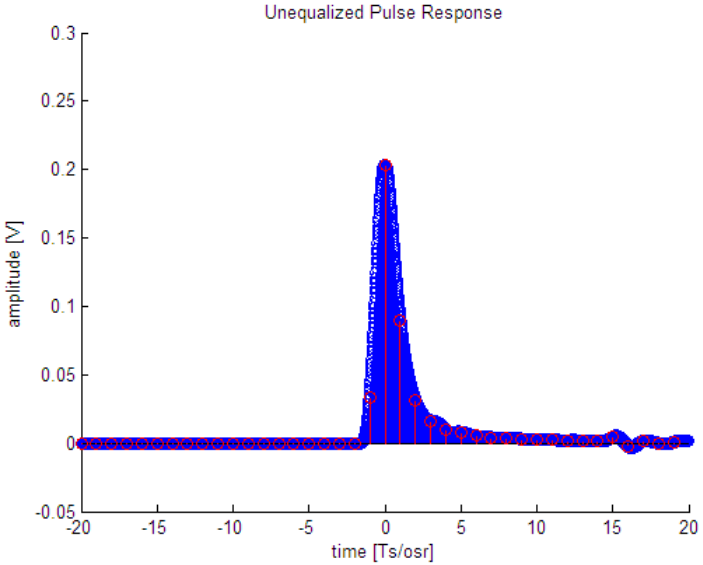
Normalized to an ideal eye opening of [-0.1,0.1])

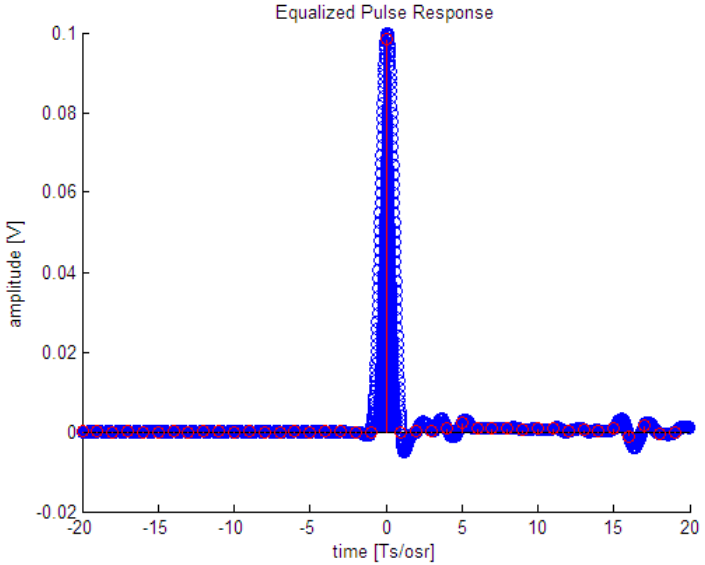
OIF2014.149.01, 9.2DB, 5 FEXT – 5-TAP TX FIR

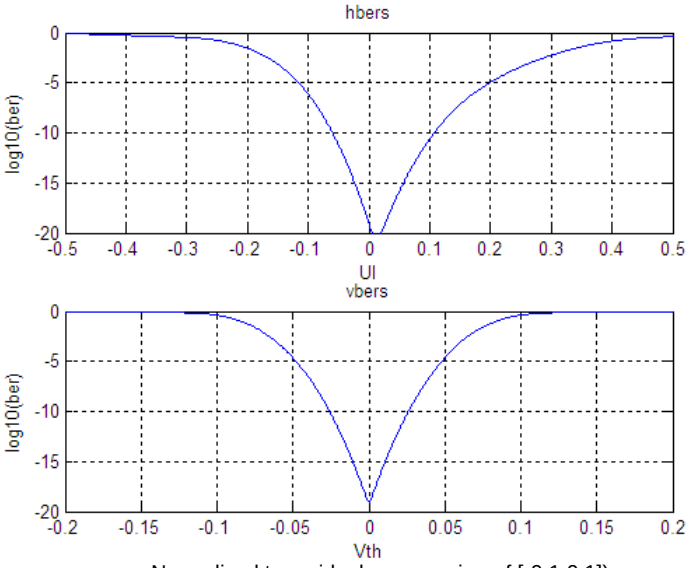












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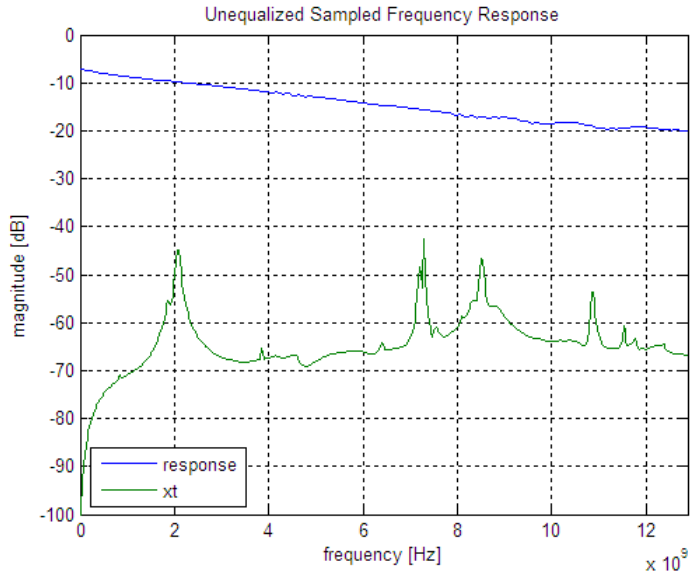
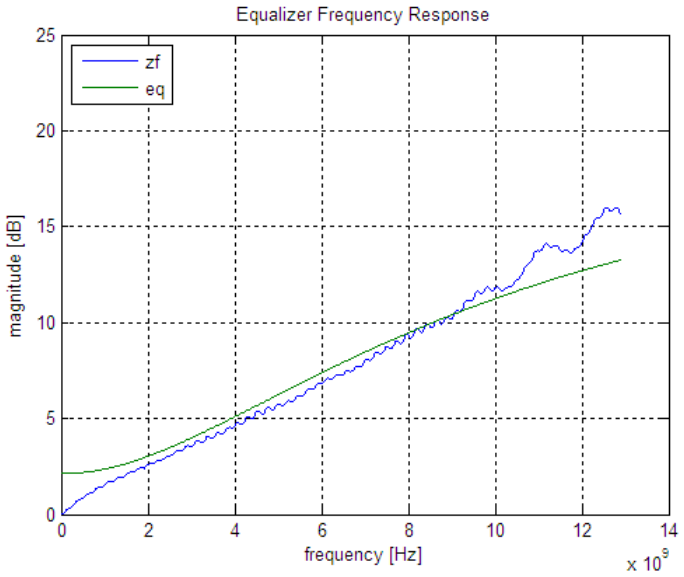
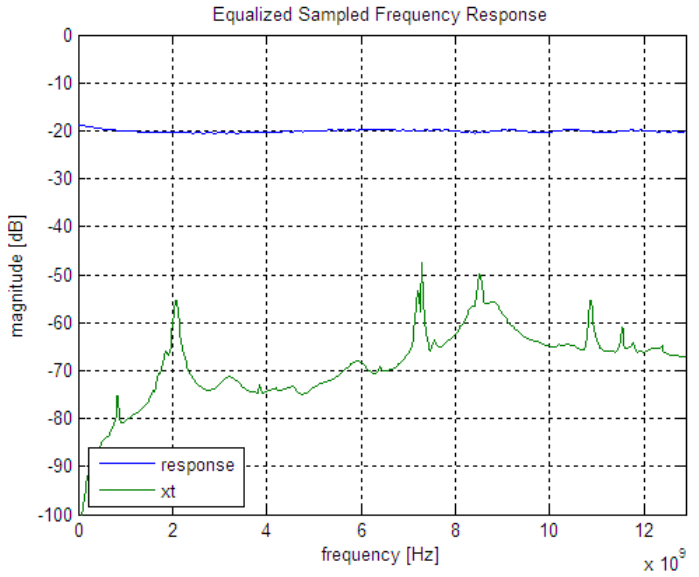
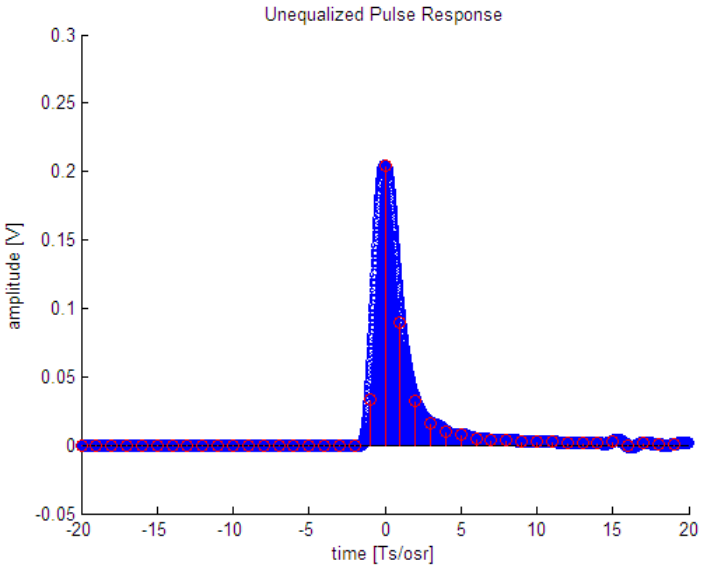
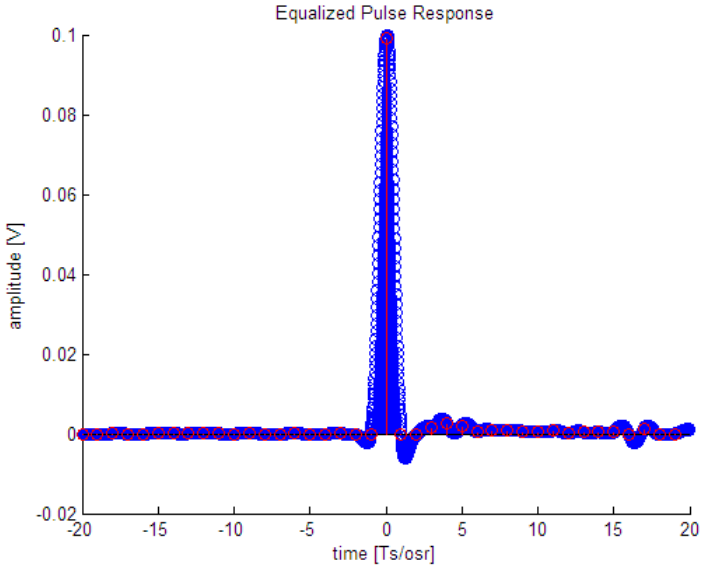
OIF2014.150.00, 9.1DB, 11 FEXT – 3-TAP TX FIR

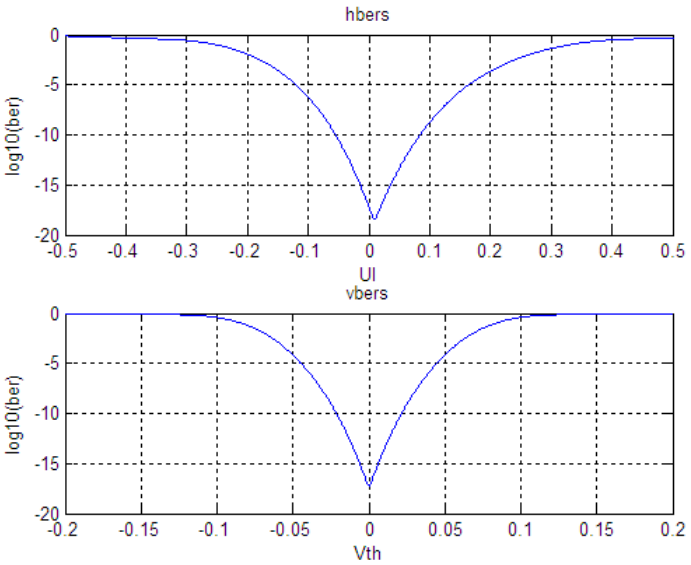












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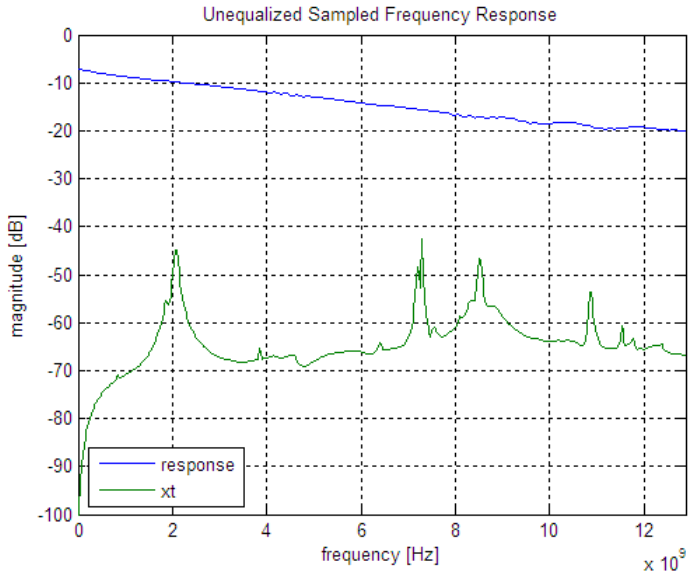
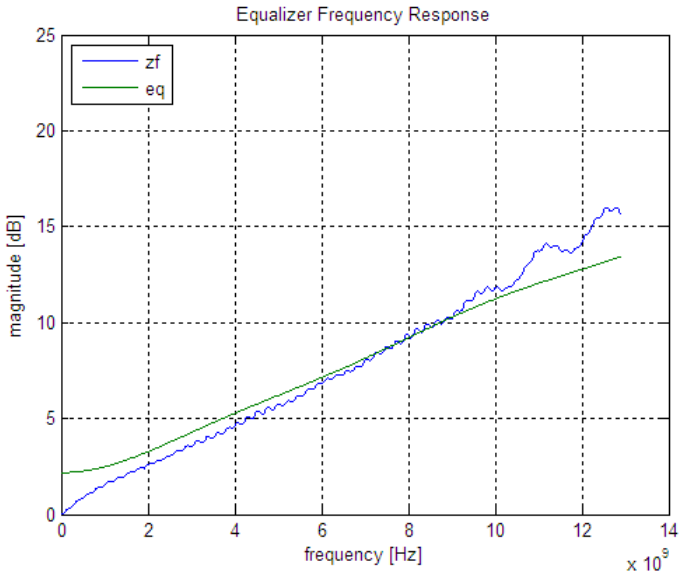
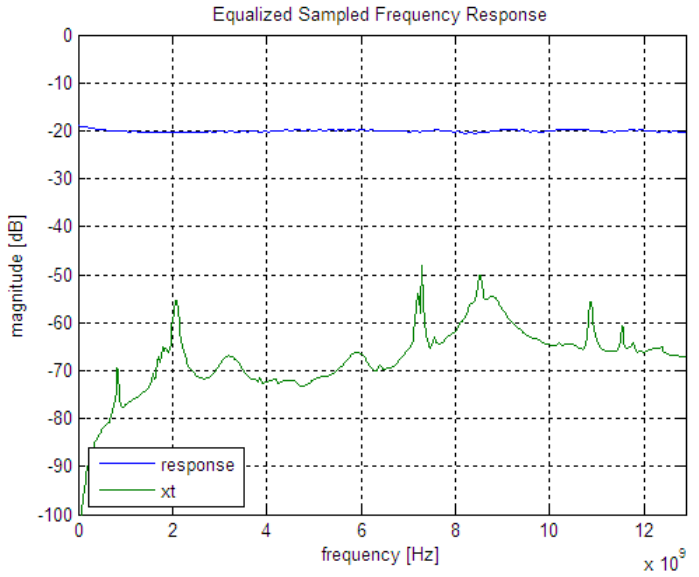
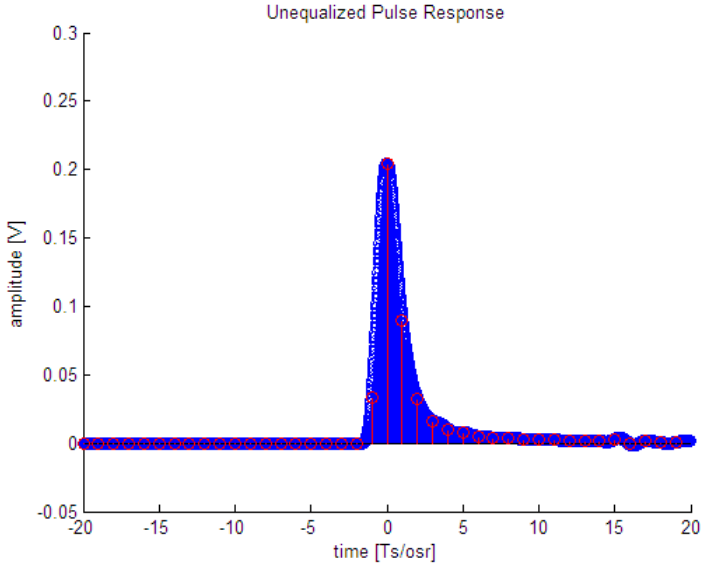
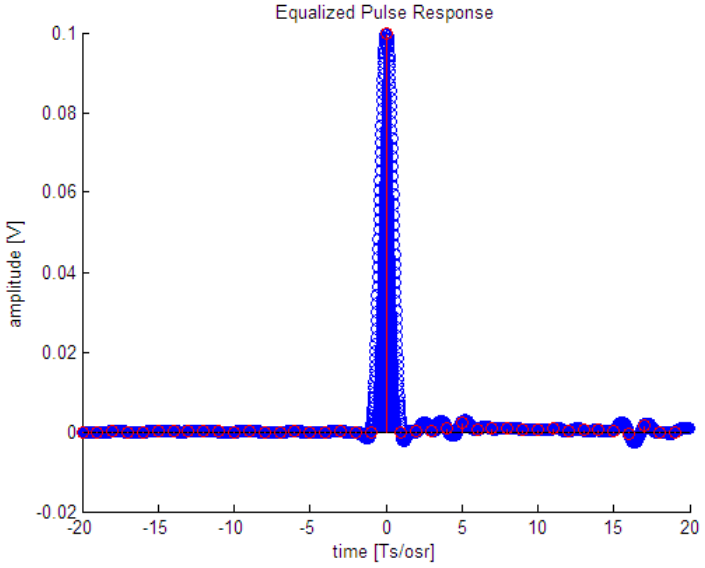
OIF2014.150.00, 9.1DB, 11 FEXT – 5-TAP TX FIR

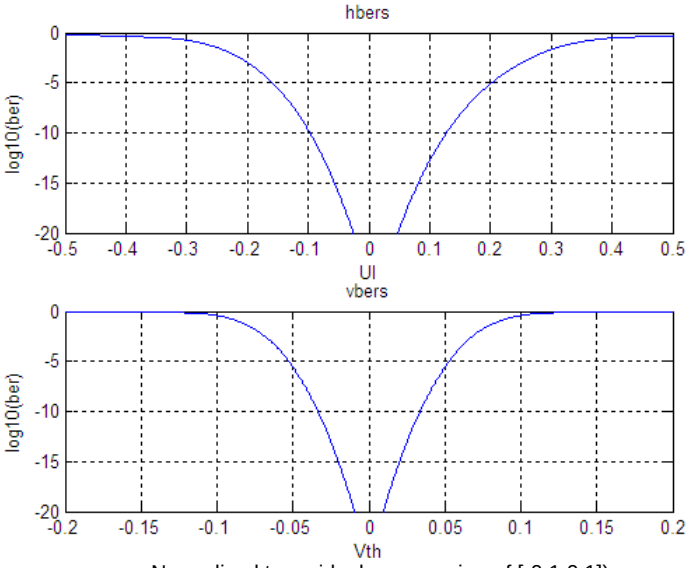












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RESULTS

Channel	BER	
	3-tap Tx FIR	5-tap Tx FIR
OIF2014.149.01, 9.2dB IL, 5 FEXTs	$4x10^{-15}$	$9x10^{-20}$
OIF2014.150.00, 9.1dB IL, 11 FEXTs	$6x10^{-18}$	$1x10^{-25}$

SUMMARY

- **Meets BER requirement of 10^{-18}, without FEC**
- **Simple scheme, allows low-power implementation**
- **No DFE ➔ No error propagation issues**
- **Extendable to higher loss channels**
  - Additional mechanisms (coding, precoding, etc.)