System SNR
vs
Pre-Coder Choice
(Time Domain Analysis)

IEEE P802.3an Task Force

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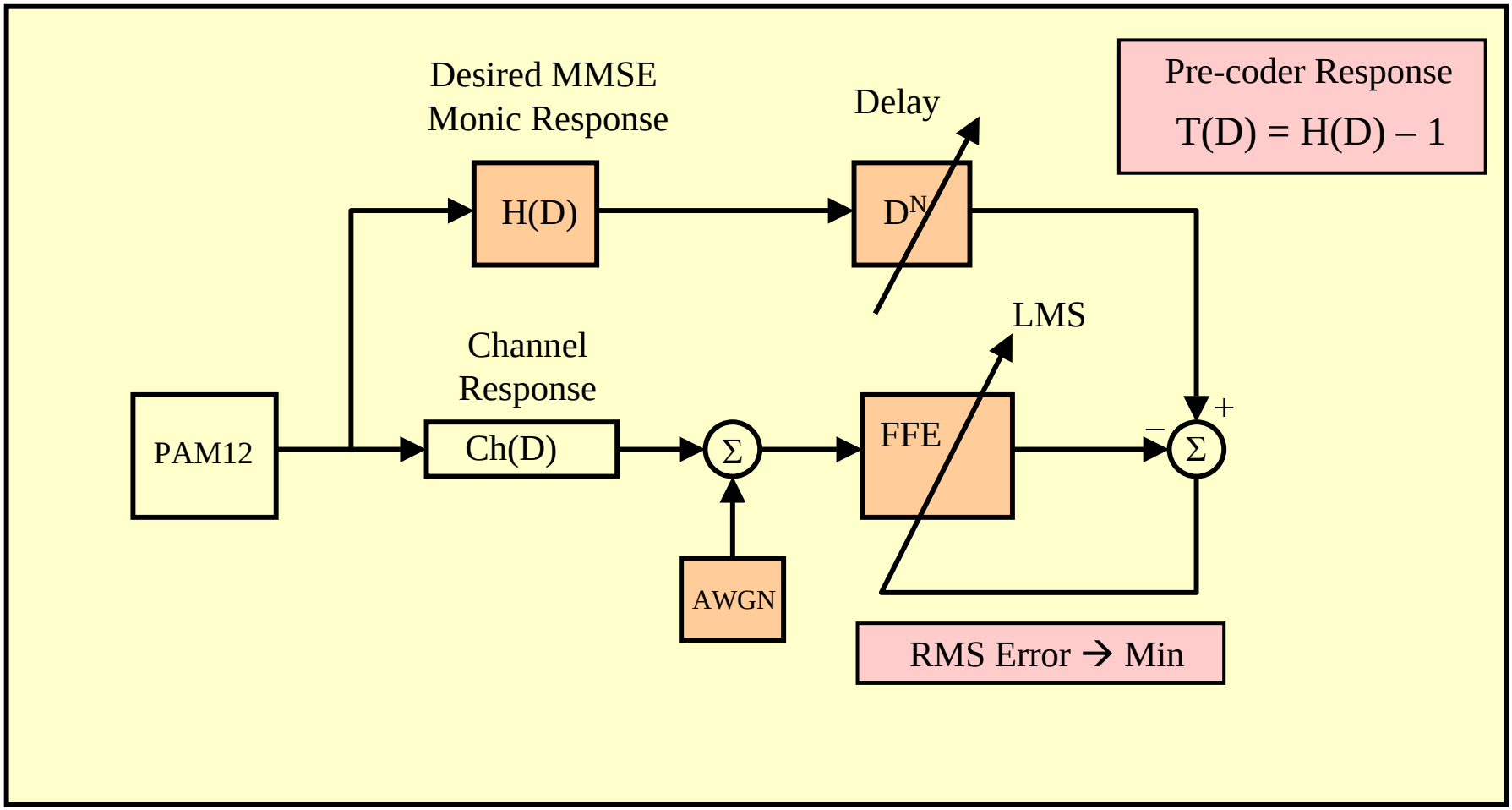
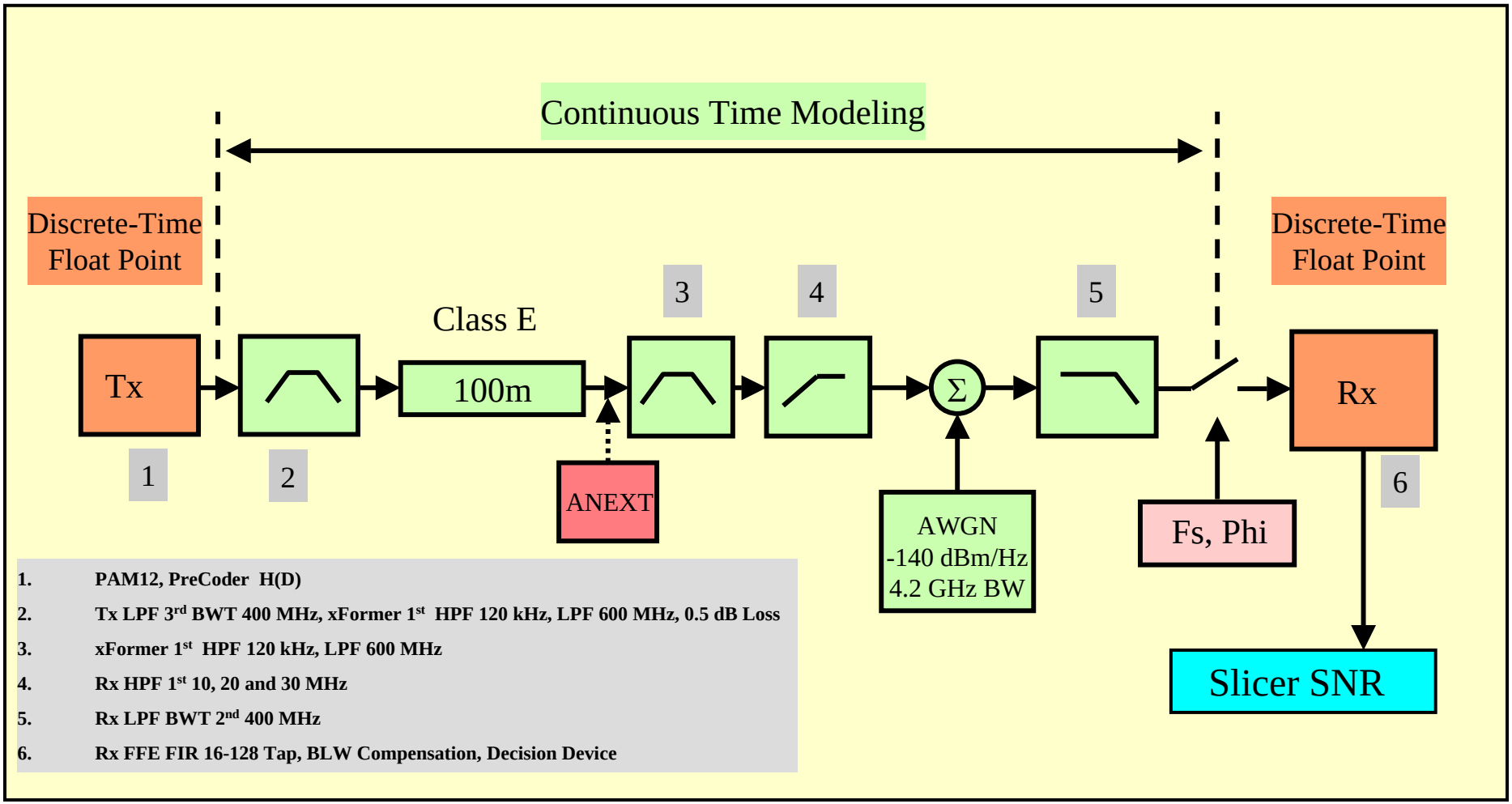
Key Considerations

- **Salz SNR Analysis per se Assumes no Limitations on the System Equalizer (EQ) Complexity – Theoretically could require Infinite FFE and/or DFE Filters**
- **Fixed Pre-Coder in the Transmitter Essentially Forces FFE Characteristics in the Receiver – An Overly Complex FFE in the Receiver Could Consequently Result**
- **Frequency Domain Consideration Alone Does Not Necessarily Yield Receiver EQ Complexity**
- **Time Domain End-To-End System Analysis is Required to Confirm Equalization Efficiency and Performance for a Chosen Pre-Coder Function(s)**
- **Analysis Example Given: IIR Pre-Coder, Class E 100m Channel**

Pre-Coder Corresponding FFE Derivation Block Diagram



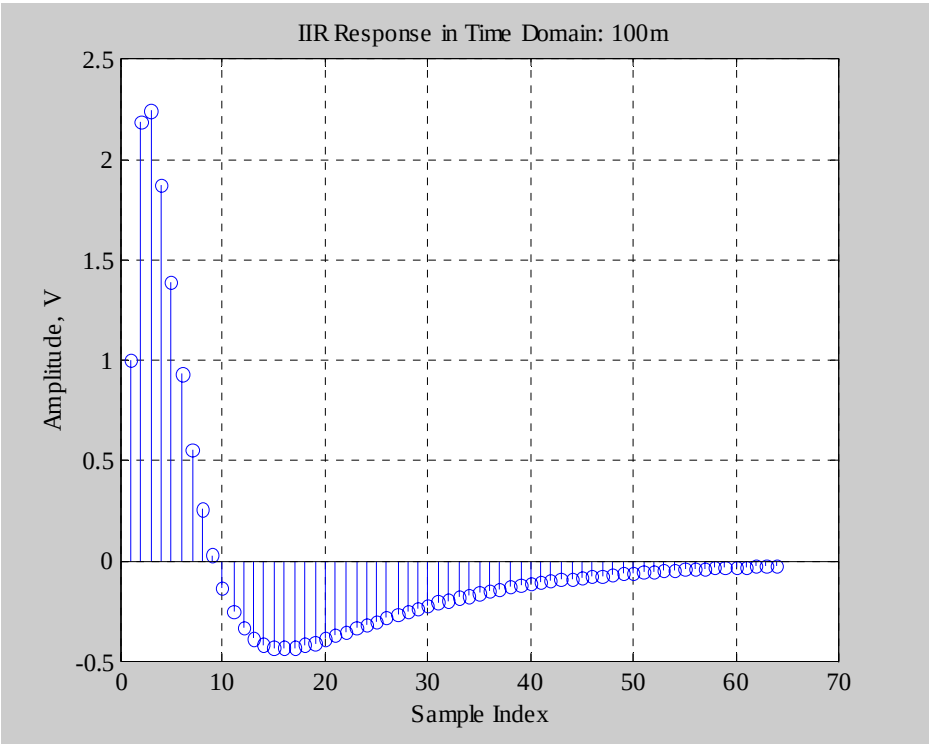
Pre-coder Performance Evaluation Block Diagram

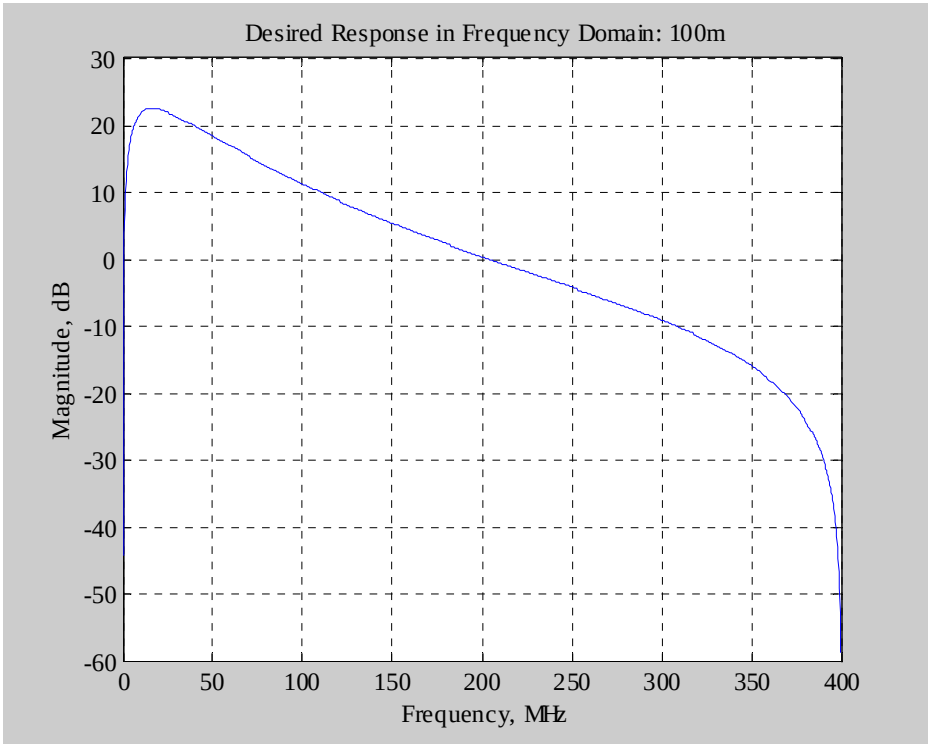


1. PAM12, PreCoder H(D)
2. Tx LPF 3rd BWT 400 MHz, xFormer 1st HPF 120 kHz, LPF 600 MHz, 0.5 dB Loss
3. xFormer 1st HPF 120 kHz, LPF 600 MHz
4. Rx HPF 1st 10, 20 and 30 MHz
5. Rx LPF BWT 2nd 400 MHz
6. Rx FFE FIR 16-128 Tap, BLW Compensation, Decision Device

IIR Pre-coder for 100m Case: Desired Monic Response

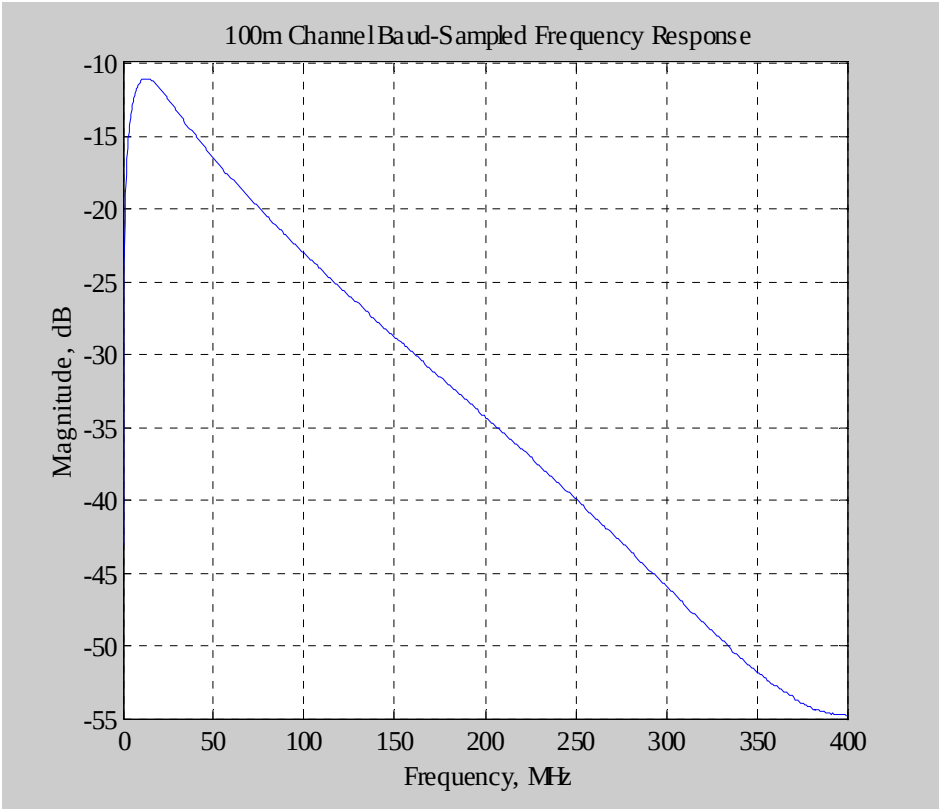
$$h_{IIR}(D) = \frac{(1-D)(1+D)}{(1-\frac{15}{16}D)(1-\frac{3}{4}D)(1-\frac{1}{2}D)} = \frac{1-D^2}{1-\frac{35}{16}D+\frac{99}{64}D^2-\frac{45}{128}D^3}$$

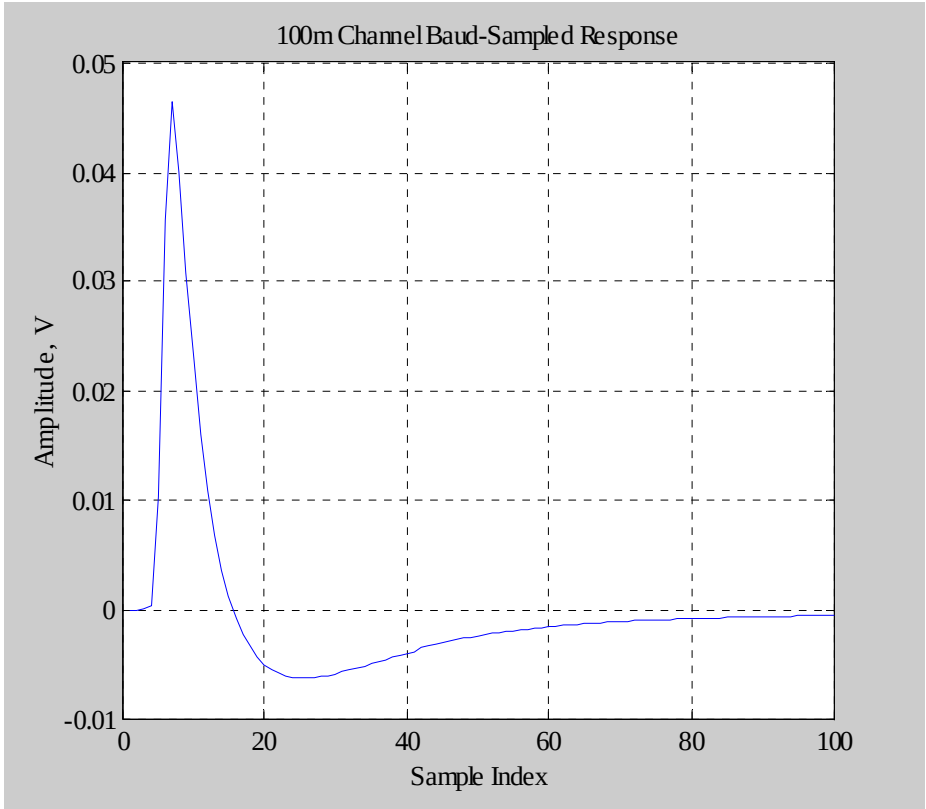




Desired Monic Response in Time and Frequency Domain from “ungerboeck_1_07_04”

Channel Response 100m





100m Channel Frequency and Time Domain Responses:
3rd Tx and 2nd Rx Butterworth LPF @ Fs/2, 1st 10-MHz Rx HPF

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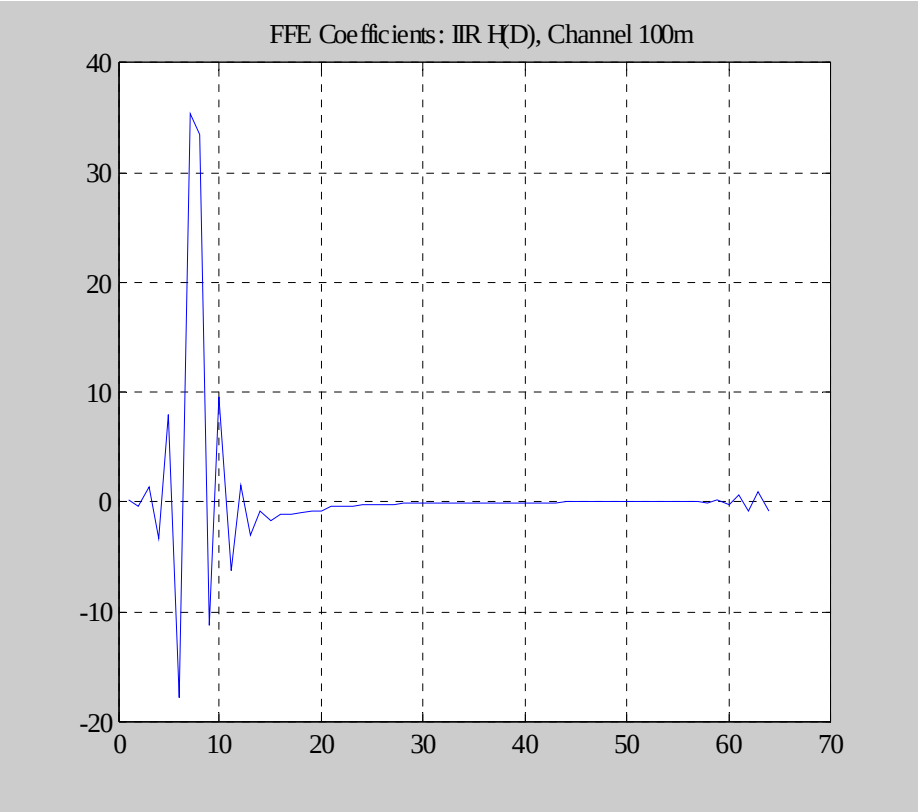
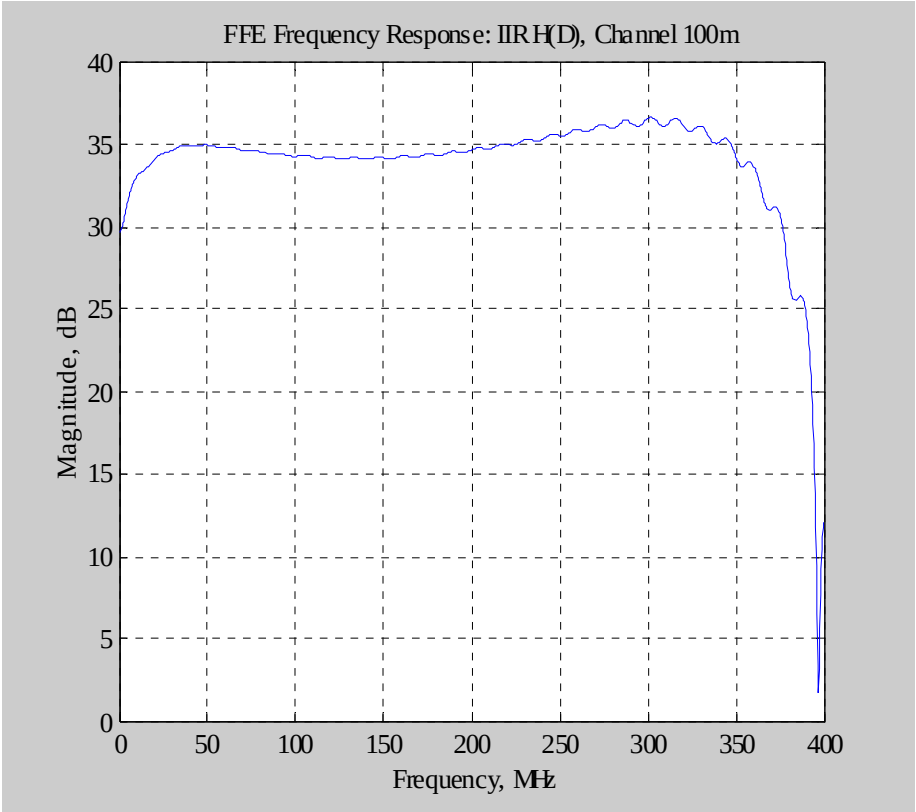
Corresponding 64-Tap MMSE FFE

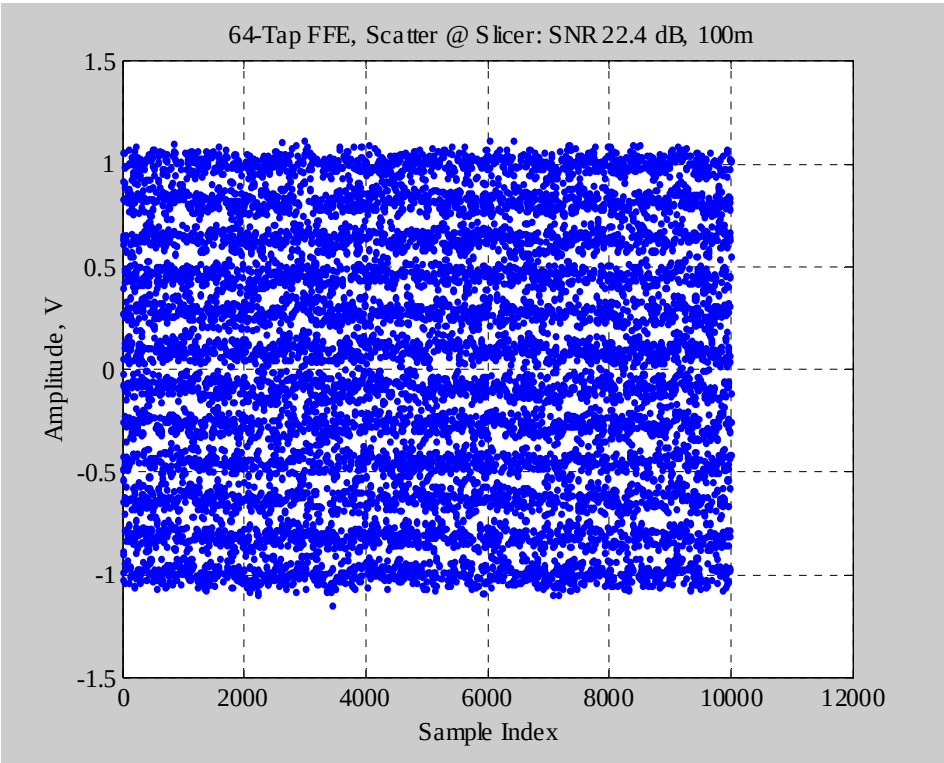




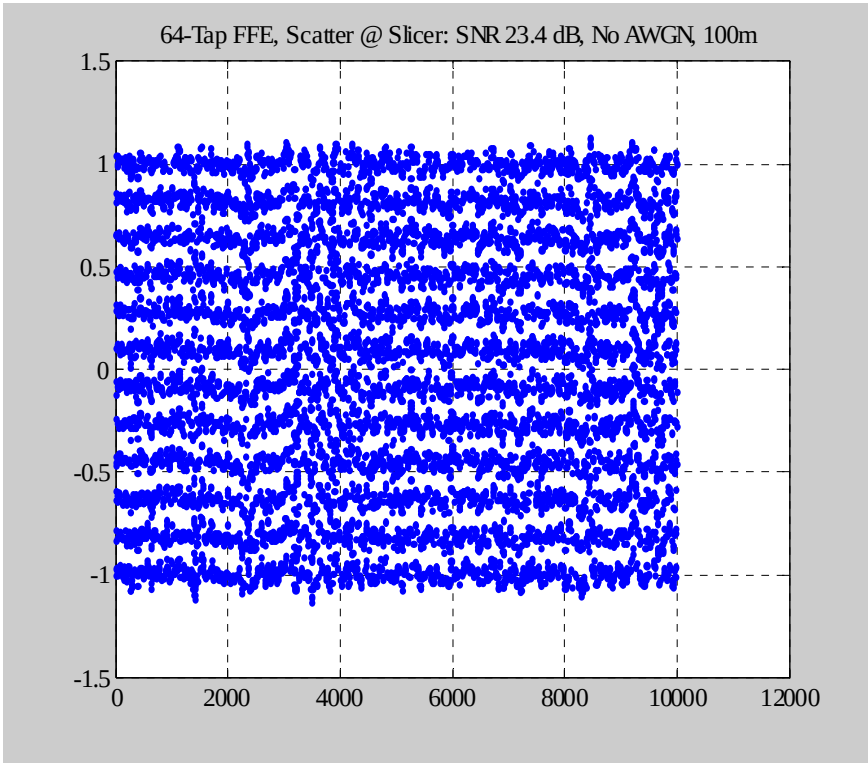
Corresponding 64-Tap MMSE FFE Response

64-Tap FFE System Performance

SNR Only 22.4 dB (Loss of ~2.6 dB)



AWGN = -140 dBm/Hz → SNR 22.4 dB



ISI Only – No AWGN → SNR 23.4 dB

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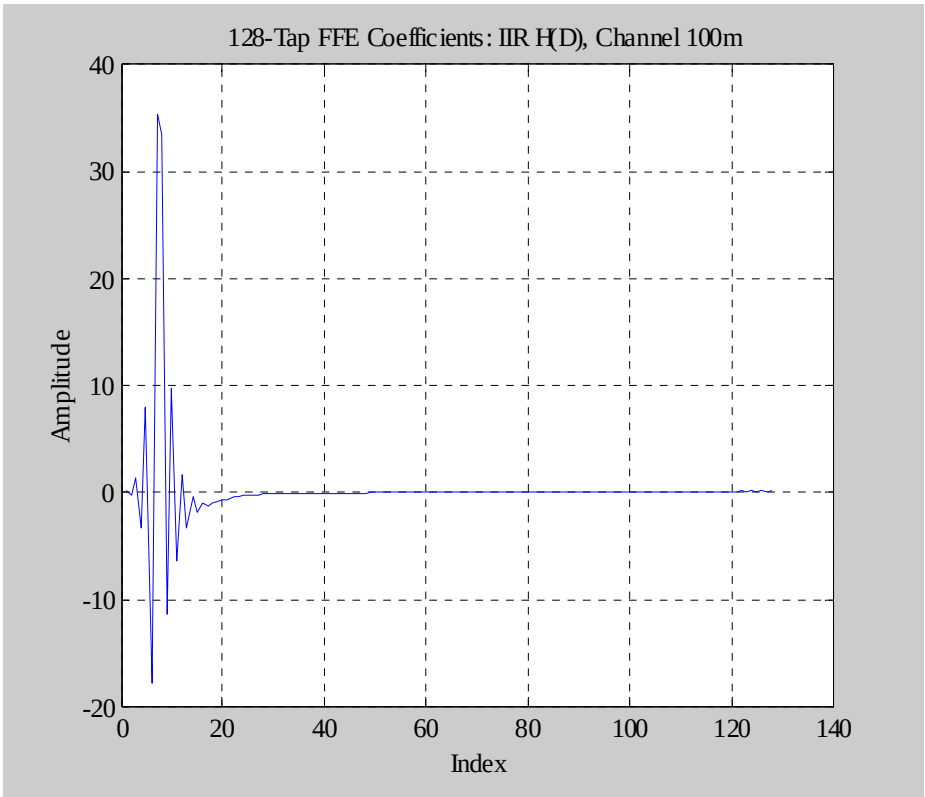
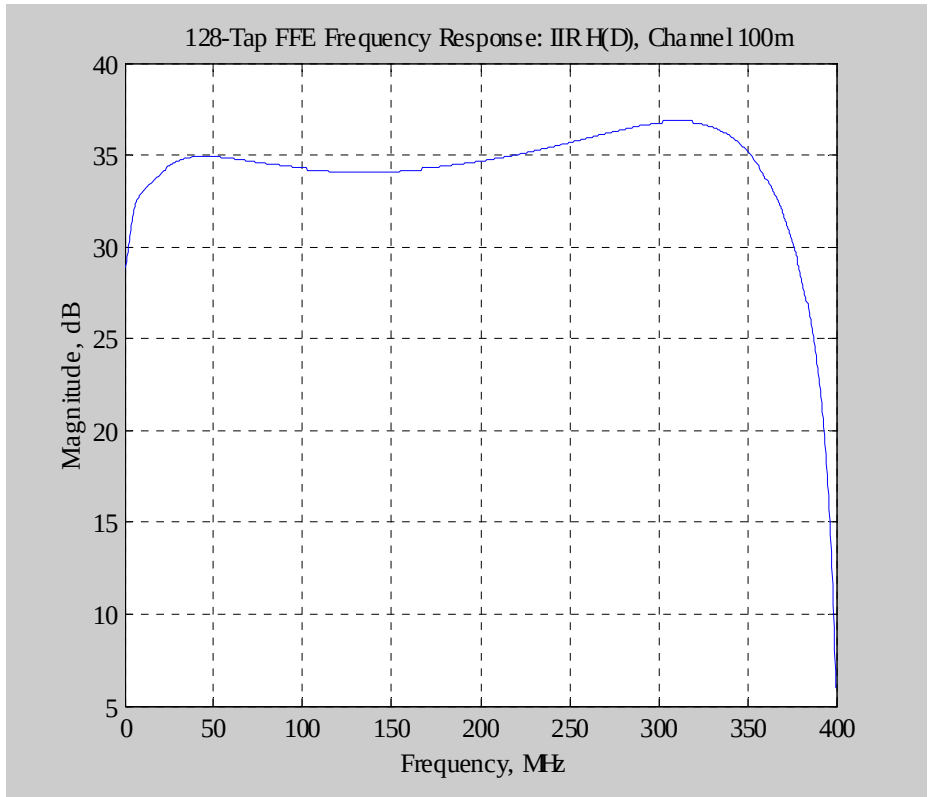
IIR Pre-coder 100m Case: 128-Tap Extended FFE





Extended 128-Tap MMSE FFE Response

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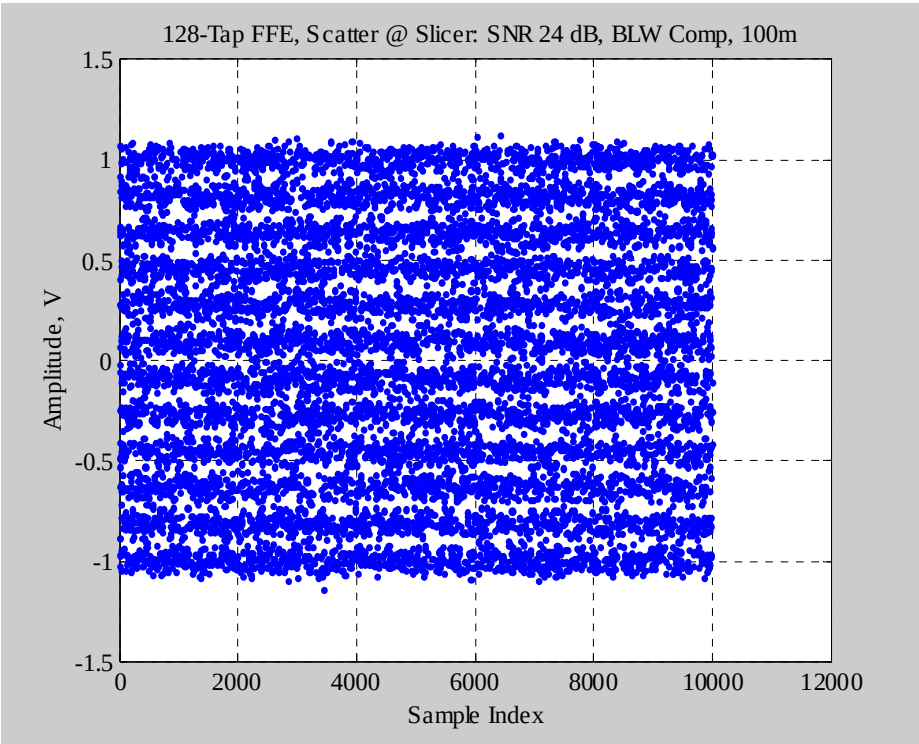
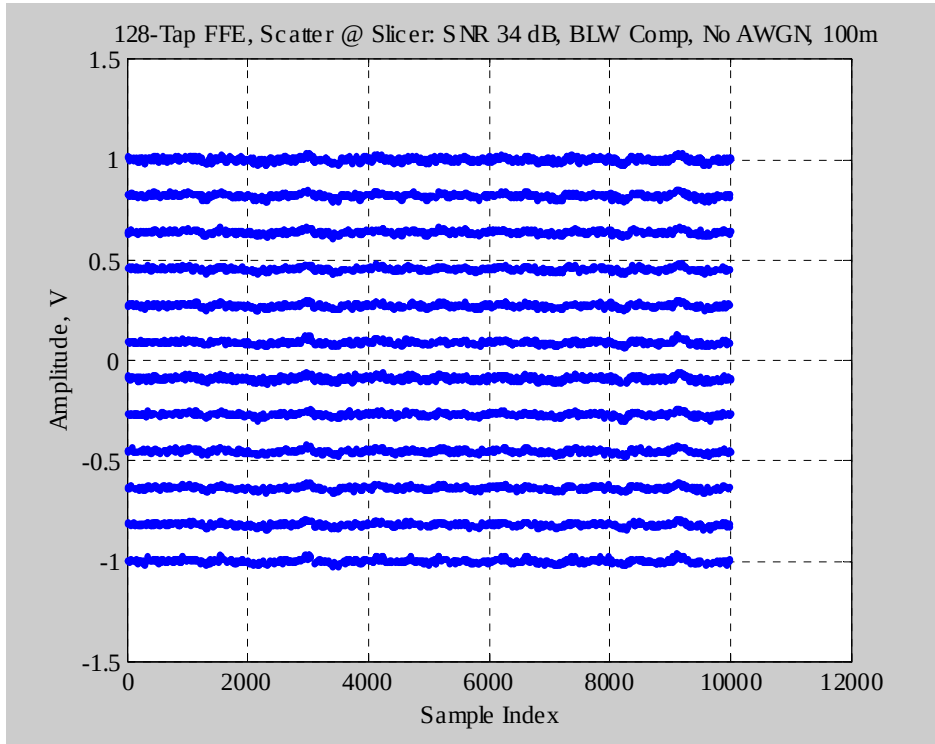
128-Tap FFE + BLW Compensation

Improved SNR 24 dB, Still ~1 dB Short from Predicted





AWGN = -140 dBm/Hz → SNR 24 dB

ISI Only – No AWGN → SNR 34 dB

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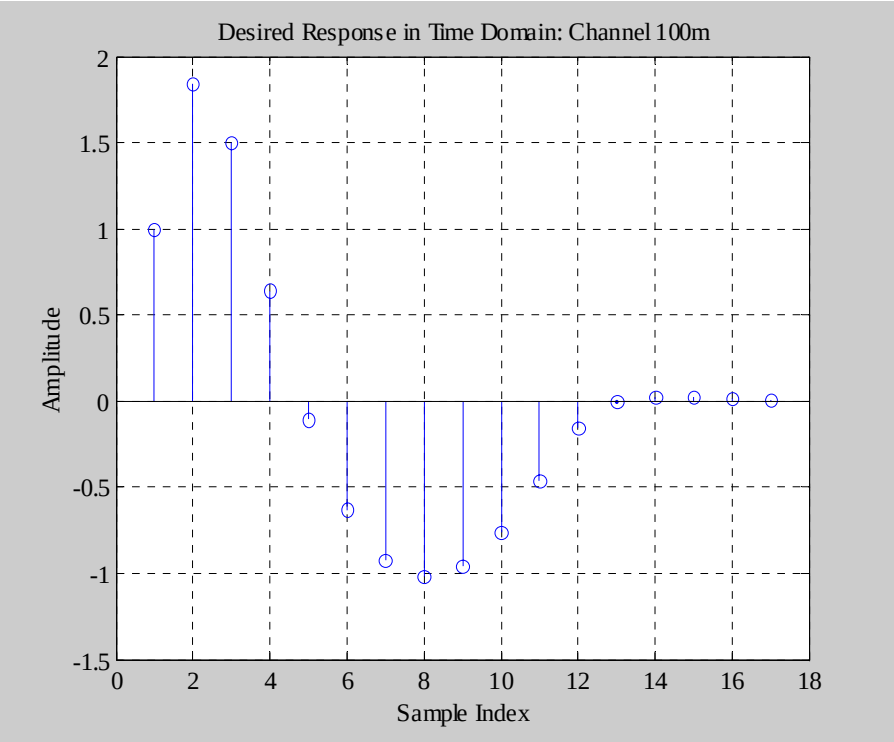
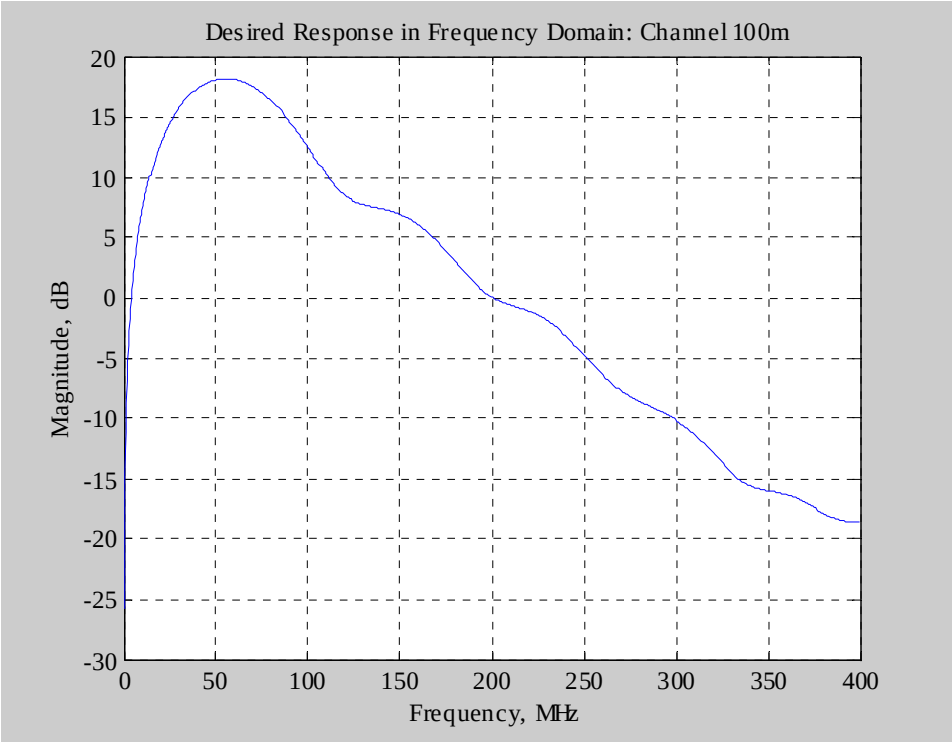
Alternative Constrained-MMSE FIR Pre-coder
16-Tap Desired Monic Response





Desired Monic Response in Time and Frequency Domain
Equi-Ripple Like Behavior – Does Not Attempt Opt. at Every Fr. Point

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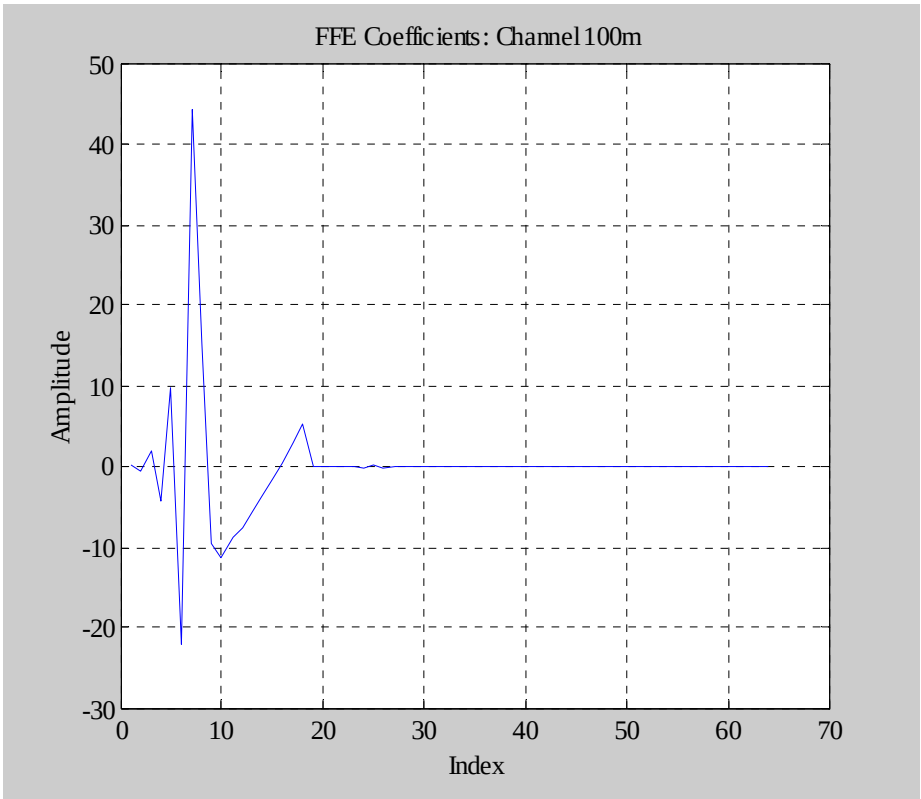
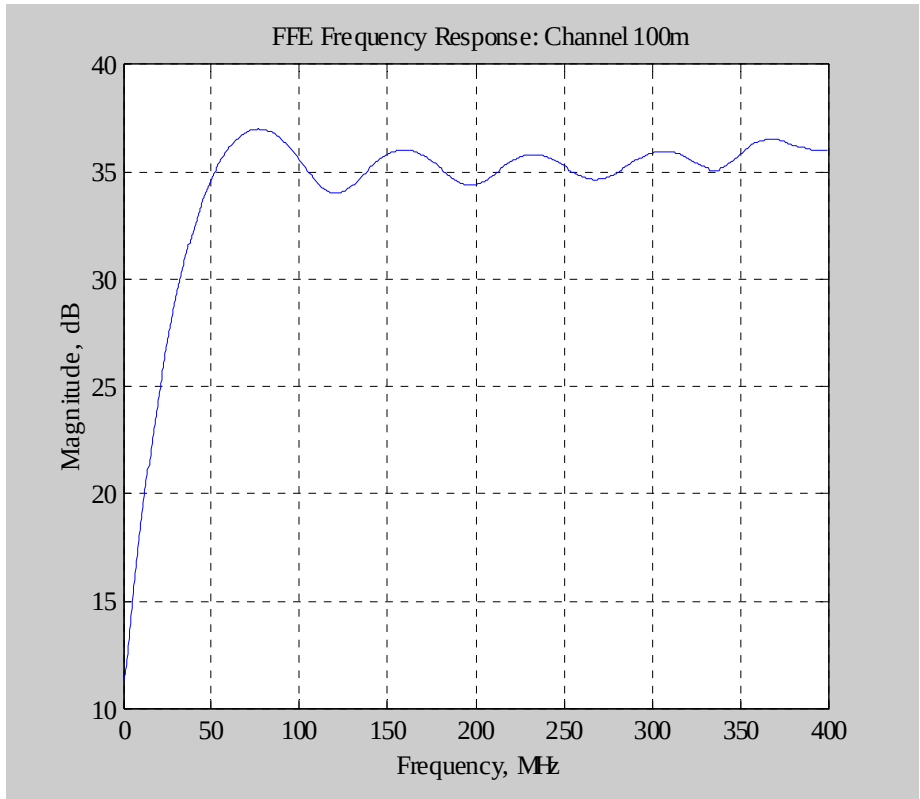
Constrained Pre-coder Corresponding 64-Tap FFE





Corresponding 64-Tap MMSE FFE Response: 16-Tap FEE would be Sufficient

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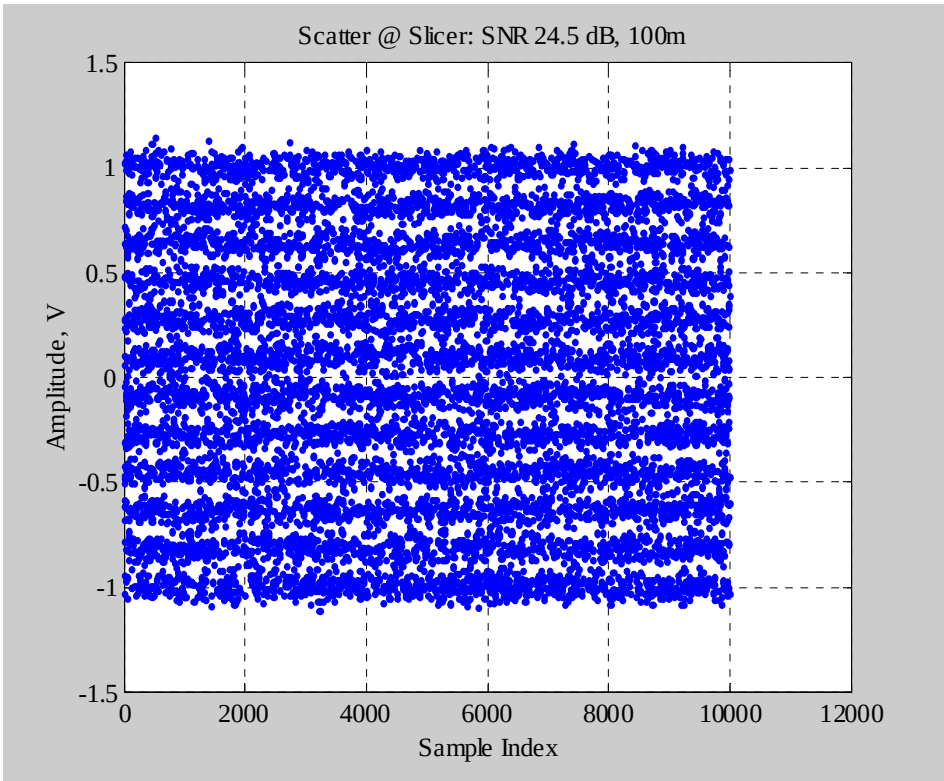
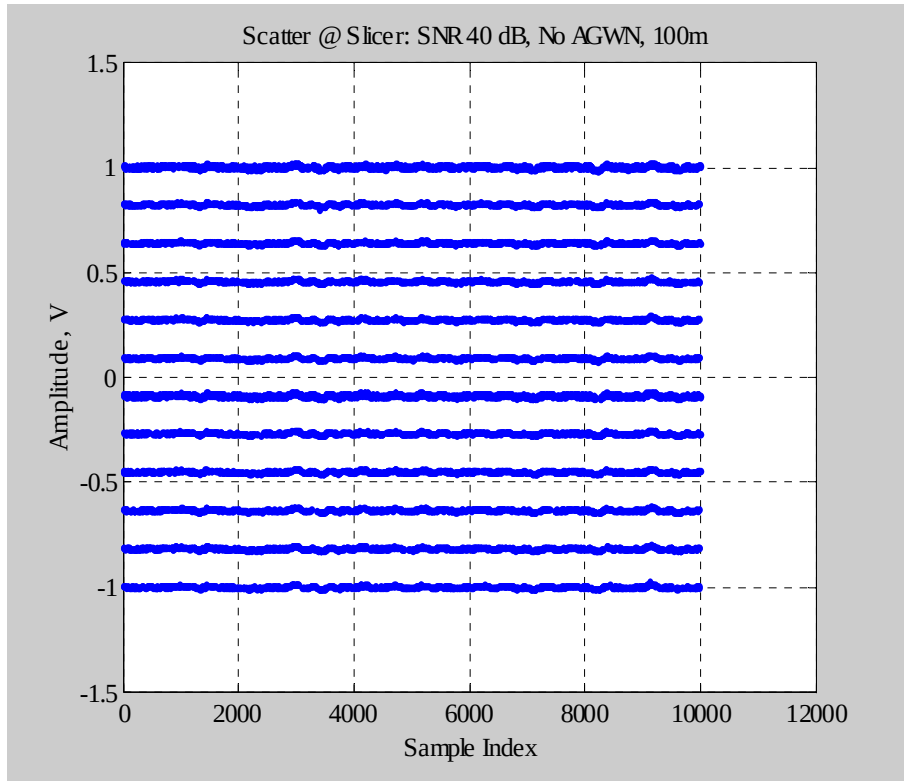
16-Tap FFE System Performance

SNR = 24.5 dB – Better than 128-Tap System





AWGN = -140 dBm/Hz → SNR **24.5** dB

ISI Noise – No AWGN → SNR 40 dB

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Conclusion

- **For a Practical (Finite) Rx Equalization the Choice of Pre-Coding Transfer Function is Crucial to Achieve High Performance and Power-Efficient 10GBASE-T System**
- **16-Tap FIR Pre-Coder should be Sufficient for Operation over Class E 100m Channel**
- **Shorter than 100m Reach Pre-Coders would Require Less than 16-Tap Filter**
- **16-Tap and Shorter FIR is Easier to Implement than 3rd Order IIR**