IEEE 802.3dm

Echo in Asymmetric Frequency-Multiplexed Systems

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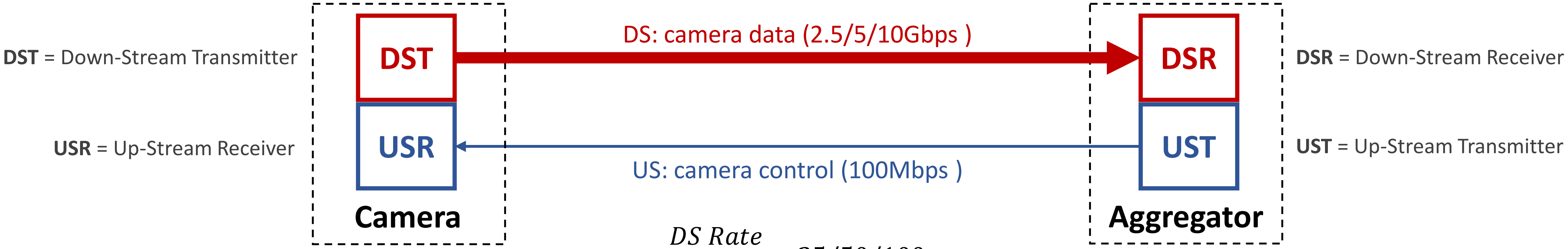
Outline

- IEEE 802.3dm is to specify an efficient PHY to support asymmetric throughput
- Echo canceller is one of the receiver blocks that can add to overall complexity of the PHY
- TDD systems eliminate the need for echo canceller by allocating different time slots for transmit and receive
- This presentation shows that given typical limits of RL, echo cancellation is not required in FDD-based systems

Asymmetric Camera Link

- High volume of video data flows down-stream (**DS**) from the PHY in the camera to the PHY in the aggregator

- Low volume of control information is transmitted up-stream (**US**) from the aggregator to the camera



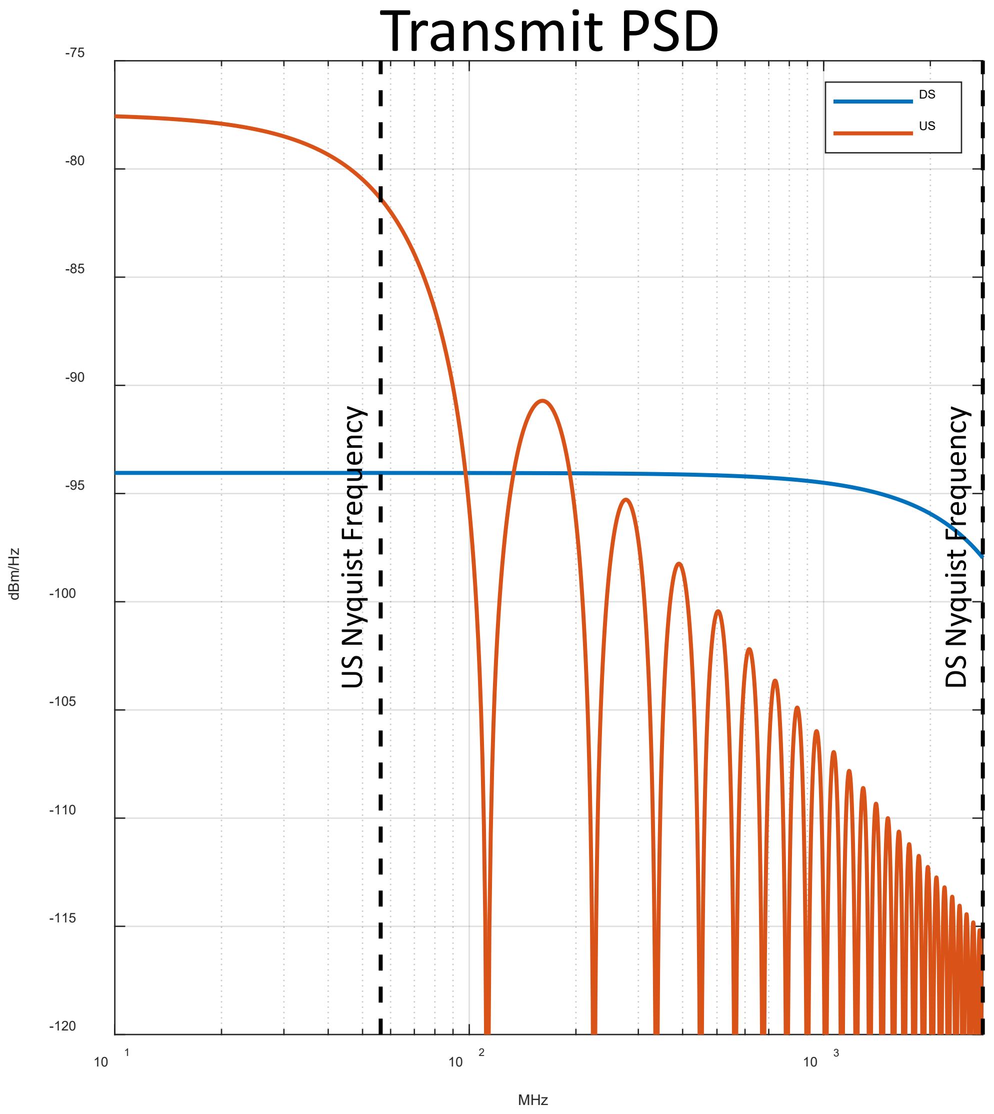
$$\frac{DS\ Rate}{US\ Rate} = 25/50/100$$

Frequency Domain Duplexing

- Both DS and US nodes transmit at the same time with symbol rates proportional to data rate

- Example:
  - DS: PMA/PCS similar to 802.3ch with PAM4 modulation and symbol rate of 5.625 GHz
  - **US: PCS similar to 802.3ch with PAM2 modulation at 112.5 MHz**
  - US and DS transmit power: 0 dBm

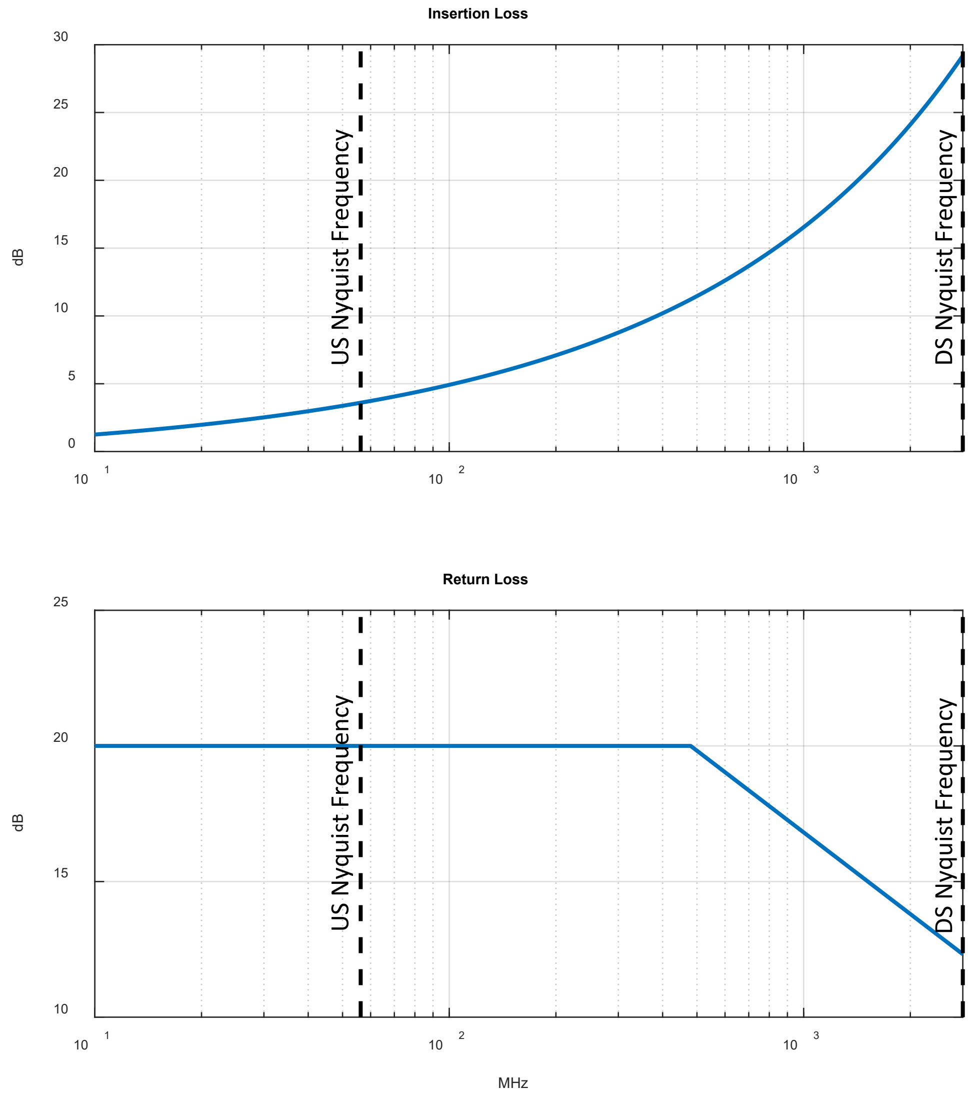
- Note that the DS PSD is ~17 dB weaker than US PSD within US band



Channel Limit Lines

Assuming limit lines per IEEE 802.3ch:

- No more than ~3 dB insertion loss at the band-edge in US direction vs ~30 in DS direction
- More than 20 dB attenuation of echo throughout the entire band of US versus 12 dB at the band-edge in DS direction



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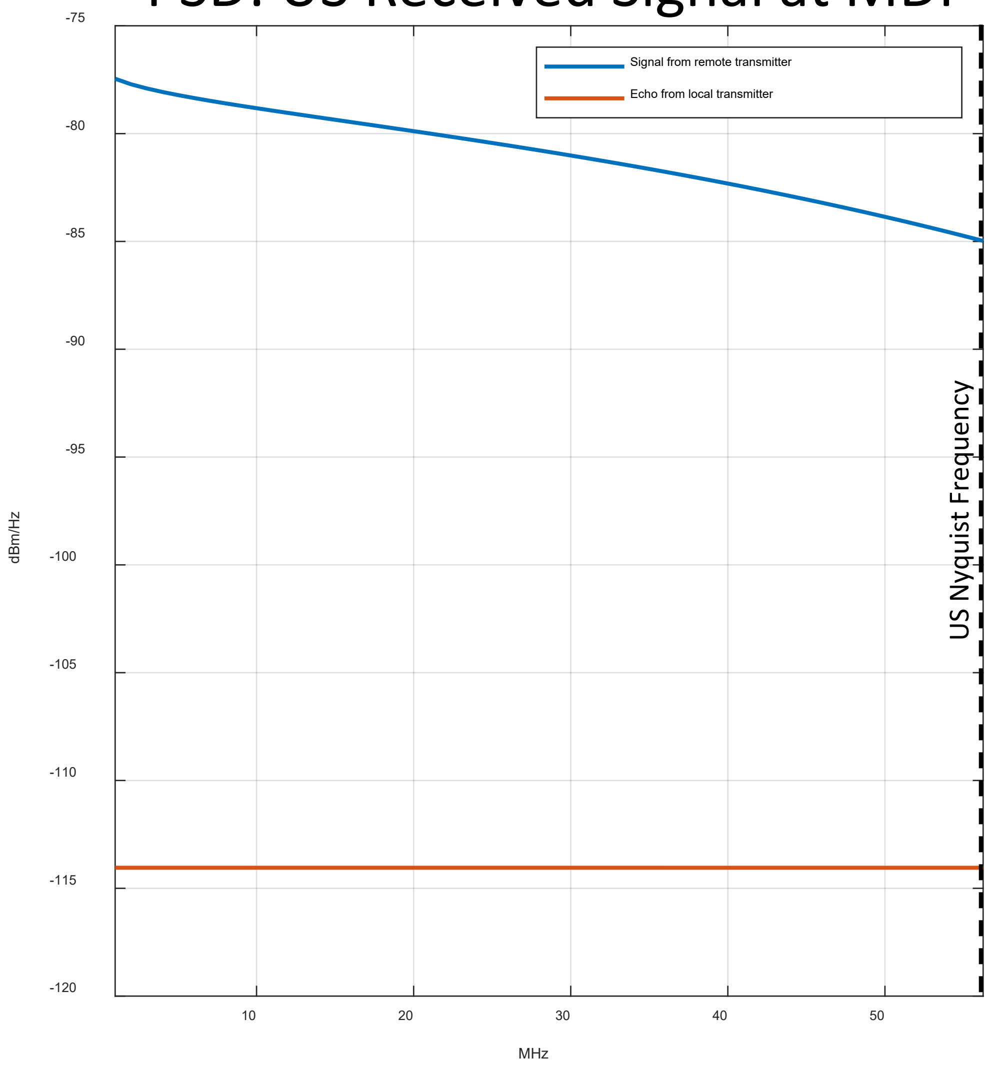
Upstream Receiver

- The power spectral density (PSD) of echo is ~35 dB below the PSD of the desired signal from remote transmitter
  - ~17 dB due to transmit PSD
  - ~20 dB more loss in echo channel vs thru channel at lower frequencies

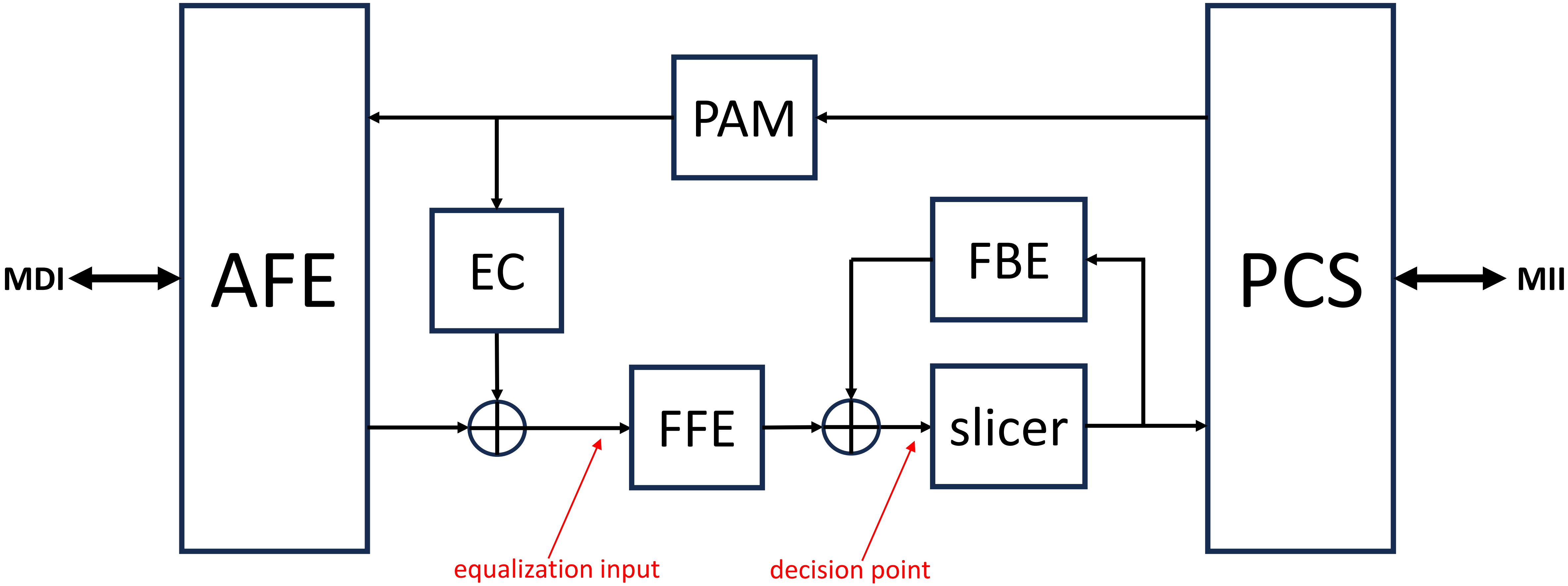
- Received signal power at MDI:
  - From remote transmitter: -3 dBm
  - From local transmitter (echo): -37 dBm

(Note that the depicted PSD of echo represents its envelop and the worst-case echo power is even lower)

PSD: US Received Signal at MDI



PMA Architecture



AFE = Analog Front-End
EC = Echo Canceller
MDI = Media-Dependent Interface

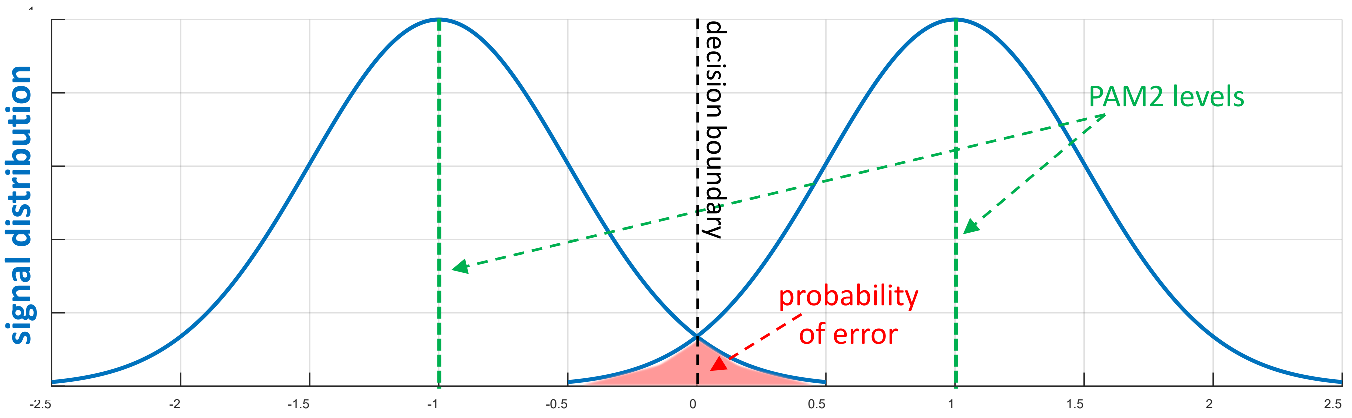
PCS = Physical Coding Sublayer
FFE = Feed-Forward Equalizer
MII = Media-Independent Interface

PAM = Pulse Amplitude Modulation
FBE = Feed-Back Equalizer

USR: SNR at Decision Point

- Target bit-error rate = 10^{-12}
- PAM2 modulation
- Design choice: allocate the entire FEC coding gain (typically around 6 dB) to cover for non-Gaussian noise sources

➔ **Required SNR at decision point = 17 dB**



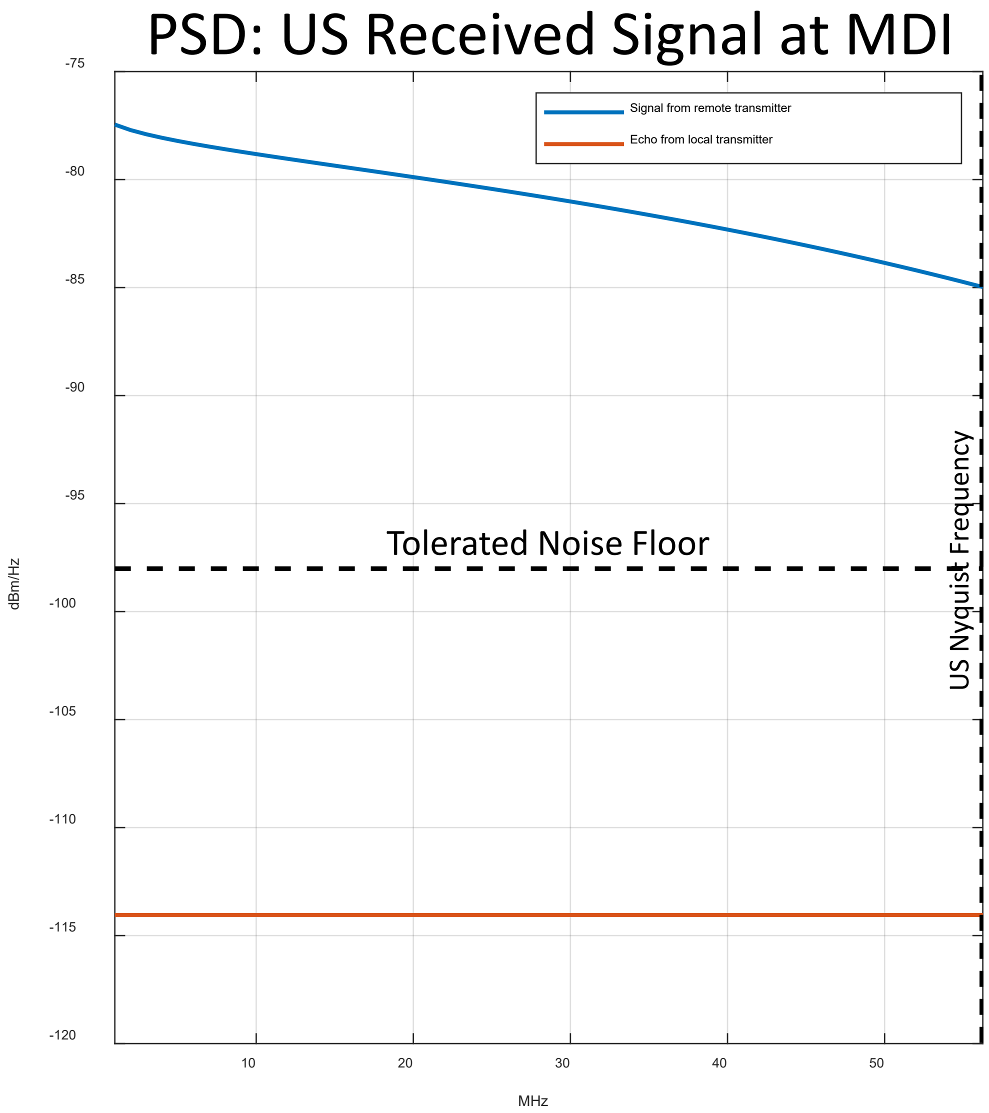
USR: Tolerated Input Noise

Assuming adequate equalization and with Salz SNR analysis:

➔ Tolerated input noise floor = -98 dBm/Hz

➔ Required input SNR = 17.5 dB

- Echo is 16 dB weaker than the tolerated noise level
- The impact of uncancelled echo on overall noise budget is insignificant (~0.1 dB)



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Downstream Receiver

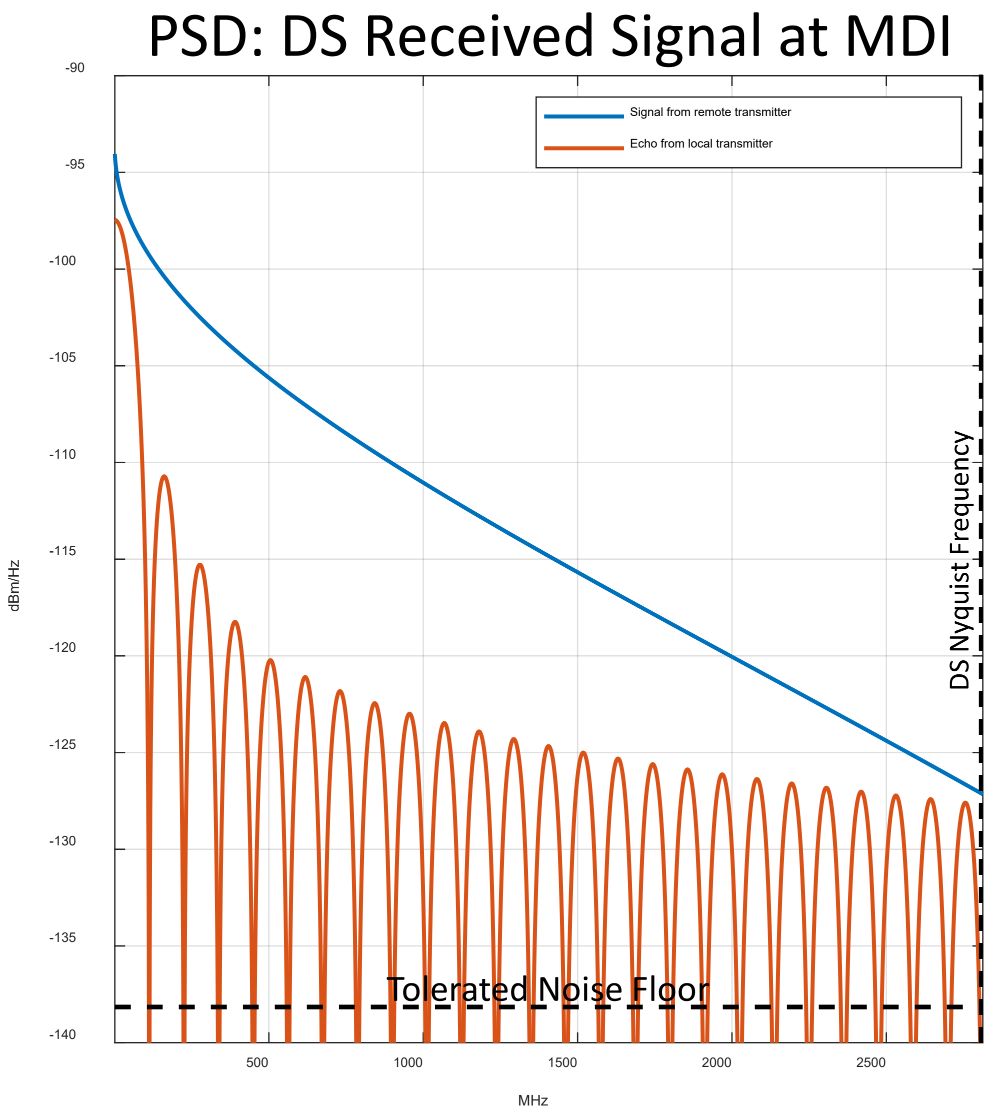
- Signal-to-echo ratio (MDI) > 7 dB*
- Target bit-error rate = 10^{-12}
- PAM4 modulation
- FEC dedicated to non-Gaussian noise sources

→ Required SNR at decision point = 24 dB

→ Tolerated input noise floor = - 138 dBm/Hz

→ Required input SNR = 31 dB

* Typical transmit/receive filtering, which significantly reduces the echo at higher frequencies, are not considered here



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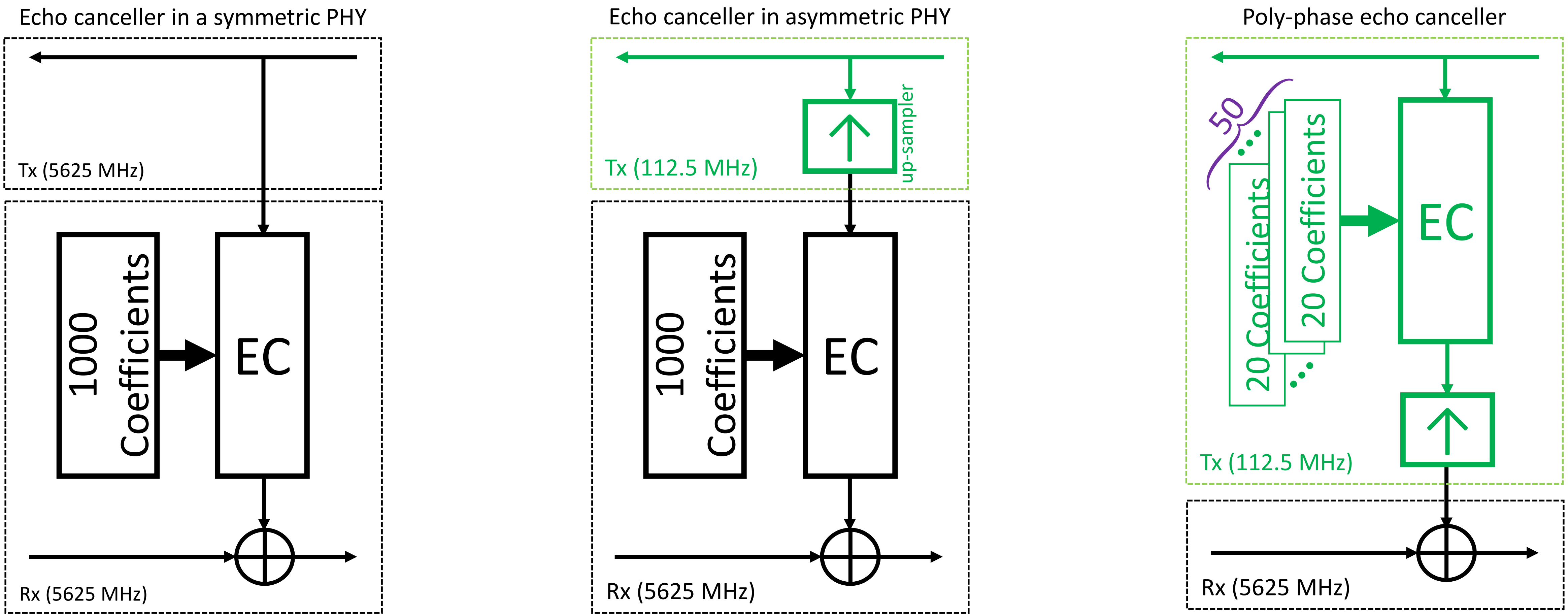
DSR: Poly-phase Echo Canceller



1000 multiply & add per Rx symbol

1000 multiply & add per Rx symbol

20 multiply & add per Rx symbol

Note that time-domain constraint, similar to what is defined in 802.3cy, can further simplify the complexity of the echo canceller

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Summary

- FDD upstream receiver is very efficient
  - There is no need for echo cancellation
  - Equalization is trivial
  - Noise requirements, AFE dynamic range, and A/D sampling rate are very low

- FDD downstream receiver is not complex
  - The complexity of equalization and AFE match the symbol rate
  - Echo cancellation through poly-phase implementation is simple


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Thank You