IEEE 802.3dm

Receiver Complexity in Code-Multiplexing Systems

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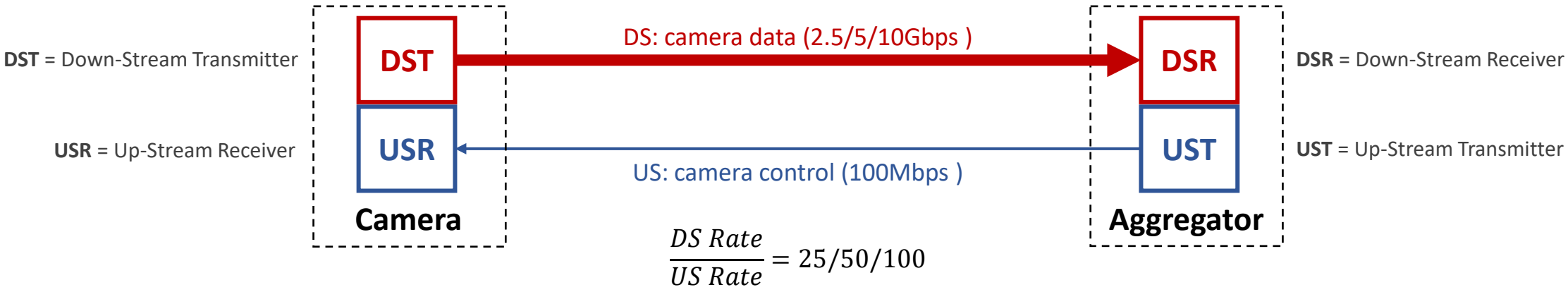
Outline

- Frequency-domain duplexing (FDD) is an efficient method to support asymmetric data rate
  - In the low data-rate direction, the symbol rate is low, and the signal bandwidth is narrow ➔ trivial receiver (sedarat_3dm_02_202405, sedarat_3dm_202407)
- There are potential reasons (e.g. AC coupling circuit) that having a wider bandwidth in low data-rate direction may be beneficial
- Frequency spreading (AKA code-multiplexing) is a technique that can widen the signalling bandwidth without adding much to the complexity of the receiver

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



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

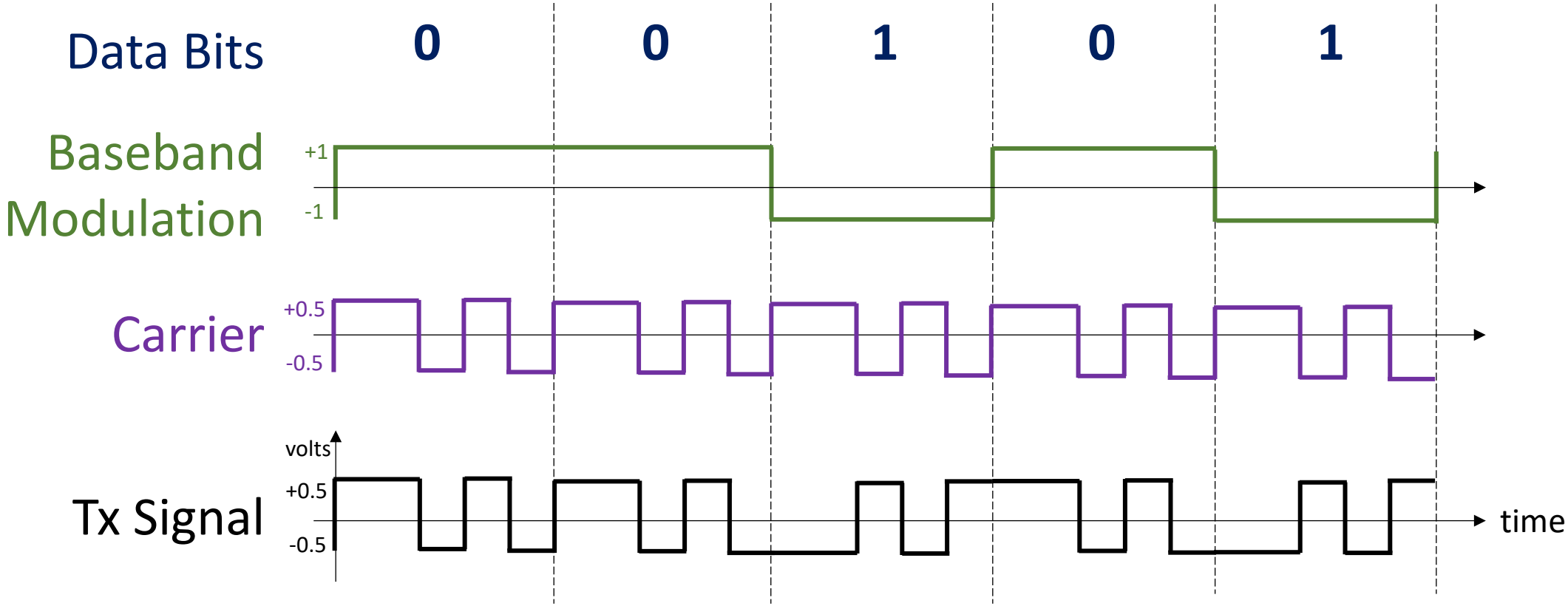
Frequency Spreading

- Both DS and US nodes transmit at the same time continuously and with no interruptions

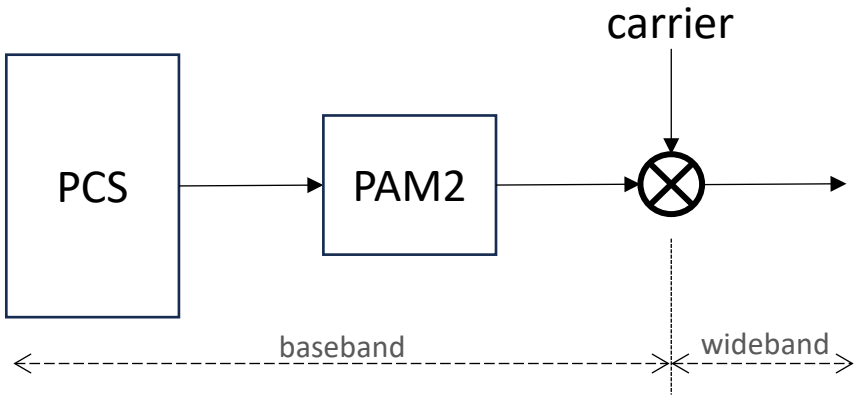
- Example:
  - DS: PMA/PCS similar to 802.3ch with PAM4 modulation and symbol rate of 5.625 GHz
  - US: PCS similar to 802.3ch with PAM2 modulation at symbol rate of 112.5 MHz

- The US signal is spread over frequency by modulating a high frequency carrier

US Transmit Signal

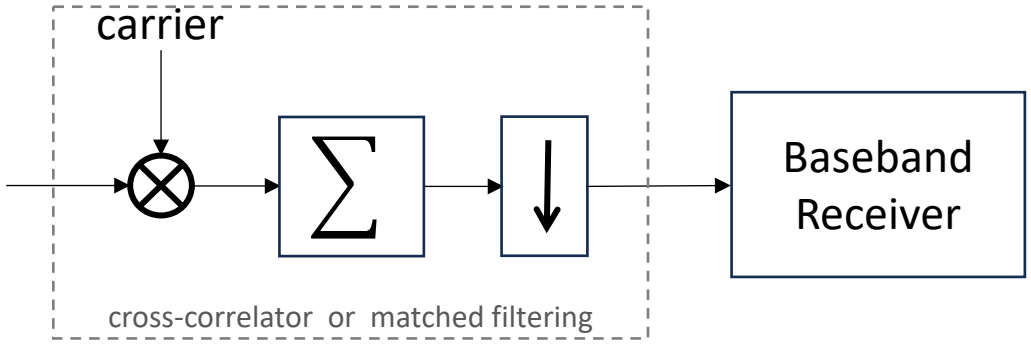


US Transmitter



- Carrier may be a period pattern (as shown in previous slide)
  - It offers spectral shaping
- Carrier may be a long stream of white pseudo-random pattern
- Carrier signal is known to the US receiver

US Receiver



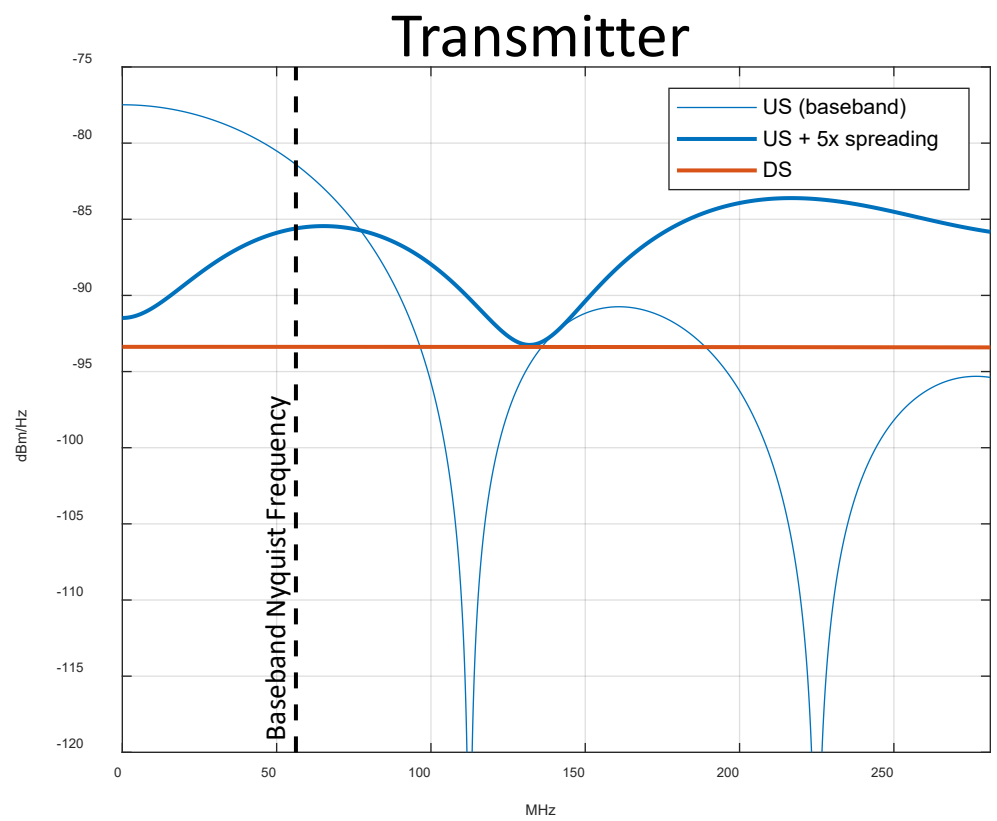
- The receiver includes an initial matched filtering, followed by a down-sampler
- The Matched filter
  - Coherently and constructively combines high frequency symbols received from far-end
  - Averages out other uncorrelated signals like echo and other interferers

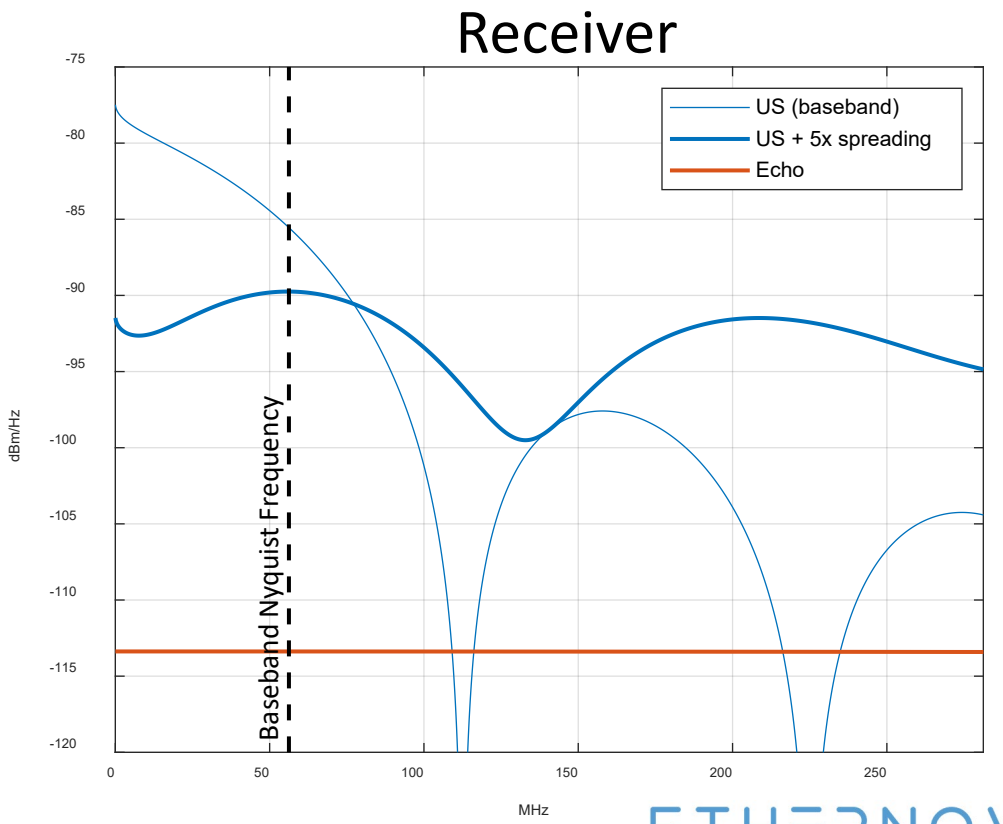
  ➔ SNR gain proportional to spreading factor

  (similar to Alert or Link-Synch detection)

Power Spectral Density

- Using the 5x spreading sequence shown in previously
- Assuming limit line channels as defined in IEEE 802.3ch





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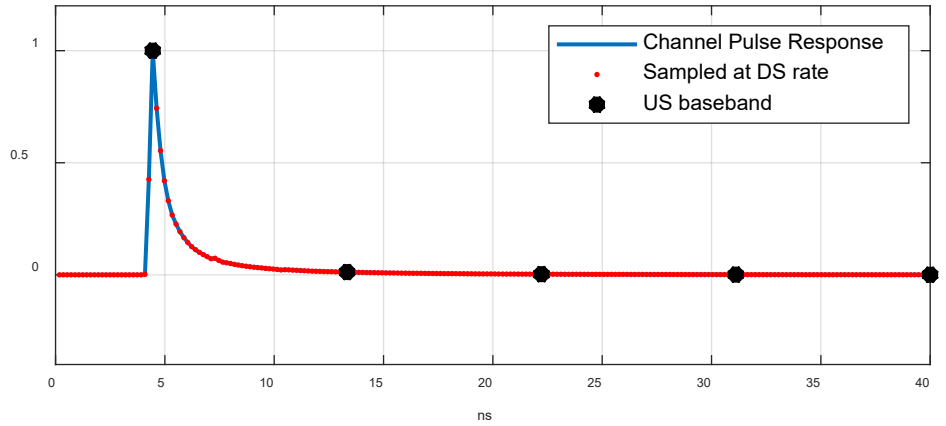
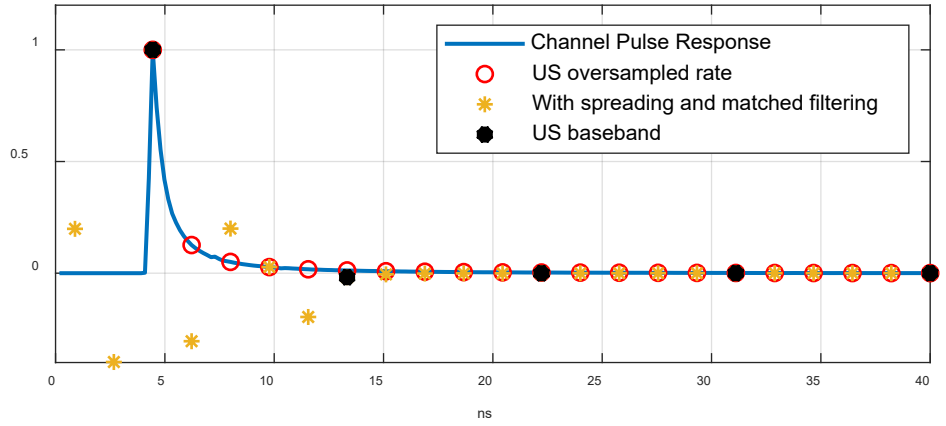
Pulse Response



➔ Comping to an FDD system, equalization is significantly more challenging in an TDD where US signal is sampled at DS rate



➔ Although spreading widens the US transmit bandwidth, after matched filtering and down-sampling the pulse response becomes trivial to equalize

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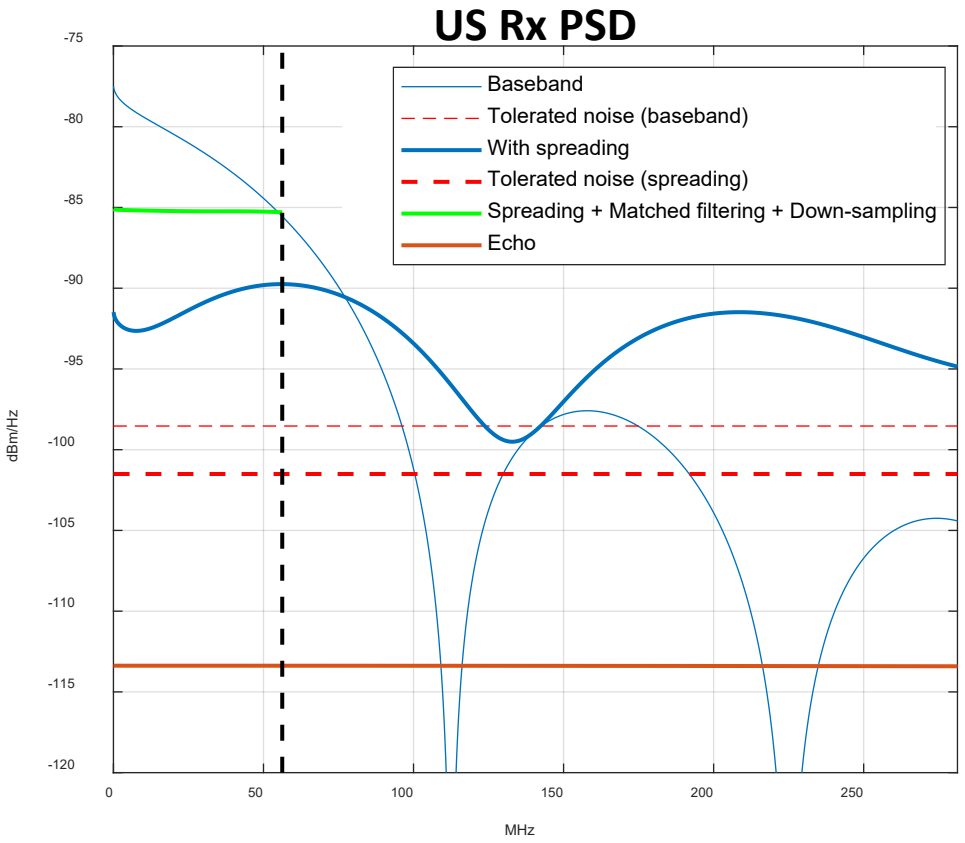
SNR Requirements

With an analysis similar to sedarat_3dm_202407, with additional time-domain simulations, the requirements are as follows

	Baseband (FDD)	5x Spreading
Required input SNR	17.5 dB	11.0 dB
Tolerated noise floor	-98 dBm/Hz	-102 dBm/Hz
Penalty from uncancelled echo	0.1 dB	0.3 dB



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Summary

- If there is a need to have higher frequency content in the US direction, spreading is a good technique to achieve the goal

- Although the signaling bandwidth spreads to higher frequencies, the incremental complexity of the receiver is simply limited to higher sampling and a simple cross-correlator

- Like a baseband FDD system
  - echo power remains negligible with no need for echo cancellation
  - equalization remains trivial


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Thank You