IEEE 802.3dm

PHY Block Complexity

Hossein Sedarat

ETHERNOVIA®

May 2024

Supporters

- Ragnar Jonsson
- William Lo
- Thomas Hogenmueller
- Alireza Razavi

Overview

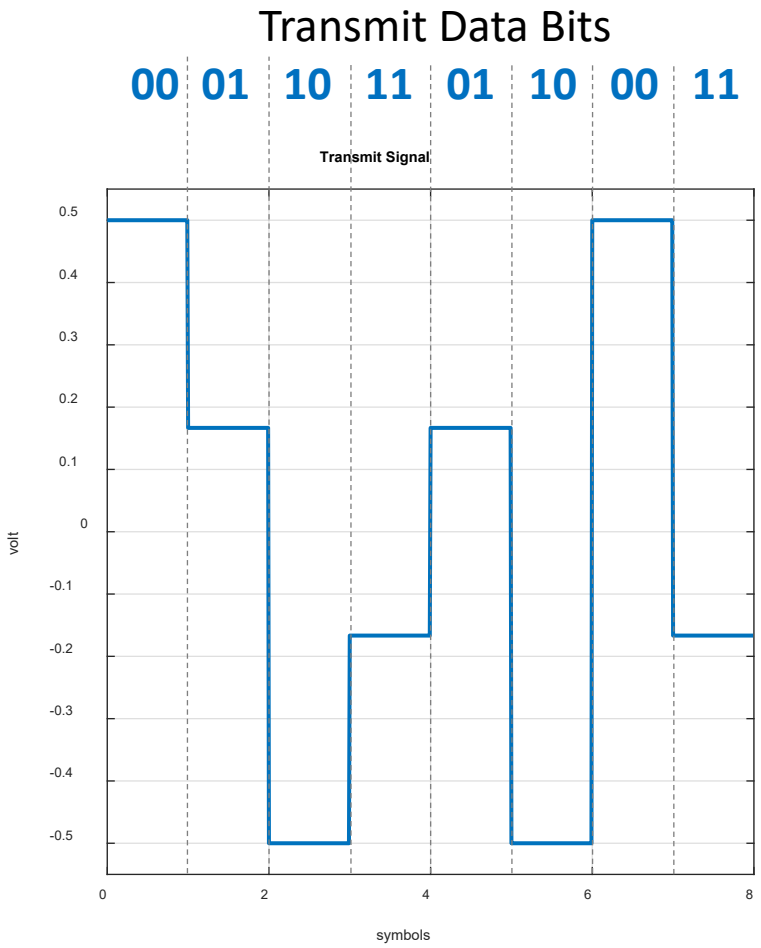
- IEEE 802.3dm is to specify a transceiver with minimal complexity to support asymmetric throughput
- This presentation offers a high-level review of the complexity of the Physical Medium Attachment (PMA) sublayer
- Outline:
  - Transmit signal, channel interference, EMI and other sources of noise
  - PMA functions and high-level block diagram
  - PMA blocks complexity and how it scales with symbol rate
    - Equalization
    - Echo cancellation
    - RF immunity
    - Analog front end (AFE)

Signal & Interference

- Pulse-Amplitude Modulation (PAM) is typically used to map data bits to electric pulses launched on the cable
  - PAM4: every pair of data bits is mapped to a pulse with one of 4 voltage values

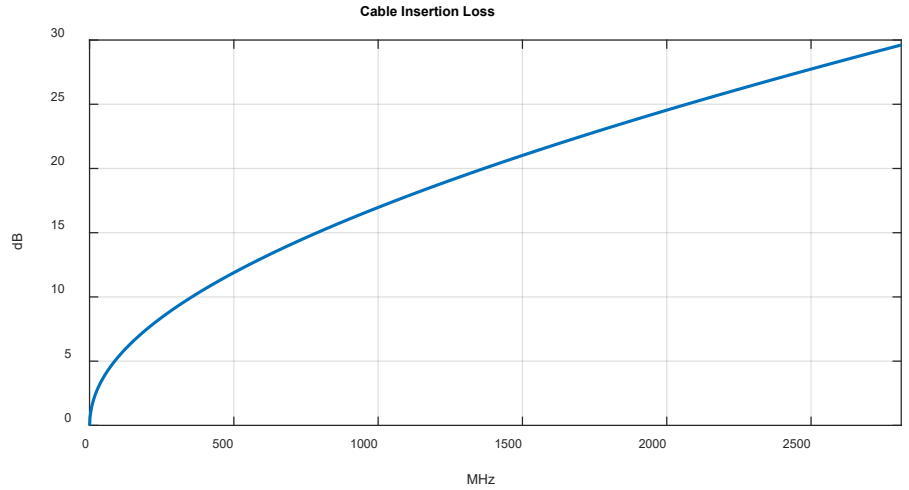
- These pulses are attenuated and distorted as they travel through cable and contaminated by various sources of interference and noise

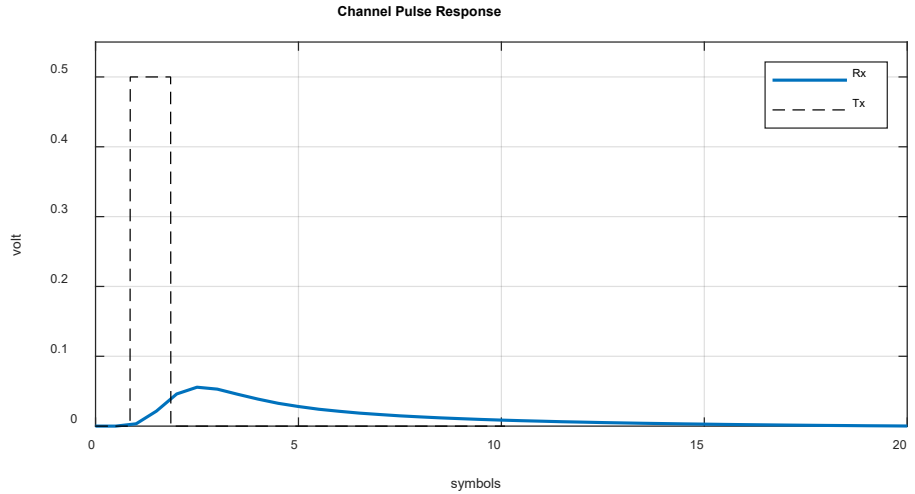
- PMA layer of the receiver is responsible to recreate these pulses



Inter-Symbol Interference (ISI)

- Insertion loss of a cable increases with frequency
- A sharp transmit pulse is attenuated in magnitude and spread in width at the receiver
- Inter-symbol interference (**ISI**) is the overlap of multiple received pulses due to the spreading effect of cable
- **Equalization** is a receiver process that eliminates the effect of ISI

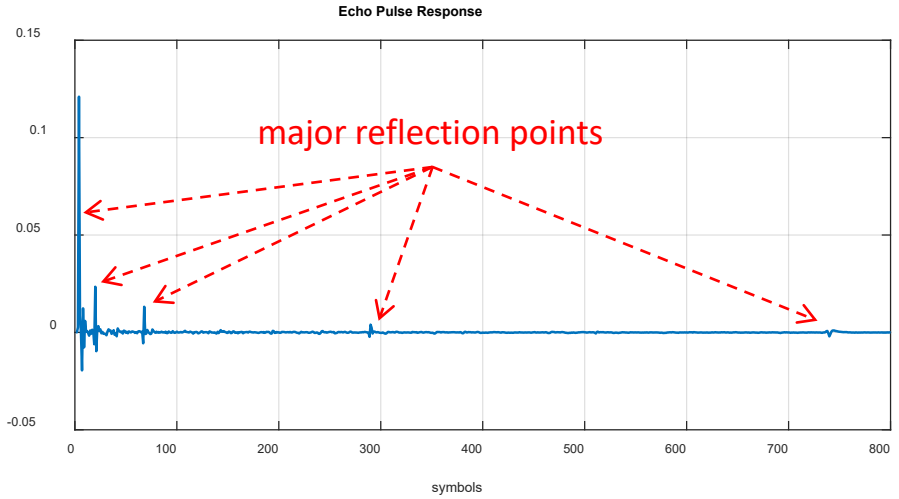


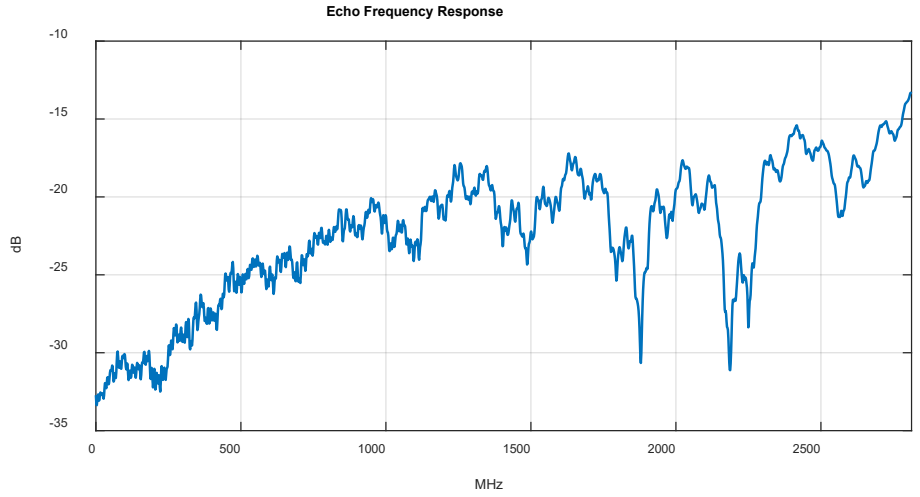


ETHERNOVIA®
VIRTUALIZING VEHICLE COMMUNICATION

Echo

- Link-partners share the same transmission medium
- Transmit signal echoes back to the local receiver as a source of interference to the far-end signal
- **Echo Canceller** is responsible to remove this source of interference
- Basic properties of echo signal:
  - More power at higher frequencies
  - Balk of the power is confined to major reflection points limited to small time windows





ETHERNOVIA®
VIRTUALIZING VEHICLE COMMUNICATION

Other Noise and Interference Sources

- Wideband thermal noise
- Wideband impulse noise
- Narrowband electro-magnetic interference (EMI)
- Crosstalk
- Various AFE noise sources including
  - Thermal, shot noise, quantization noise, etc.
  - Nonlinearities
  - Common-mode to differential conversion
  - etc.
- PLL noise jitter and phase noise

PMA Functions

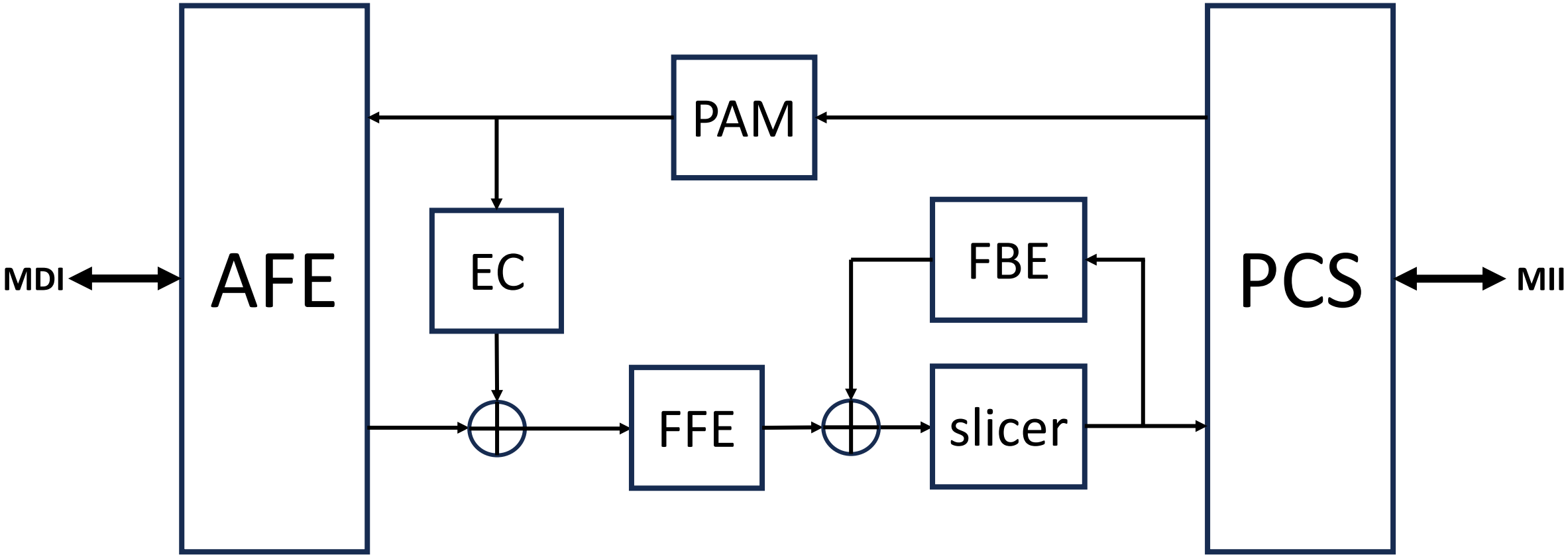
Primary function of the transmitter in PMA sublayer is:

- Pulse-amplitude modulation (PAM)
- Precoding

Primary functions of the receiver in PMA sublayer are:

- Equalization
- Echo Cancellation
- Noise and EMI rejection
- Timing Recovery

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

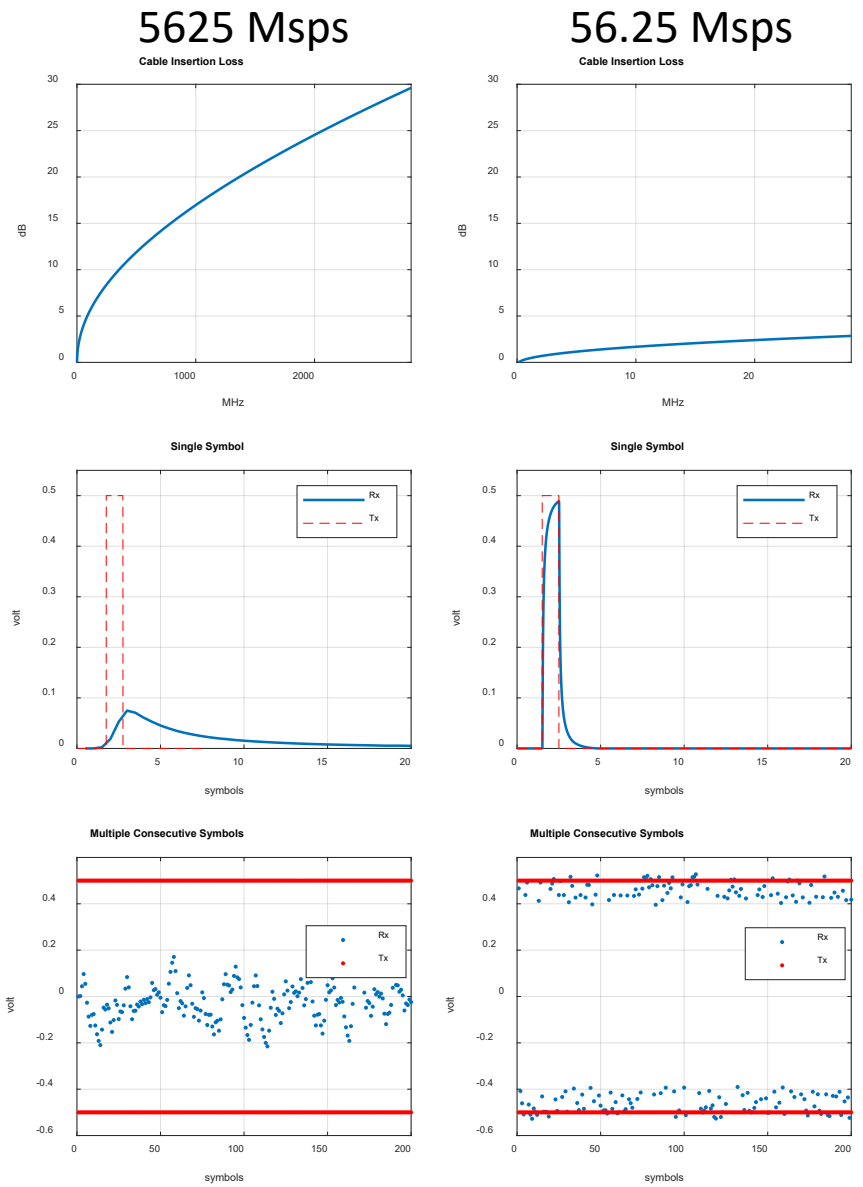
Equalizer Complexity

Higer symbol rate results in

- Wider signalling bandwidth
- Higer channel loss
- Increased ISI

➔ More complex equalization blocks

- Feedback equalizer (FBE), which due to timing constraint is hard to implement, becomes a necessity
- Equalizing filters run at higher frequency
- Longer filters are needed
- Higher resolution of data-path is needed
- Higher resolution of filter coefficients



ETHERNOVIA®
VIRTUALIZING VEHICLE COMMUNICATION

Echo Canceller Complexity

Higer symbol rate results in

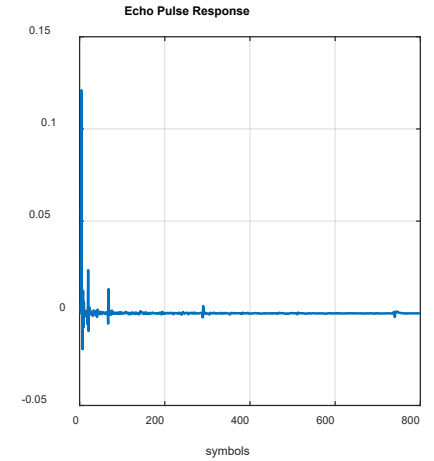
- Wider signalling bandwidth
- Longer span of echo
- More power of echo

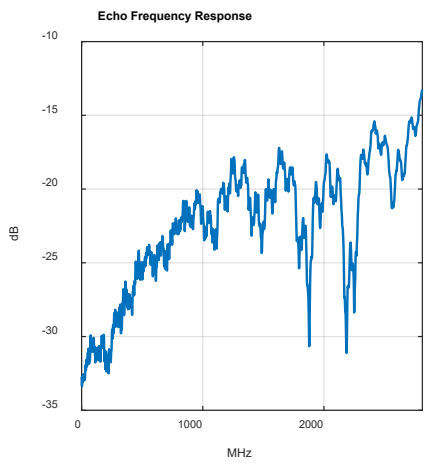
➔ More complex echo canceller

- Echo canceller runs at higher frequency
- Longer filter
- Higher resolution of the coefficients

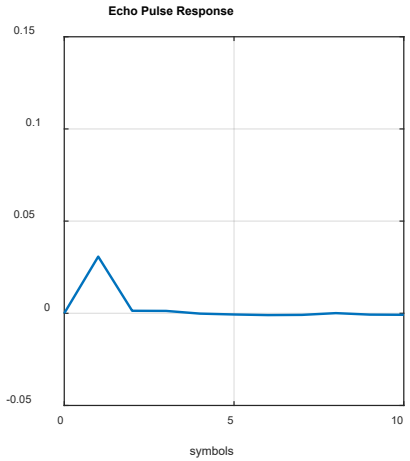
Note: Time domain limits on echo cannel (similar to 802.3cy) reduces the complexity significantly

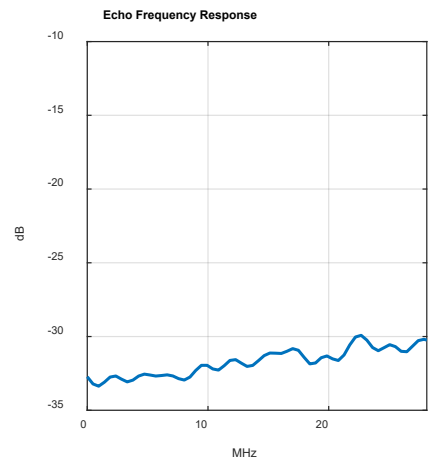
5625 Msps





56.25 Msps





ETHERNOVIA®
VIRTUALIZING VEHICLE COMMUNICATION

EM Immunity

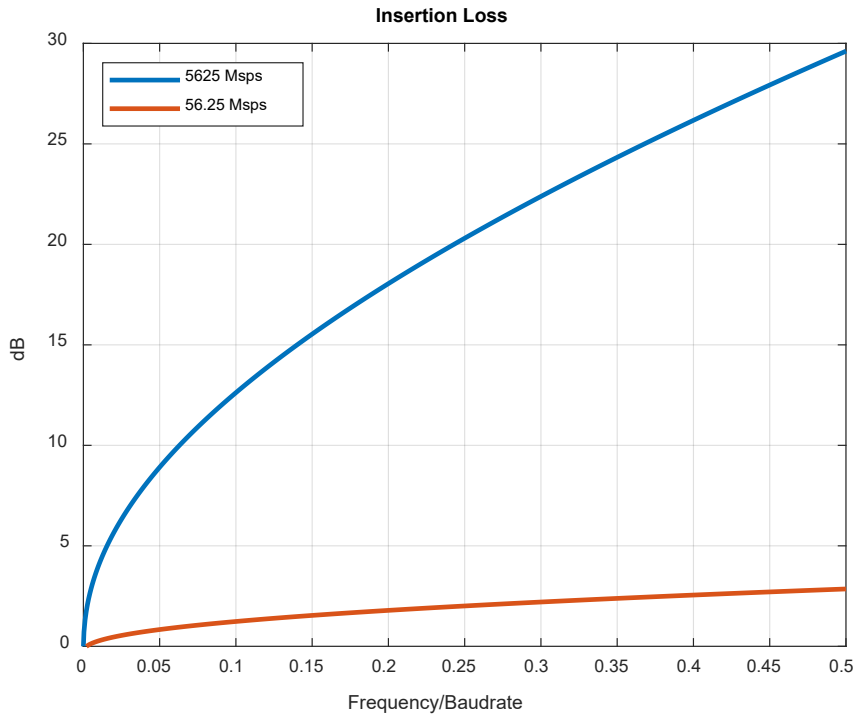
Higher transmit symbol needs wider receiver bandwidth, resulting in:

- More EM sources to fall in the receiver bandwidth
- More powerful EM interference due to higher mode conversion of the cable at higher frequencies
- More complex design to maintain limited mode conversion gain within AFE over a larger bandwidth
- More difficulties in rejection and cancellation of EM interference

AFE and PLL Complexity

Higer symbol rate results in

- 100x wider signalling bandwidth
- 100x higher Analog-Digital conversion rate
- ~37 dB lower tolerated noise floor (from Salz SNR analysis)



Complexity of PLL and clock distribution increases by

- 100x higher clock frequency
- ~30 dB of more phase noise (relative to signal power) from the same amount of timing error

Summary

- Presented an overview of the important sources of noise and interference
- Presented an overview of the fundamental PMA blocks in a transceiver
- Presented an overview of block complexity and their relationship with symbol rate

➔ Complexity grows with symbol rate


ETHERNOVIA®
Thank You