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Channel Requirements for Optimum/Robust PHY Design Beyond 1000BASE-T1

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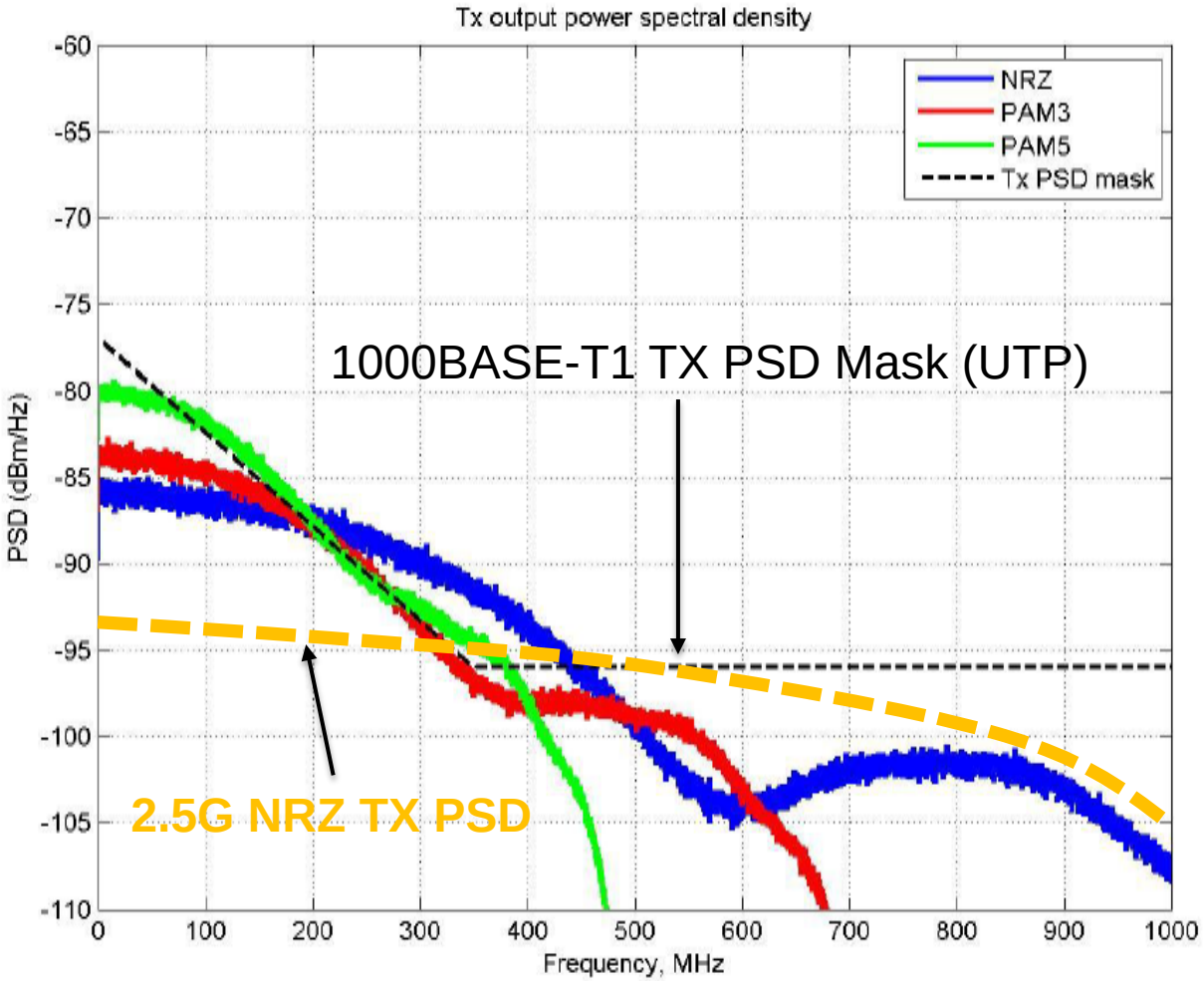
Baud Rate/Modulation and Emission Concerns



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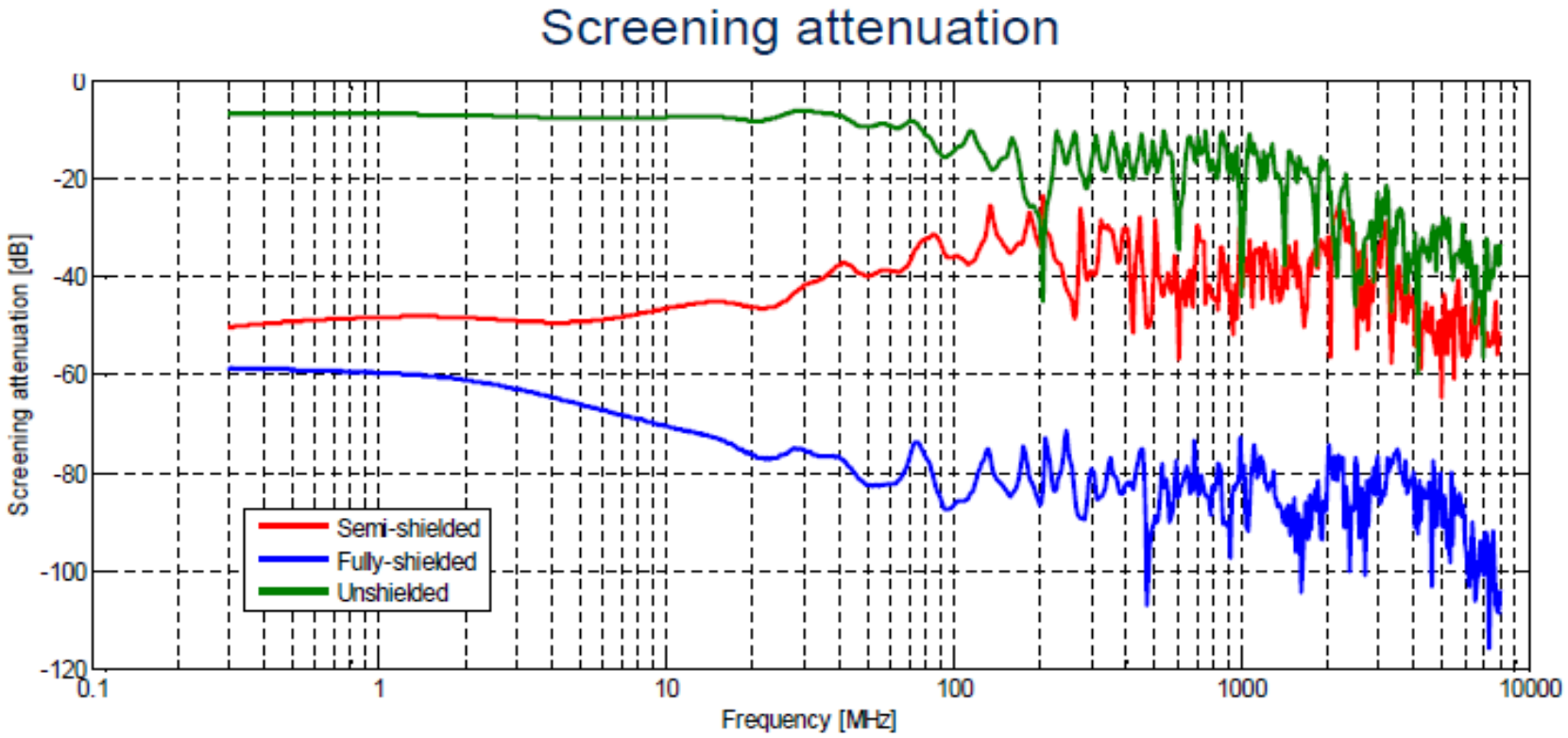
- 1000BASE-T1 modulation selection was not derived by optimum system SNR
- 1000BASE-T1 chose UTP cables as target medium
  - Lack of cable shielding leads to radiated emission violations
- In order to meet emission specs standard committee considered lower baud rates combined with Tx-filtered PAM3 modulation to pass Tx PSD limit line for UTP
- Higher baud rates have proportionally lower PSD levels at a fixed Tx swing
  - Helps meet the target UTP Tx PSD mask

Baud Rate/Modulation and Emission Concerns

- Additionally, STP cables provide notable shielding attenuation compared to UTP
  - Eliminates Tx emission as a limiting factor for baud rate and/or PAM level selection
  - Modulation selection should be based on best SNR per channel characteristics



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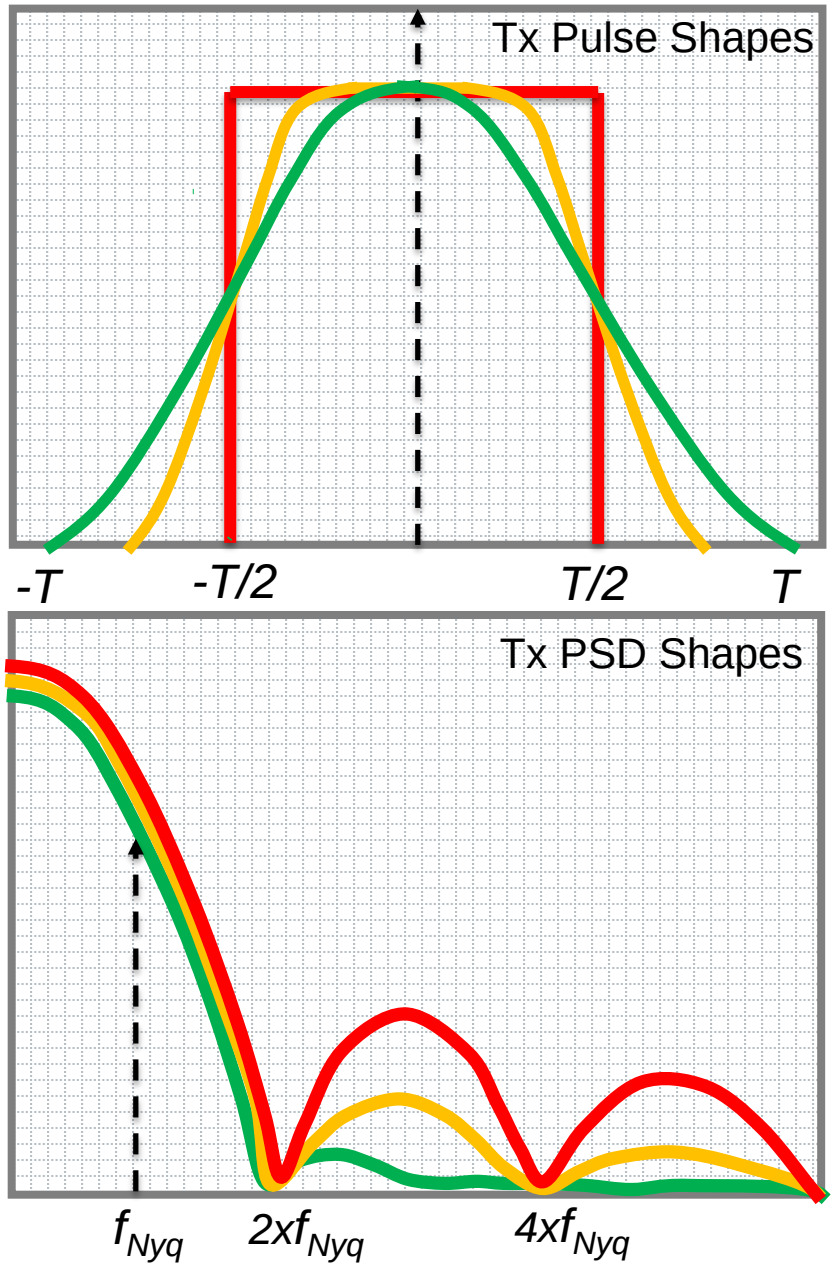
- Also the Committee should define shielding/coupling limit line specs (absolute voltage on the line)
  - Shield proper ground termination plays a major role

Echo Cancellation and Channel Excess BW



- There is a fairly strong transmit power beyond Nyquist frequency, even with proper pulse shaping

Tx Power	Red	Yellow	Green
(f_{Nyq} → Infinite)dB - (0→f_{Nyq})dB	-5.5dB	-7.5dB	-7.9dB

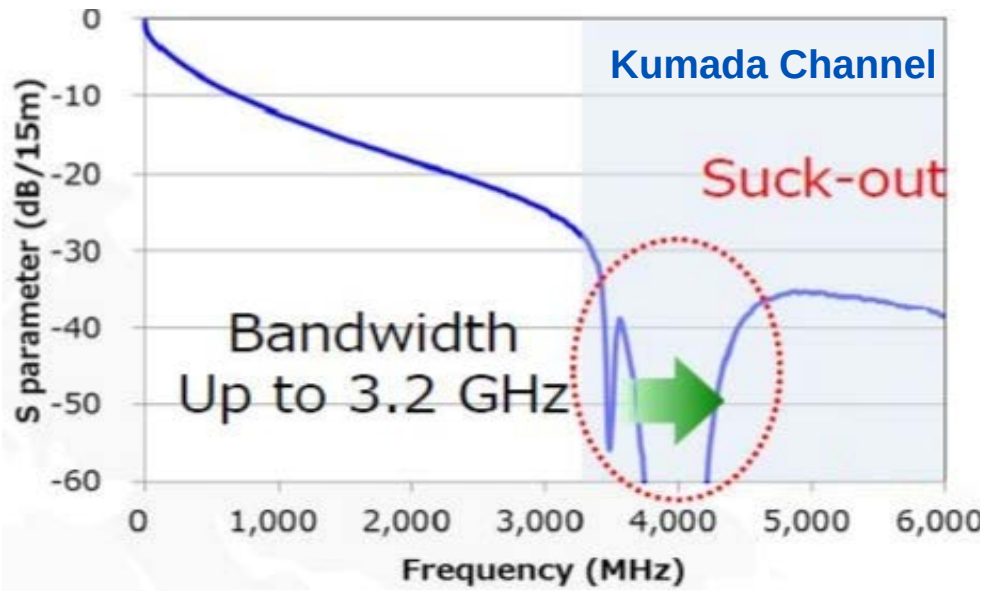
Assuming fixed transmit amplitude

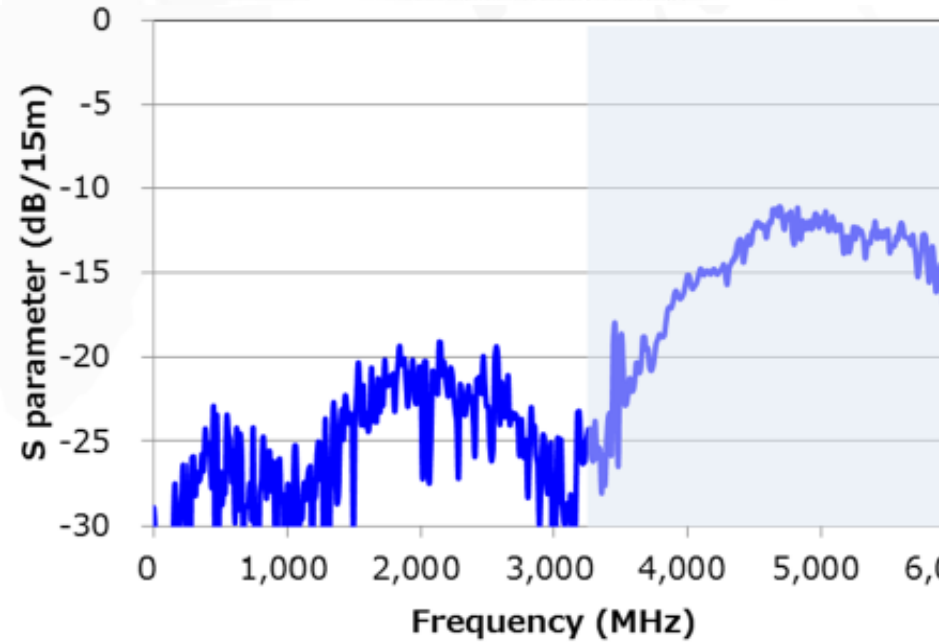
Green Pulse Tx Power	K=100%	K=50%	K=25%
(f_{Nyq} → K.f_{Nyq})dB - (0→f_{Nyq})dB	-8.0dB	-8.5dB	-10dB

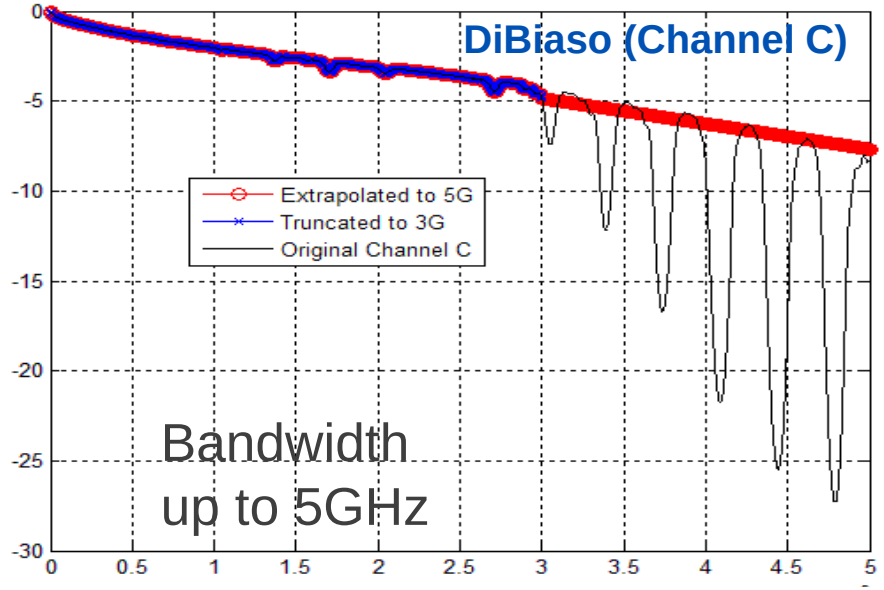
K: Excess Bandwidth

- Tx power beyond f_{Nyq} can be stronger than received signal
  - 10Gbps with PAM8 over DiBiaso/TE channel (IL=~35dB@3GHz)
  - → Received Signal Power= ~11dB (Below Tx Power)
  - → Rx Power < Tx Power in excess BW (even for Green Pulse)
- Echo power can be comparable to Rx power in channels with very low return loss (RL) above f_{Nyq}

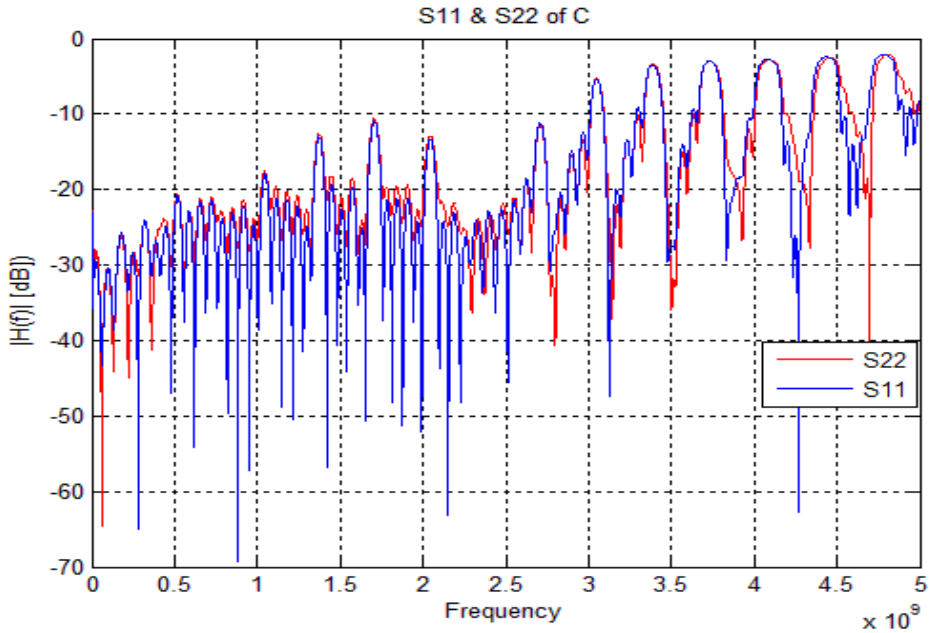
Echo Cancellation and Channel Excess BW





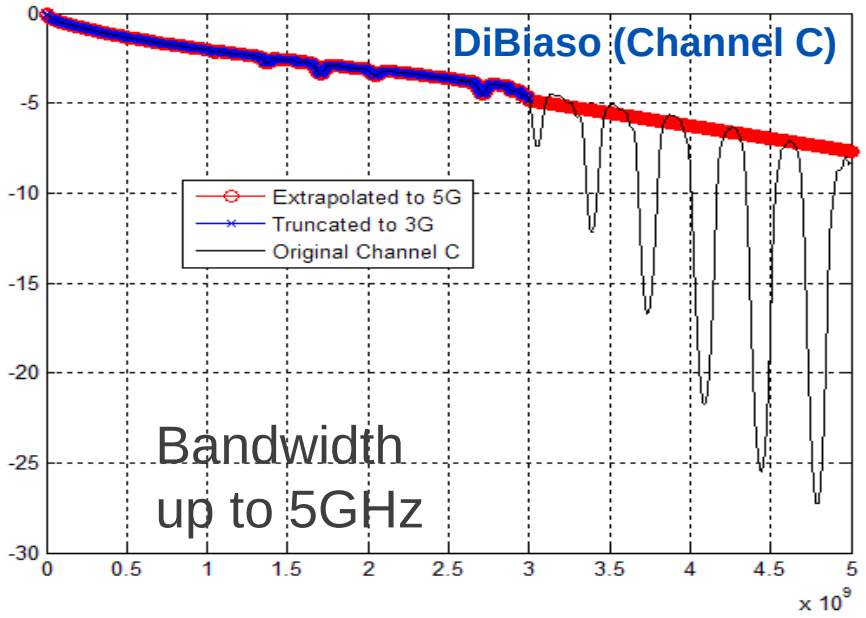


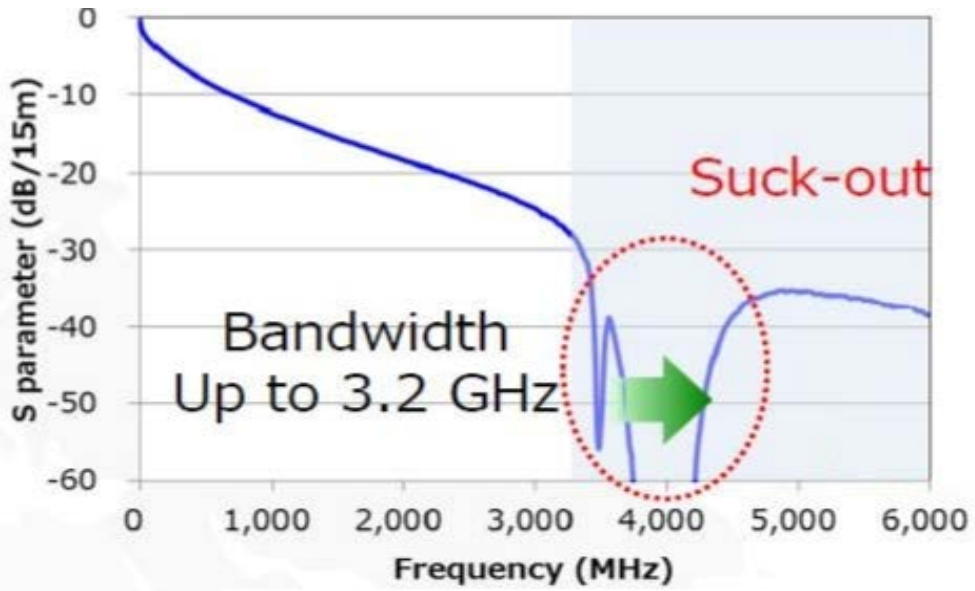
← Insertion Loss (IL)



← Return Loss (RL)

Echo Cancellation and Channel Excess BW





- Given the considerable transmit power above f_{Nyq}, channel response with excess BW beyond Nyquist is necessary in the full-duplex PHY design for proper echo cancellation analysis
  - →Minimum: 25% Excess BW (Covers ~94% of Tx power)
  - →Preferred: 50% Excess BW (Covers ~98% of Tx power)
- This does not dictate the target channel to behave well above f_{Nyq}, but the channel limit lines should be specified for higher frequencies for a robust PHY designed to worst case

  The higher the PAM levels, the higher the accuracy requirements for echo calculation/cancellation
  - →PAM8-PAM16 may need 50% Excess BW
  - →PAM2 (highest baud) should be fine with 25% Excess BW

Coding Overhead

- Major coding overhead is defined by choice of FEC
  - 1000BASE-T1 selected a RS-FEC with 10% overhead
  - FEC choice for 2.5Gbps-10Gbps data rates
    - Negative: Less SNR margin due to higher cable loss and/or higher PAM levels
    - Positive: The cable will be shielded, thus less alien interference coupled to signal

  ➔ FEC overhead of 10% should still be a good rough estimation
- Ethernet coding adds additional (minor) overhead
  - Coding: 64/65 to 512/513 → Worst case overhead: 1.55%

- Need to consider ~11.5% of coding overhead

Bandwidth Requirements for Channel Limit Lines

- A proper DSP analysis should consider all possible modulations to arrive at most robust PHY design
- Therefore, the following bandwidths are recommended for measurements and spec limit lines

*Bandwidth requirement = (Baud@PAM2)/2 * (1+Excess BW) * (1+Coding Overhead)*

  - 2.5Gbps BW Requirement→ 1.25GHz x 1.25 x 1.115 = **1.75GHz**
  - 5.0Gbps BW Requirement→ 2.5GHz x 1.25 x 1.115 = **3.5GHz**
  - 10.0Gbps BW Requirement→ 5.0GHz x 1.25 x 1.115 = **7.0GHz**

Conclusion

- The target channels for higher rates than 1000BASE-T1 are shield cables
  - There will not be any limitations on choice of modulations because of emission requirements
- An optimum and robust full-duplex PHY architecture design should
  - Consider all possible modulations schemes & detailed channel information
- Have as much information as possible about the channel/environment
  - Define voltage magnitude limit lines for different interference sources coupled to the signal lines (e.g. NBI, Impulse)
    - Necessary to find a proper FEC and its associated overhead
  - Define Channel S-parameter limit lines with 40% excess BW above Nyquist
    - 1.25 (Excess BW) x 11.5% (Code overhead) = ~1.40

Thank you.

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