Considerations for Modulation Scheme at 200Gbps/lane

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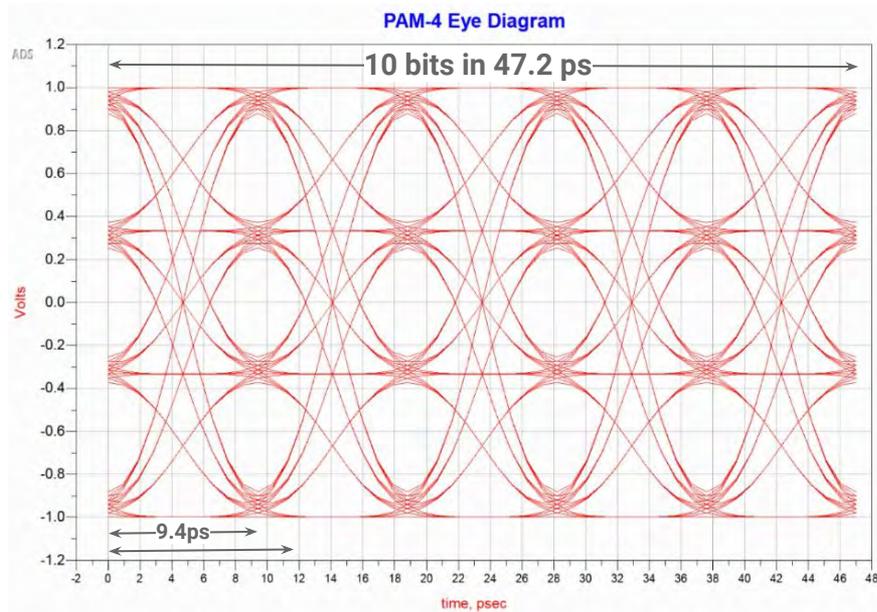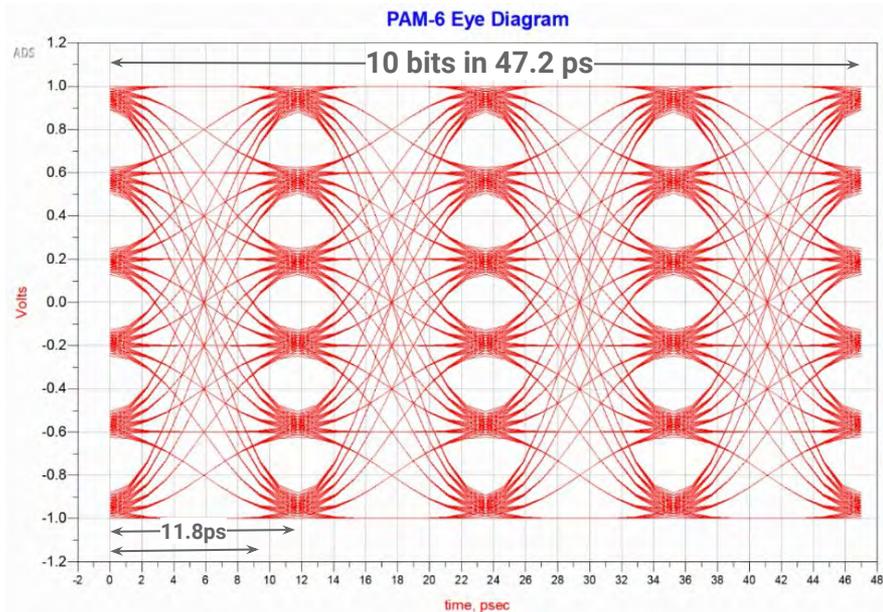
Outline

- PAM modulation review
- Optical vs electrical modulation
- Channel characteristics
  - trace loss
  - BGA
  - connector
- Channel requirements
- Recommendations

PAM6 and PAM4

PAM-6 Eye Diagram — 10 bits in 47.2 ps, 11.8ps

PAM-4 Eye Diagram — 10 bits in 47.2 ps, 9.4ps

	PAM6	PAM4
Nyquist frequency @ 212.5Gbps	42.5 GHz	53.125 GHz
Unit Interval	11.8 ps	9.4 ps
Relative TX eye height	0.20	0.33

Plots courtesy J. LaDue, Keysight

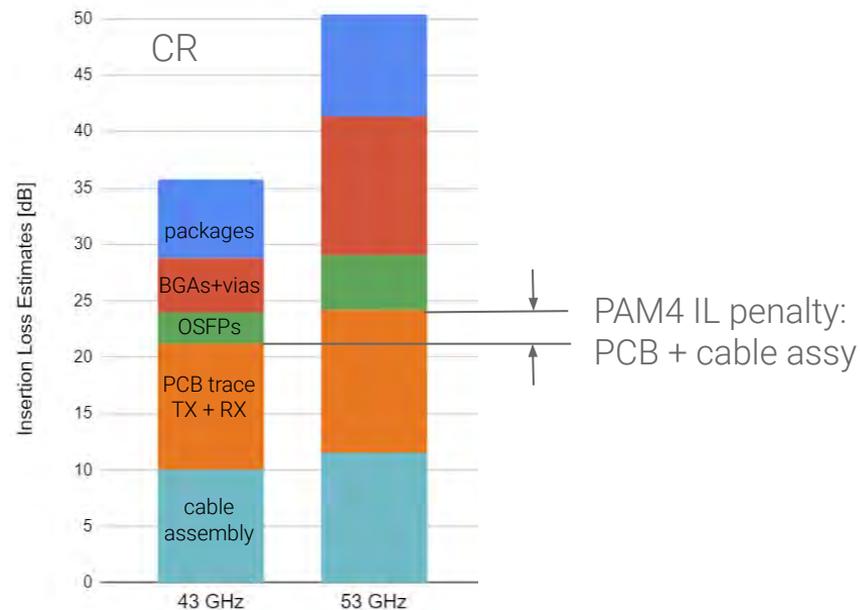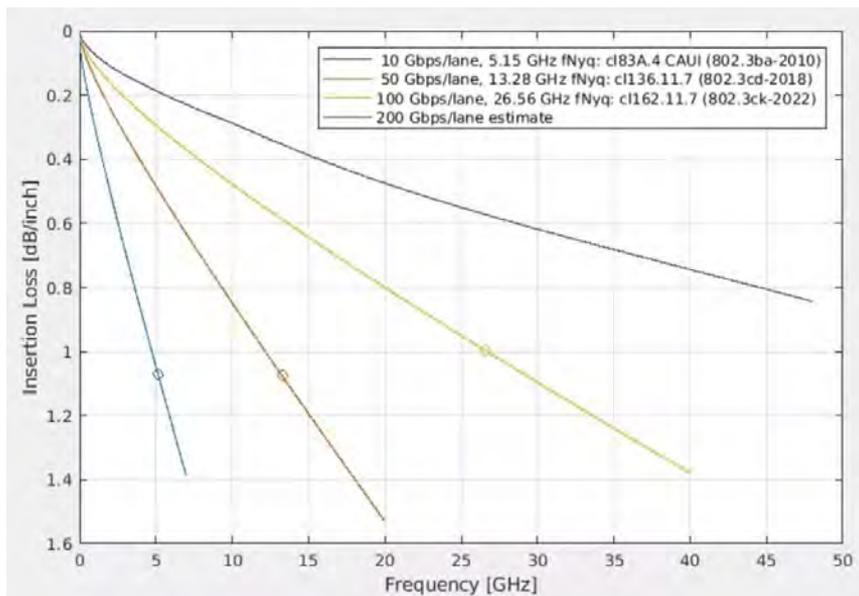# Modulation Considerations

PAM6	PAM4
Pros - Lower loss channels - Nyquist farther from IL cliff Cons - Eye height penalty ~4.4dB - Differs from optical modulation - More complex serdes - Backward compatibility	Pros - Simpler, proven modulation - Backward compatibility with 50G PAM4, 25G NRZ Cons - Higher trace, package and twinax insertion loss - Impairments accentuated by higher Nyquist - Mating interface less robust - Transverse dimensions approaching half-wavelength

Modulation Considerations

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PCB trace loss

- Best-in-class resin, glass, and copper can achieve ~0.8dB/inch at 43GHz, ~0.9dB/inch at 53GHz
- Loss is well behaved, suited to CTLE compensation
- For CR channels, PCB trace + twinax loss difference (43->53GHz) is similar to PAM6 eye height penalty (4.4dB); different penalty models for PAM4 and PAM6, key area of investigation for task force
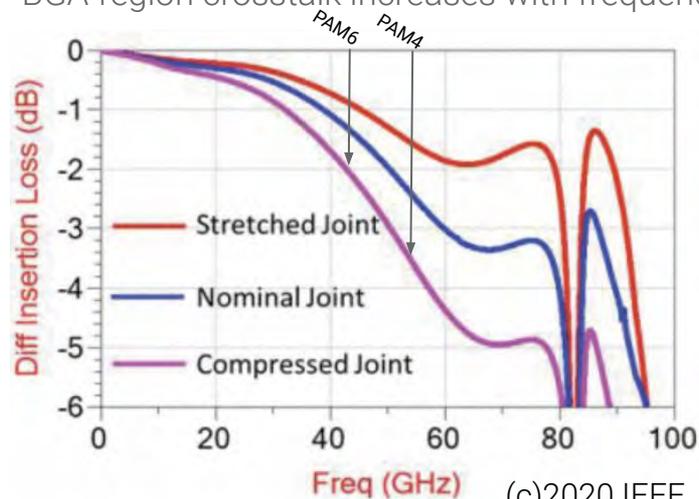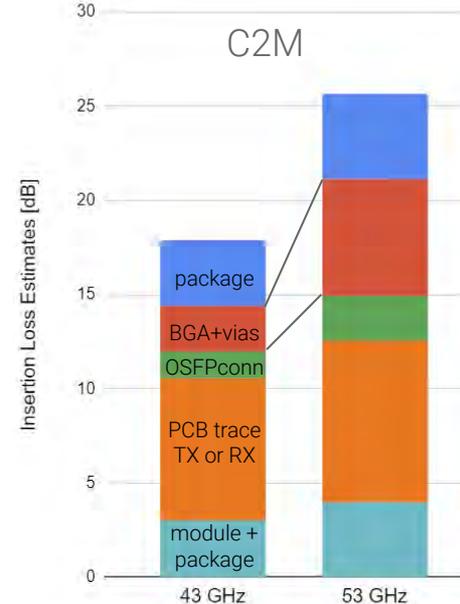
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Impairments in Next Generation: BGA

- Solder ball (BGA) dimensions affect roll-off characteristics - multiple reflections, challenging for short channels
- No measured data in 40-60GHz band - simulation only
- Large ASIC BGA/via roll-off differs from small testchip (large package => larger joint to mitigate warpage)
- BGA-region crosstalk increases with frequency eg additional 8dB 43GHz->53GHz

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J. Sun, Z. Qian, C. S. Geyik and K. Aygün, "Accurate BGA Package Solder Joint Modeling for High Speed SerDes Interfaces," *2020 IEEE 29th Conference on Electrical Performance of Electronic Packaging and Systems (EPEPS)*, Oct. 2020.
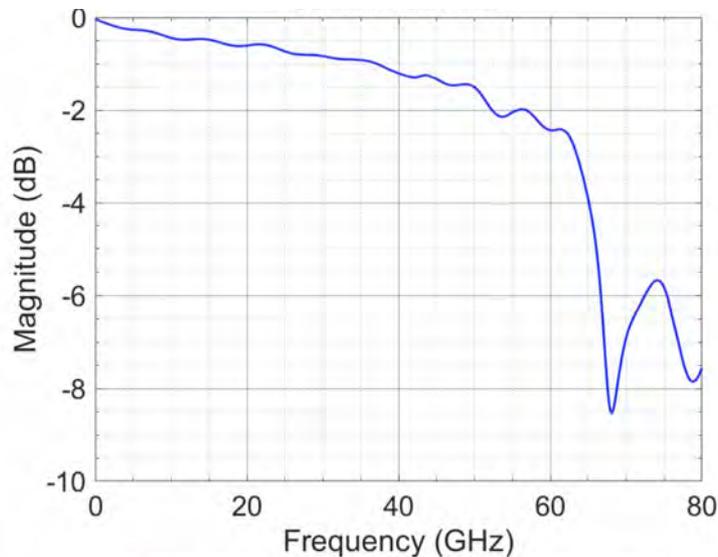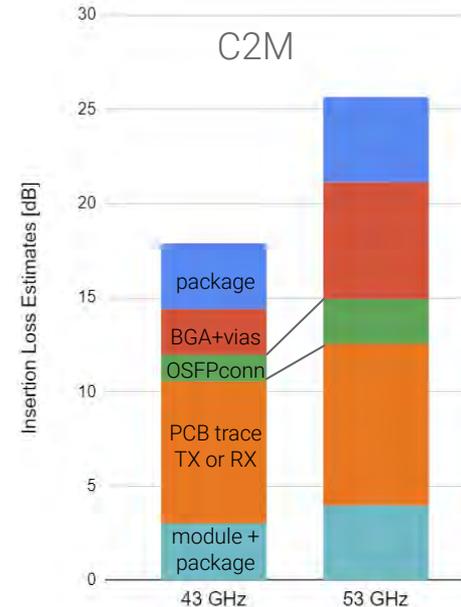
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	  ● **Mating interface less robust**
	  ● Transverse dimensions approaching lambda/2

Impairments in Next Generation: Connectors

- mating interface for 200GEL under consideration in OSFP200 MSA
- no measured data - simulations only
- sharp rolloff (with strong reflection) just beyond Nyquist - acceptable?
- modifications to pad geometries to shift rolloff - field robustness concerns if shift too far


With permission A.Hammoodi, Amphenol

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Channel Frequency Limit

- What channel bandwidth is required for 200Gbps/lane-generation serdes?
    - Investigate benefits of choosing Nyquist well below IL cliff - manufacturability, yield
- Need to consider channel limitations when studying FEC overhead
- Recommend we specify channel to 67GHz (and not beyond) to align with test equipment broad availability (1.85mm test connector limit is 67GHz)
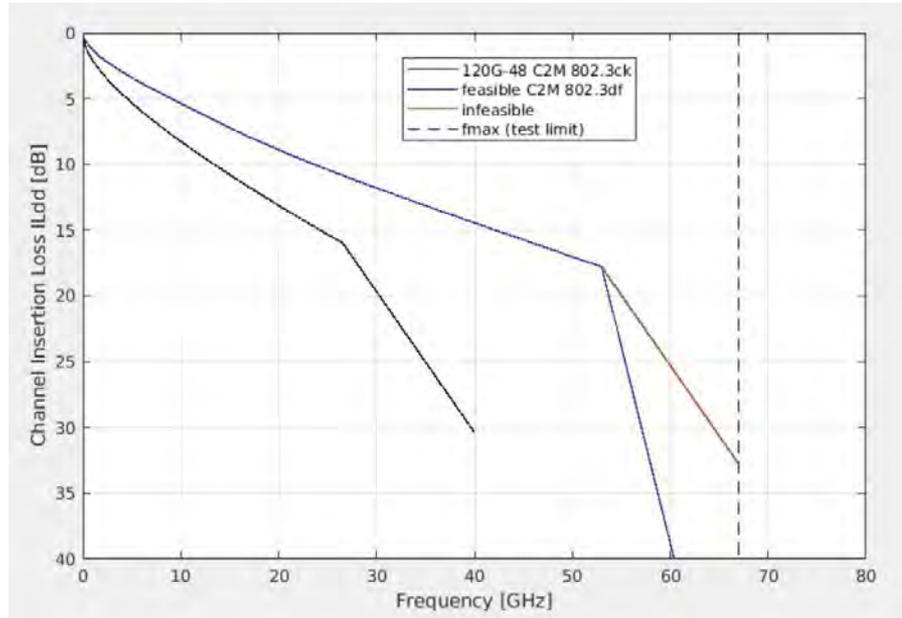
Recommendations

Choose host-side modulation based on electrical channel characteristics and serdes capabilities
- Consider line-side modulation (optical PMDs) independently
- Strong preference for universal port supporting C2M and CR

Align on channel assumptions; use measured data
- Solder ball characteristics
- Connector mating interface
- Crosstalk - particular concern in BGA/via region

Explore Serdes capabilities
- Define steep rolloff - frequency and slope
- Restrict range over which we specify and measure channel to <= 67GHz

PAM6 has many advantages from a channel impairment perspective.
These advantages warrant a detailed end-to-end link analysis and comparison with PAM4 in the task force