Power Comparison of 106Gbps Dual-Duplex and Single-Duplex PHY Architectures

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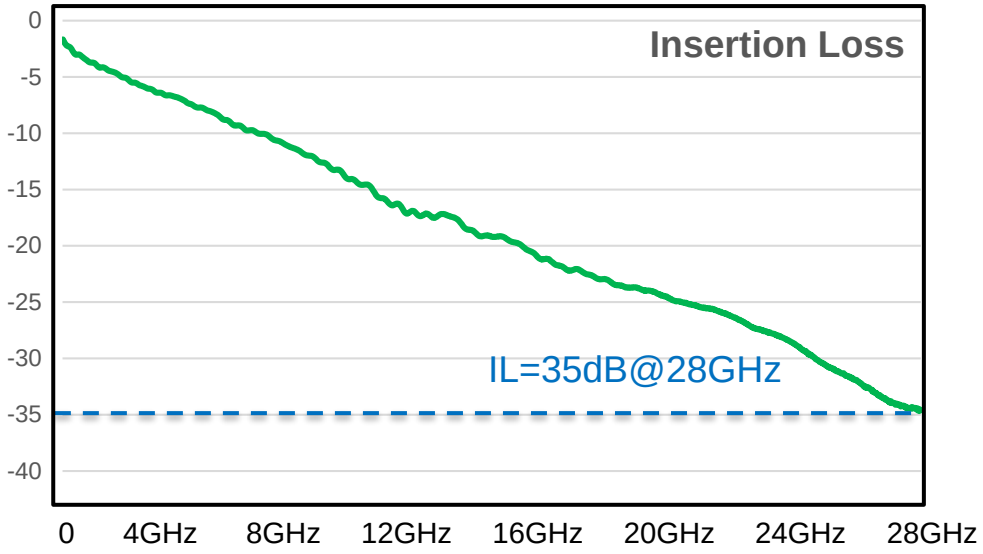
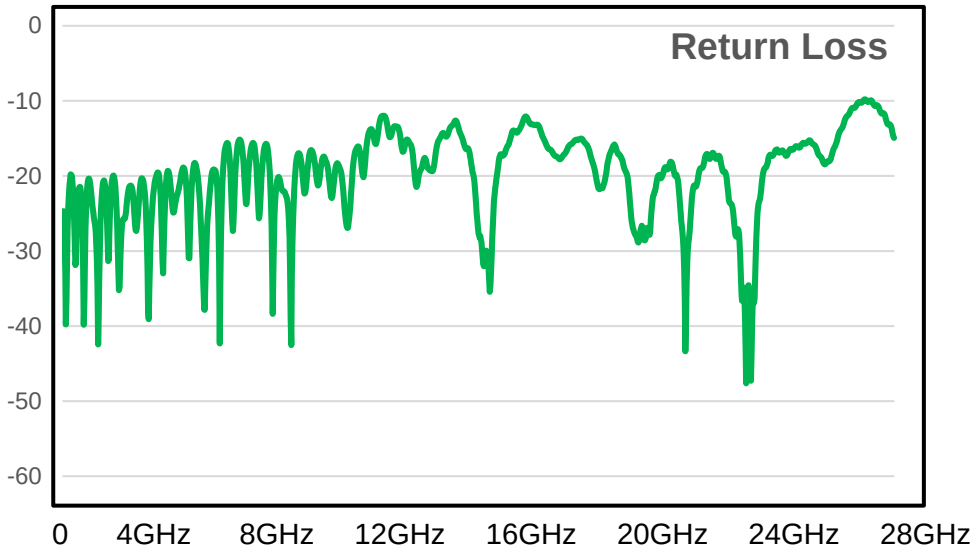
100Gbps Power Tradeoffs Over a Common Electrical Link

Sample 20” PCB + Connector





Goal: Power comparison analysis for Single-Duplex (SD) and Dual-Duplex (DD) schemes over a common channel (shown) and common process technology node (7nm)

Dual-Duplex: 2xReceiver/2xTransmitter

- DSP: 53Gbps Equalizer + Echo Cancellers
- AFE: 53Gbps ADC/DAC/CTLE/PGA
- Clocking: 53Gbps jitter spec
- 106Gbps Mux/Demux & FEC/PCS

Single-Duplex: 1xReceiver/1xTransmitter

- DSP: 2x-4x FIR Equalizer of 53Gbps
- AFE: 2x Sampling rate/2x Gain. BW of 53Gbps
- Clocking: ½ jitter spec of 53Gbps
- 106Gbps Mux/Demux & FEC/PCS

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Digital/DSP Power Comparison over an Electrical Link

Single Duplex: PAM4 & 53Gbaud

- Assumptions:
  - ADC:8bit/6.5ENOB, Tx:1Vpk-pk,Jitter:0.15ps-rms
  - Channel Noise: -150dBm/Hz (AWGN)
  - 1-Tap DFE
  - FIR Power: 0.03mW/tap/Gbaud/data_res

FFE Taps	16 Tap	32-tap
SNR Margin	2.0	3.8

  - ➔FFE Power:
    - 32 Taps → 0.03*32tap*8bit*53Gbaud=~400mW
- Total DSP Canceller FIR Power=~**400mW**
  - 1-tap 53Gbaud DFE: More pipelining/buffering
    - ~2x power of 1-tap 26.5Gbaud DFE

Dual Duplex: PAM4 & 26.5Gbaud

- Assumptions:
  - ADC:8bit/6.5ENOB, Tx:1Vpk-pk, Jitter:0.3ps-rms
  - Channel Noise: -150dBm/Hz (AWGN)
  - 1-Tap DFE & 64-Tap Echo Canceller
  - FIR Power: 0.03mW/tap/Gbaud/data_res

FFE Taps	8 Tap	16-tap
SNR Margin	3.94	6.54

  - ➔FFE Power
    - 8 Taps → 0.03*8tap*8bit*26.5Gbaud =~50mW
  - ➔Echo Canceller power
    - 64 Taps → 0.03*64tap*2bit*26.5Gbaud =~100mW
- Total DSP Cancellers Power=2x150mW=~**300mW**

AFE/Clocking Power Comparison over an Electrical Link

Power Relative to SD 53G PAM4 AFE: ADC, DAC/Driver, PGA/CTLE, Clocking

Single Duplex: 1x Transceiver 53Gbaud PAM4

- ADC: 2.5xPower=250mW*
  - 2x Parallelism→ 2x Power=200mW
  - 53GHz S&H / 1:2DeMux → 0.5x Power=50mW
- DAC/Driver: 3x DAC+1x Driver= 225mW*
  - 2x Parallelism→ 2x Power=140mW
    - 53GHz 1:2Mux PreDriver → 1x Power=70mW
  - Line Driver (1V pk-pk): 15mW
- PGA/CTLE: 4xPower= 200mW*
  - 2xBW→ ½ R_{load}→ Gain=Gm.R_{load}=1 → 2xGm→ 4xI_{bias}
- AFE Total Estimate= 675mW*
- 53Gbaud Clocking: >2x Power
  - 2xf_{clk} & ½ Jitter→ 2x CV^2f_{clk} & Bigger Buffers→ >2x Power

Dual Duplex: 2x Transceiver 26.5Gbaud PAM4

- ADC: 2xPower=200mW*
  - 2x Transceiver→ 2x ADC=200mW
- DAC/Driver: 2xDAC+2x Driver= 170mW*
  - 2x Transceiver → 2x Power=140mW
  - 2x Line Driver (1V pk-pk): 30mW
- Hybrid: 2xPower= 100mW*
- PGA/CTLE: 2xPower= 100mW*
  - 2x Transceiver at same Gain.BW → 2xPower
- AFE Total Estimate= 570mW*
- 26.5Gbaud Clocking: 2x Power
  - 2x Transceiver at same f_{clk} → 2x Power

* Estimation based on extrapolation

Summary: DD vs. SD PHYs over an Electrical Link

- DD vs. SD Digital Power
  - Same 106Gbps Mux/Demux, Datapath and FEC/PCS
  - DSP power is dominated by FIR cancellers
    - Dual Duplex FIRs Power → ~300mW
    - Single Duplex FIRs Power → ~400mW

} Digital Delta= ~100mW

- DD vs. SD Analog Power
  - DD 106Gbps AFE includes 2x 53Gbps AFE and 2x Hybrid → DD AFE = 570mW
  - SD 106Gbps AFE at 2x BW consumes over 2x of 53Gbps AFE→ SD AFE = 675mW

} Analog Delta= ~100mW

- A Dual-Duplex PHY can operate 106Gbps over longer-reach/higher-loss/lower-cost media than a Single Duplex PHY, while its power consumption can be as low as ~20% (~200mW) lower than Single-Duplex PHY if operating over the same media

106Gbps/lane DAC Solution: SD Optical vs. DD Electrical

Active Optical DAC solution

- Reach:
  - > 10m over existing MMF
- Power: (assuming C-M is 100Gbps SD link)
  - ~1.1W(ASIC)+~1.1W(Mod)+~2.5W(Optics)= ~4.7W
- Cost:
  - Optical DAC always much higher cost than copper counter parts
  - Not an option for backplane applications. Needs upgrade

Passive/Active Electrical DD DAC solution

- Reach:
  - Passive: >3m on 30AWG and >5m on 26AWG
  - Active: >5m on 30AWG and >10m on 24AWG
- Power: (assuming C-M is 100Gbps DD link)
  - Passive Long Reach: ~1.2W
  - Active: ~1W(ASIC)+~1W(Mod)+1.2W(DAC)= ~3.2W
- Cost:
  - Enables use of existing legacy DAC cables at >3m
  - No need to upgrade backplanes

Thank you.