Return Loss vs. Residual ISI

Richard Mellitz

September 2006

Simulation Conditions

1. Package
    - Tline sections 42 to 55 ohms SE
    - Tline lengths 0.15” to 0.75”
    - BGA PTH vias included
2. Configuration
    - DR : 10.3125Gb/s
3. Transmitter Output (at tx output)
    - 0.8 V_{pp} at package pins
    - Tr = Tf = .24 to 42 UI
    - Rs = 45 to 55 ohms
    - Cs die (capacitance) = .5 to 1.1 pF
    - Bimodel DJ = 0.15 UI_p
    - RJ = 0.130 UI_{pp}
    - DCD = 0.0 UI_{pp}
    - Tj = .28UI
4. Receiver
    - R_L = 45 to 55 ohms
    - C_L die (capacitance) = .5 to 1.1 pF
    - Bw = Two real {poles @ 0.7 DR}
    - Input noise = 1.46mV_{rms}, flat psd to 10.3125 Ghz
5. 3 taps FIR
    5. Floating point resolution
    6. Meet the 802.3ap constraints
6. 5 taps DFE
    - Floating point resolution
7. Crosstalk characteristics
    - Amplitude:
        - Same as Tx
    - Rise/Fall : same as thru channel
    - Pattern : same as thru channel, with random offset
    - Jitter : none
    - Source Z : same as thru channel
    - Equalizer : same settings as TX in thru channel
8. Pass/Fail Criteria at BER 10^{-12}
    - 25 ps eye opening (width) at latch

HVM Card and Backplane System Simulation Conditions

There are 100,000 design variations for systems manufactured by a large variety of manufacturers around the world.

The basic characteristics of the system is that they are relatively short and have are low average loss but high ILD deviation.

The channel descriptions and variation follow.

- 2 connectors
- 6 to 8 vias
- 25-40mil via stubs
- Line card 0.093” - 0.125” mil thick
- Mixtures in length between 7” to 25” made of FR4 and Nelco 13SI
- Via placement and BGA/Connector escape routing varied
- BER Eye opening simulation include variable placement of DC blocking capacitor
- Uncompensated length mismatch (a HVM reality)
- Target impedance 85 ohms and 100 ohms +/- 15%

Channel S Parameter Characteristics

- A(f) (IL fit) has between 7 and 16 db margin at f2
- Only channels with passing ILD were used and had between 0 and 0.7 dB margin
- ICR margin with penalty at fb was between 9 to 12 dB

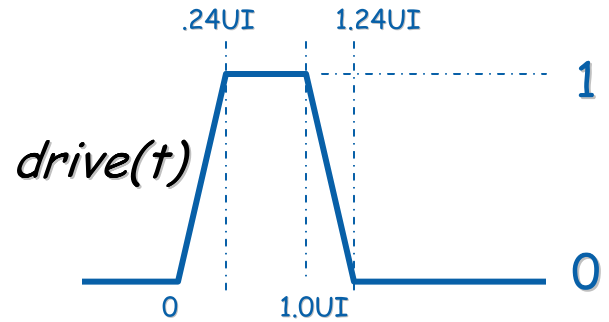
Return Loss Observations

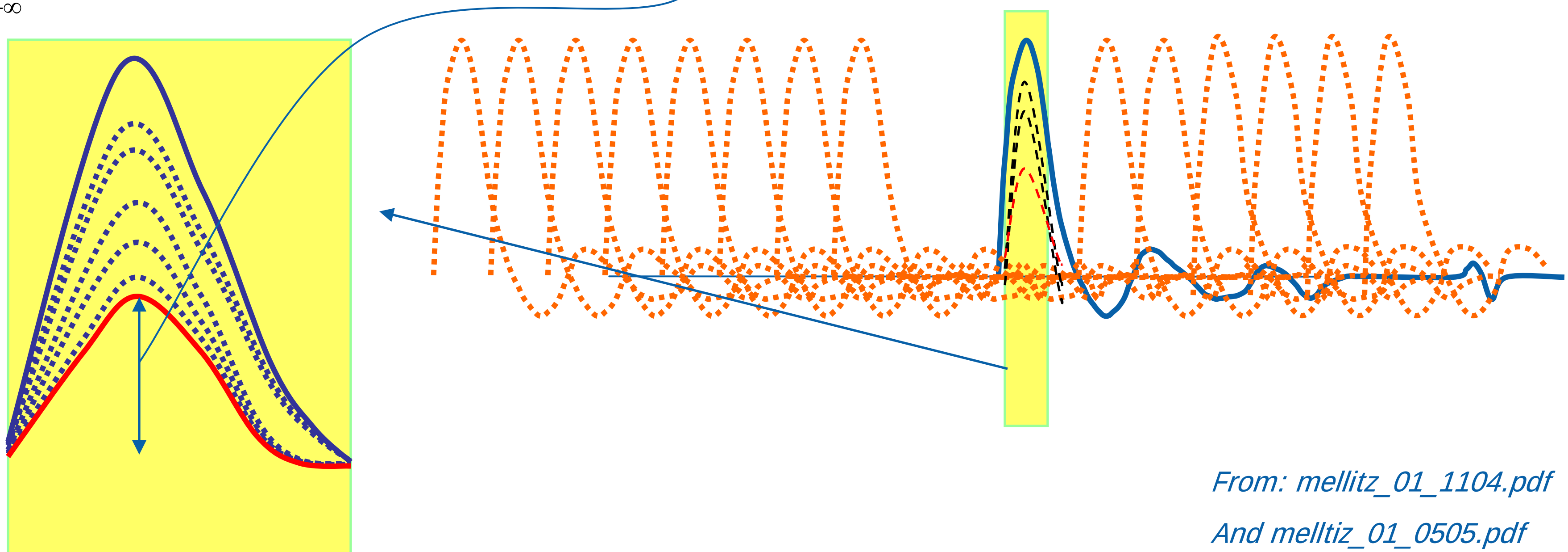
- Not all return loss is equally detrimental
- A transmission line with a differential characteristic impedance of 75 ohms may work fine.
  - Assuming other minimal channel impairments.
  - This line will likely fail the return loss spec
- A channel with reflections that occur more than 5 UI out can pass the return loss test but not work.
- The problem is where the return loss happens.
- The solution is to spec residual ISI not return loss
- Or not spec return loss at all

Max pulse height – Residual ISI Defined

$$pulse21(t) = ifft(sdd21(f)) \otimes drive(t)$$

$$\text{pulse height - residual ISI} = Max(pulse(t) - \sum_{k=5}^{\infty} \left| pulse(t - k*UI) \cdot U_{-1}(t - 5*UI) \right| - \sum_{k=-\infty}^{-2} \left| pulse(t + k*UI) \cdot (1 - U_{-1}(t - UI)) \right|$$





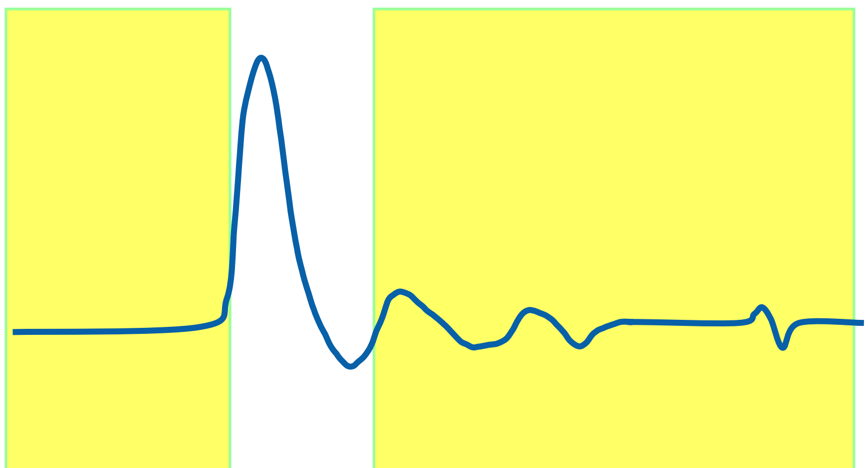
From: mellitz_01_1104.pdf

And melltiz_01_0505.pdf

dB residual ISI power like terms defined

$$\text{dB residual ISI power} =$$

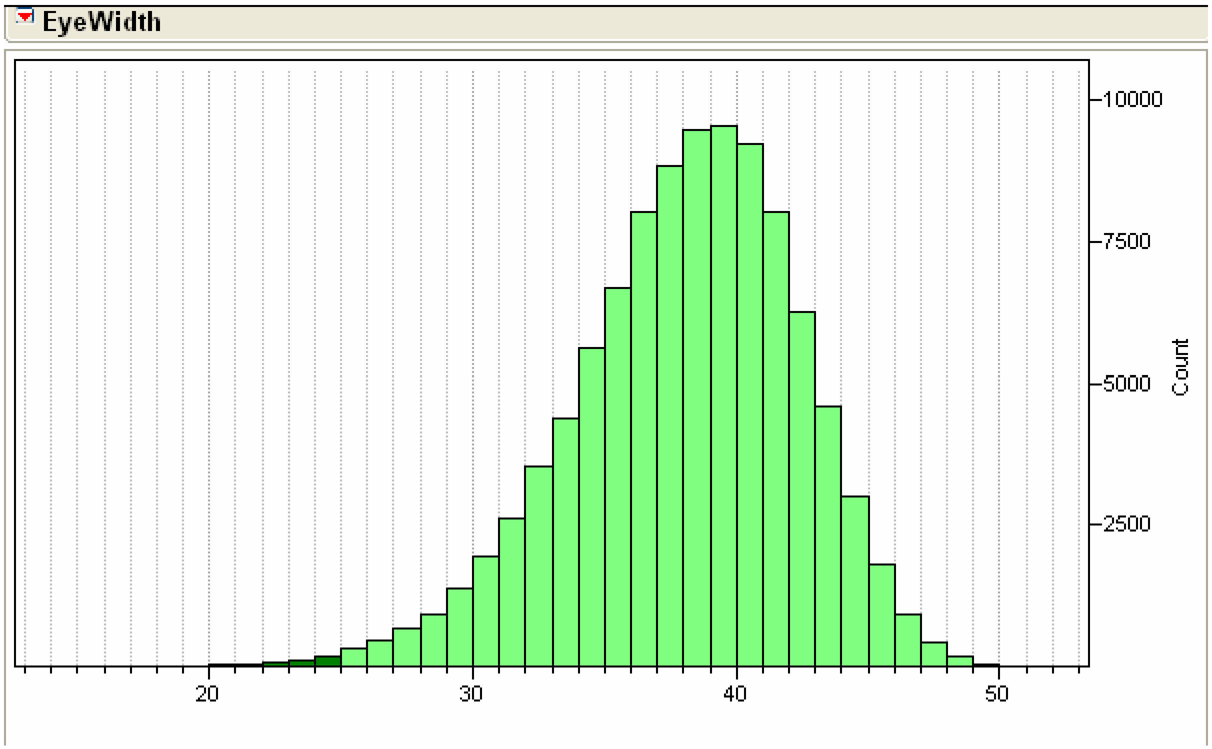
$$10 \cdot \log 10((\text{"pulse height"} - \text{"pulse height - residual ISI"})^2)$$



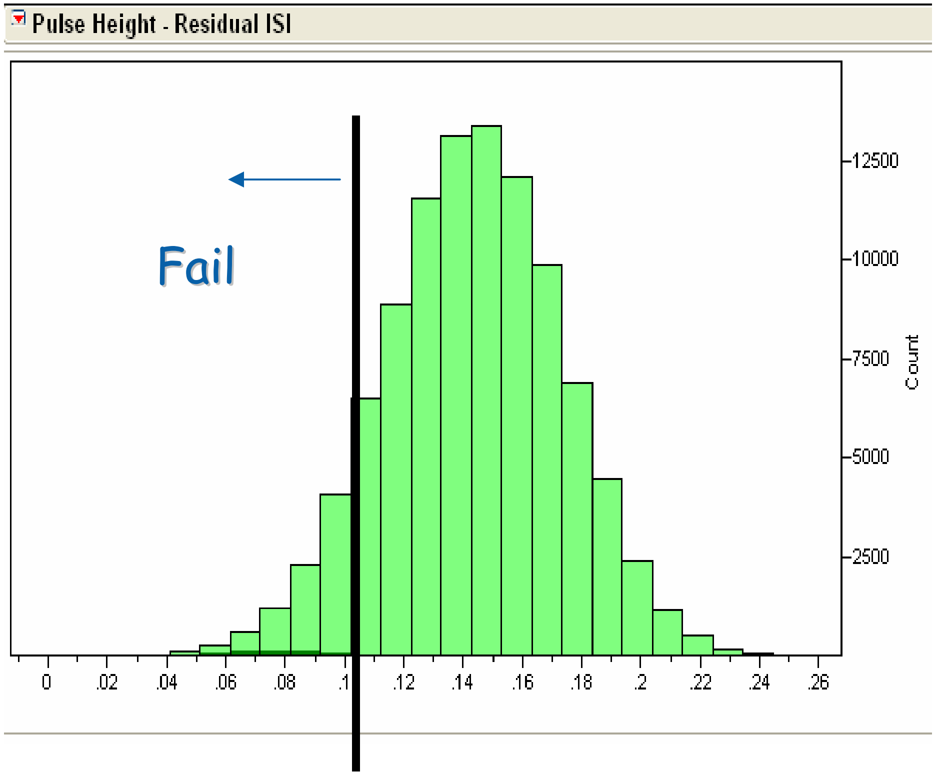
$$\text{PRI (residual ISI S/N dB)} =$$

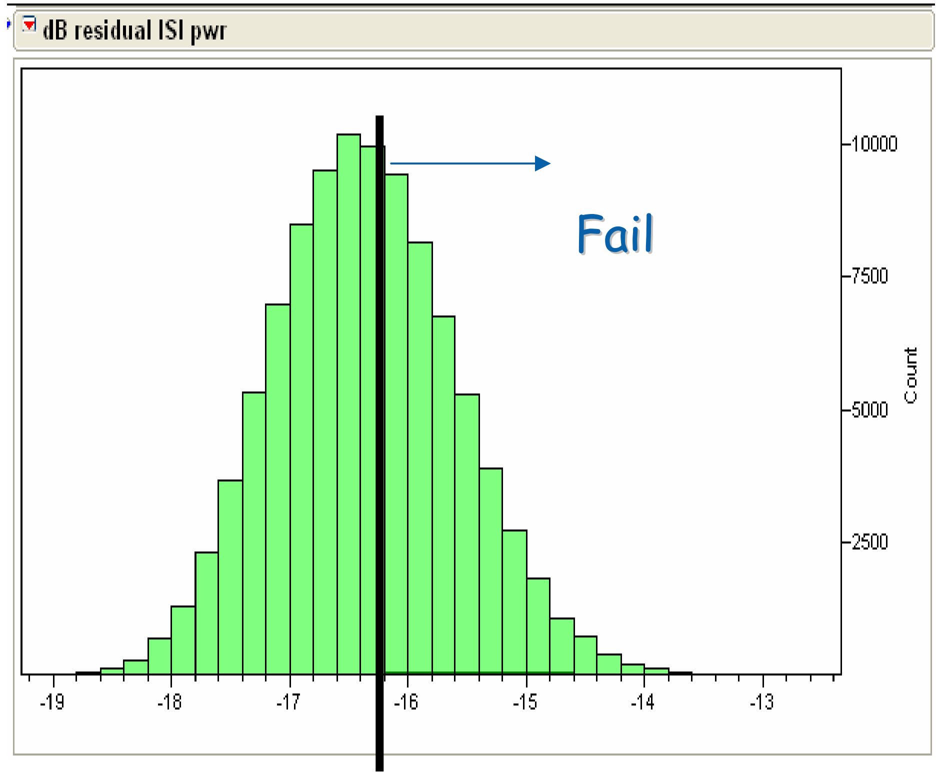
$$10 \cdot \log 10\left(\frac{(\text{"pulse height"} - \text{"pulse height - residual I})^2}{(\text{"pulse height"})^2}\right)$$

Eye width at BER 10^{-12} ~ 0.5% of Population (100000)



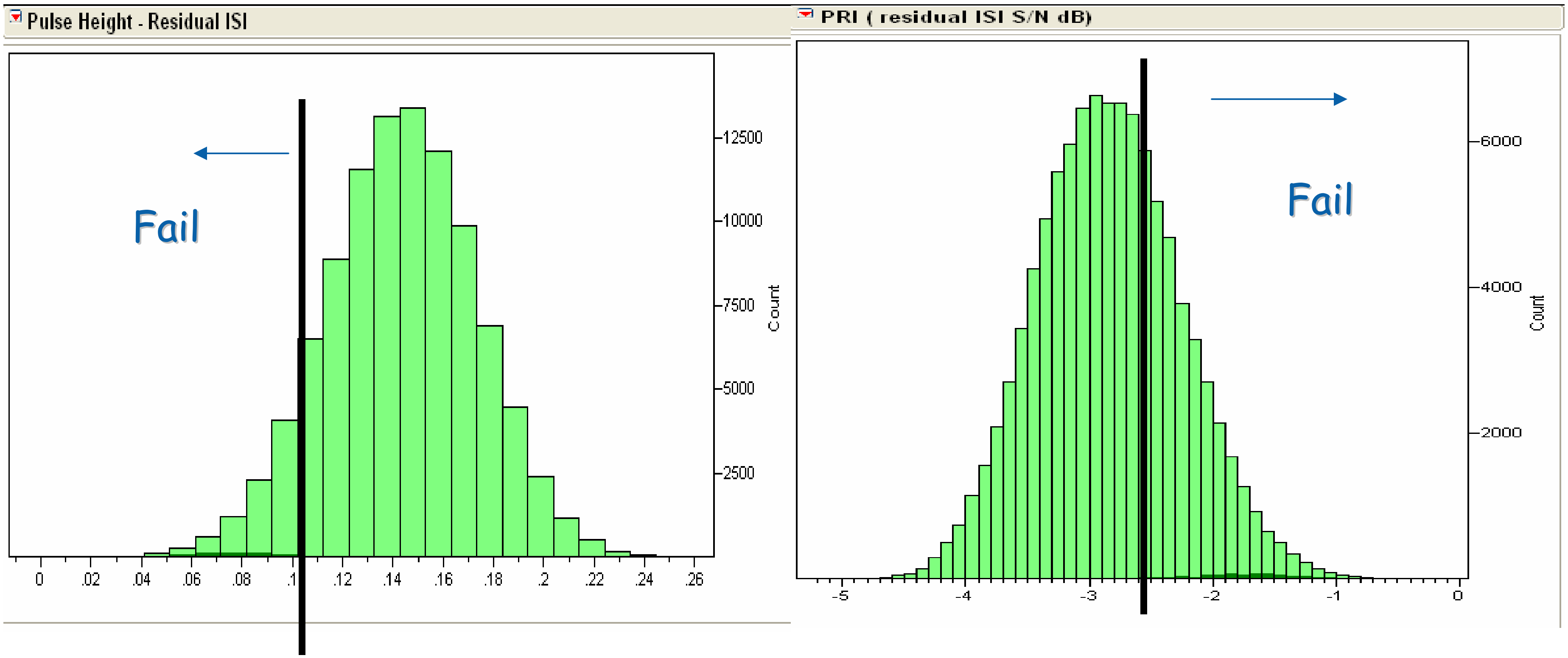
ISI measures





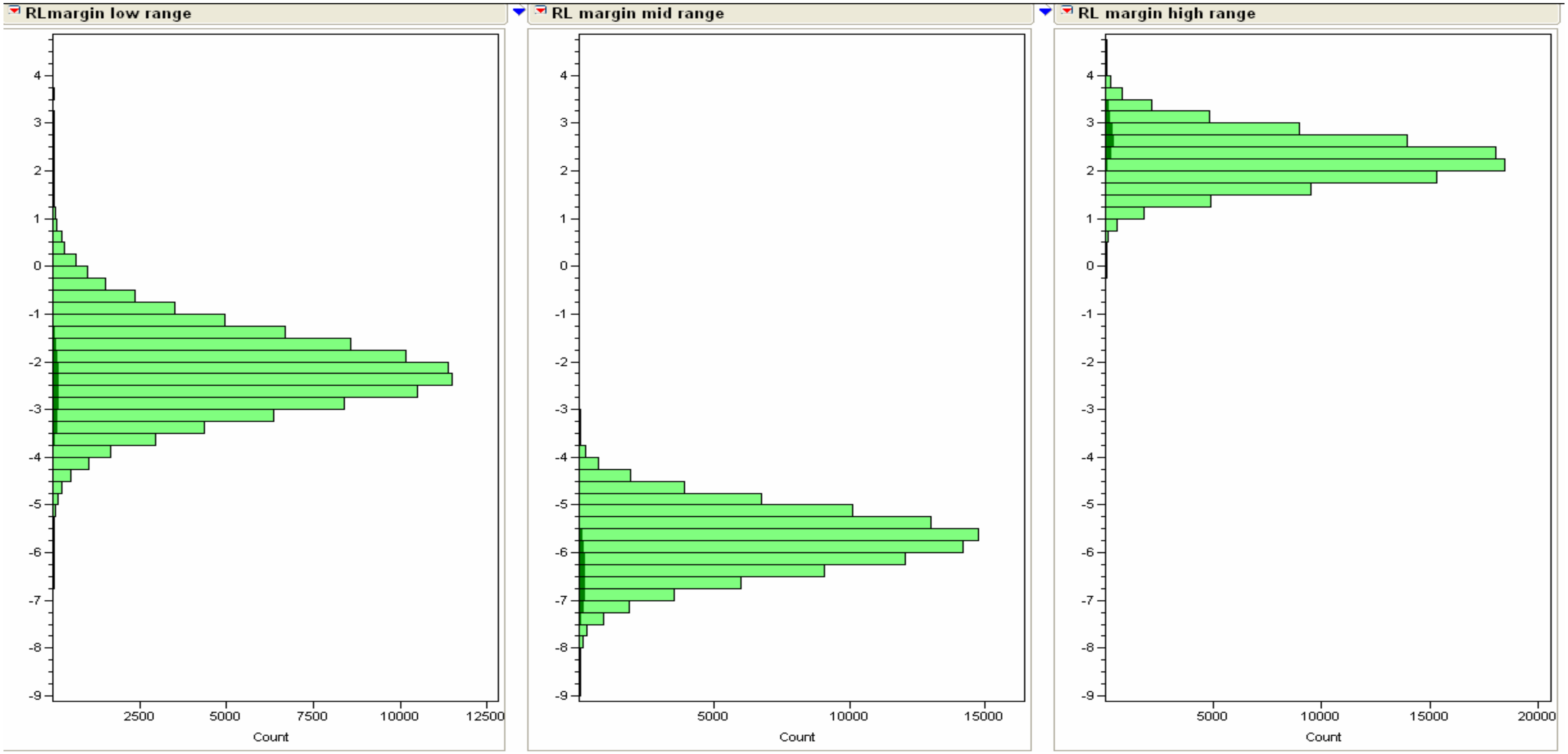
- Dark correspond to failures
- Pulse Height – Residual ISI > .1 passes which results in 8% false negatives
- dB residual ISI PWR < 16.2 passes which results in 40% false negatives

ISI measures (2)



- Dark correspond to failures
- PRI (residual ISI S/N dB)< -2.6 passes which results in 27% false negatives
- Pulse Height – Residual ISI > .1 passes which results in 8% false negatives

Now lets look at RL



- All 100000 fail return loss
- Failures seem to distributed widely over RL range

Conclusion – For Relatively Short Channels with Hi ILD

- "Max pulse height – Residual ISI" is fair predictor of HVM channel quality
- "dB residual ISI PWR" and "PRI (residual ISI S/N dB)" – are a poor predictors of HVM channel quality
- Return Loss is not a predictor of HVM channel quality
- Recommendation
  - Replace RL spec with: "Max pulse height – Residual ISI" should be > 0.1
  - Remove the RL spec
- The saving factor here, if this proposal is rejected, is that the channel model is informative