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Channel Analysis for Defining Reach and BER Objectives

IEEE 802.3 100GCU Study Group
Plenary Meeting, Singapore

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March 15-16, 2011

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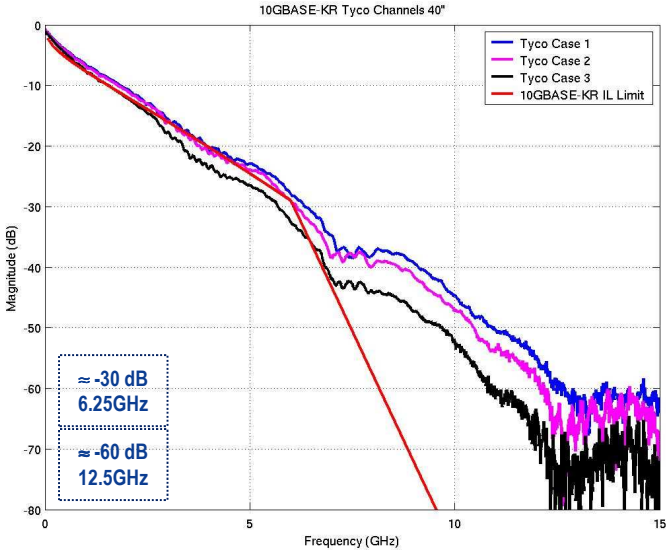
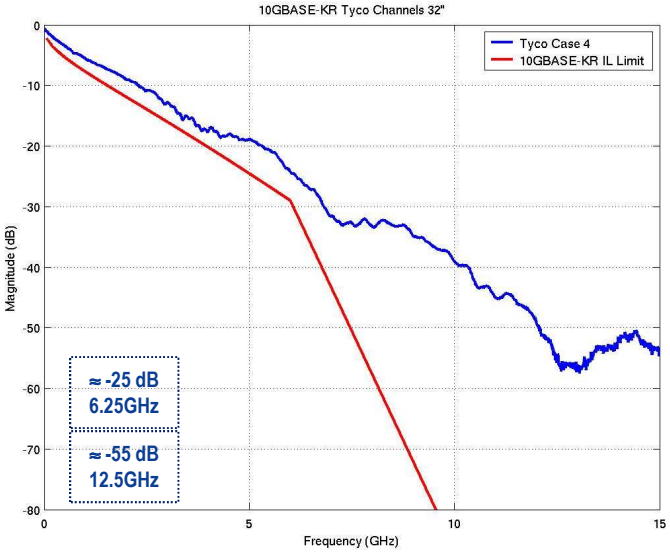
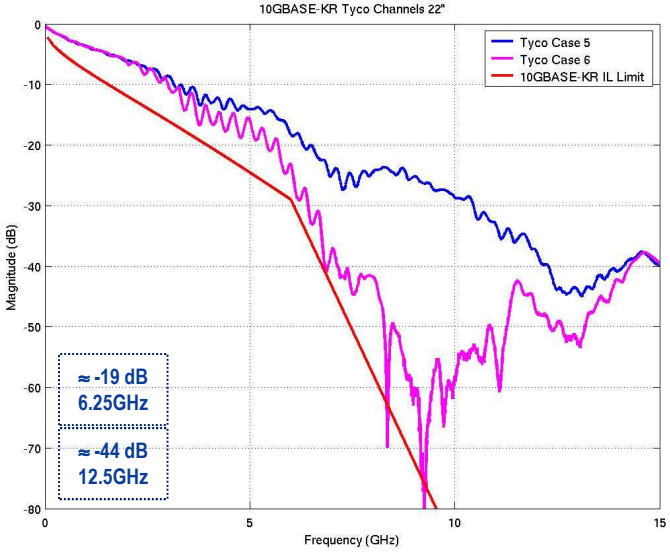
Outline

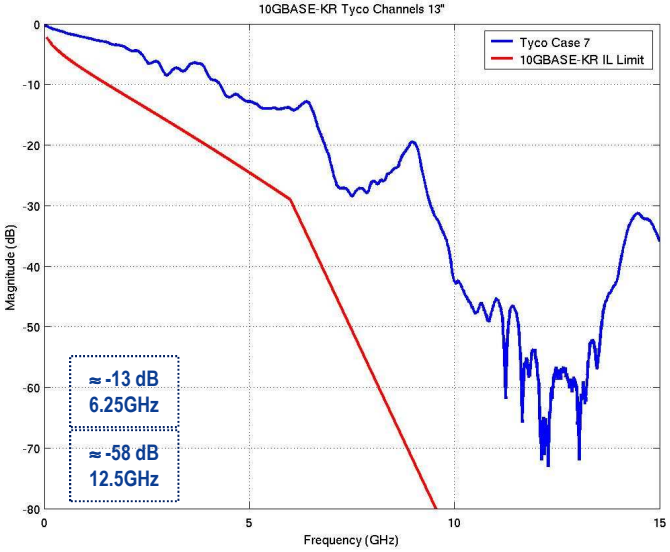
- 10GBASE-KR Channel Analysis:
  - Consider IEEE channel models: Tyco and Intel
  - Establish reference point for SNR calculations at 10Gb/s
  - Investigate performance at 25 Gb/s using PAM-4
- 100GCU Channel Analysis:
  - Consider IEEE channel models: FCI
  - Investigate performance at 25 Gb/s using NRZ and PAM-4
- Reach Objectives
- BER Objectives

10GBASE-KR Tyco Channels: 13” – 40”

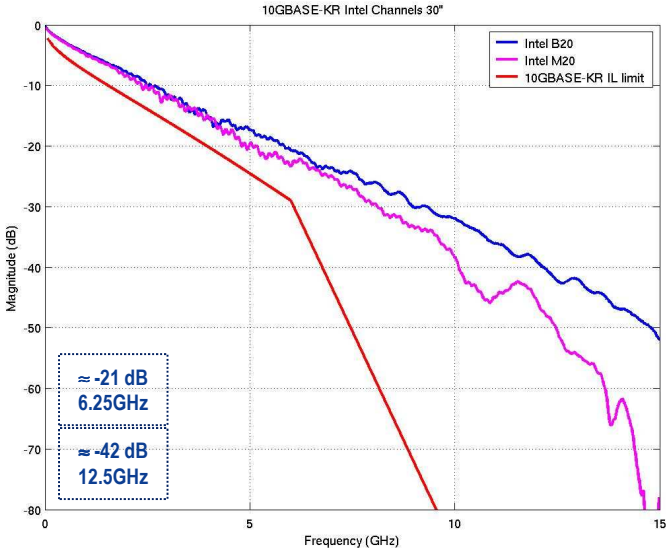


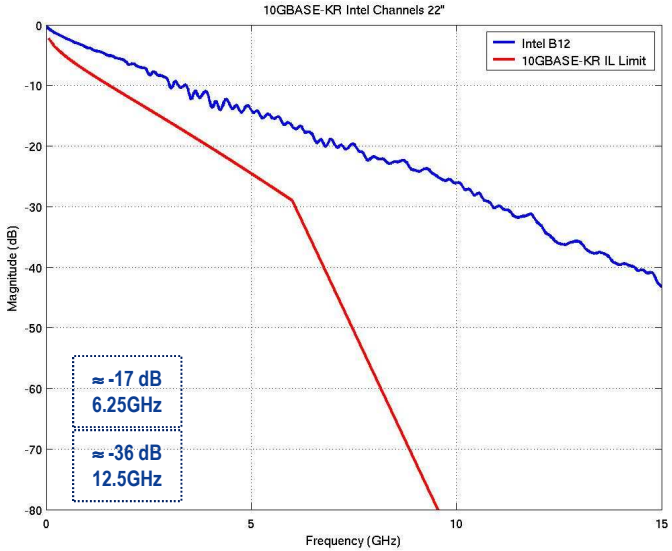


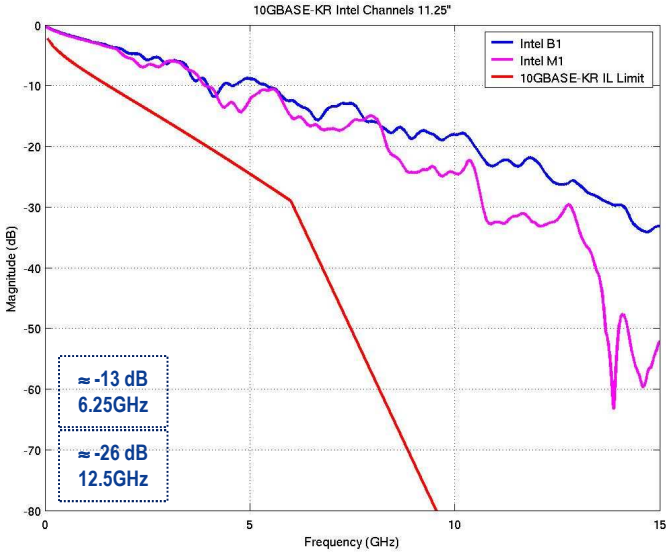




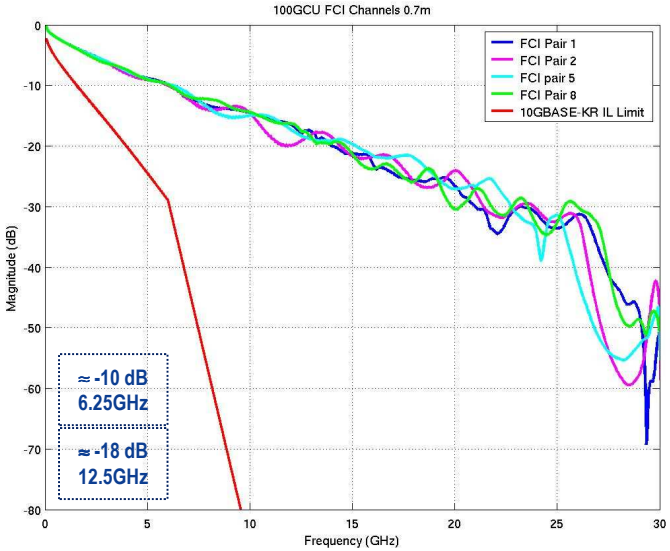
10GBASE-KR Intel Channels: 11.25” – 30”

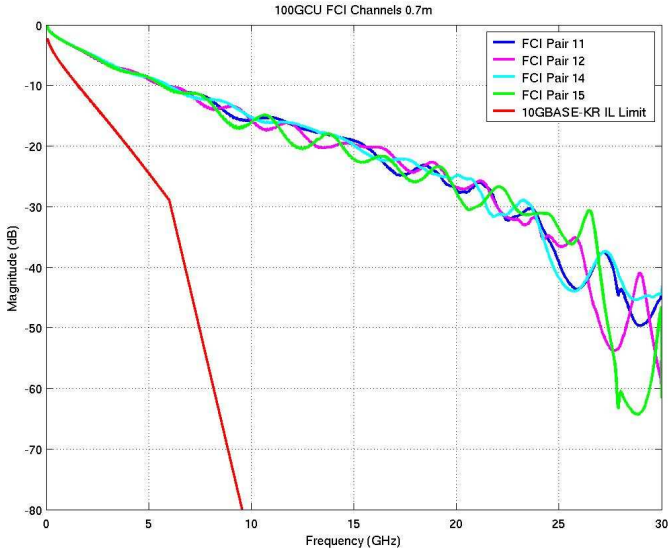


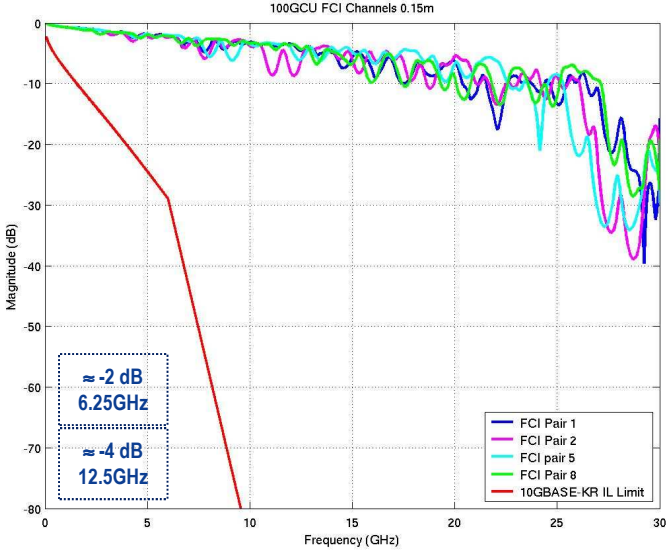


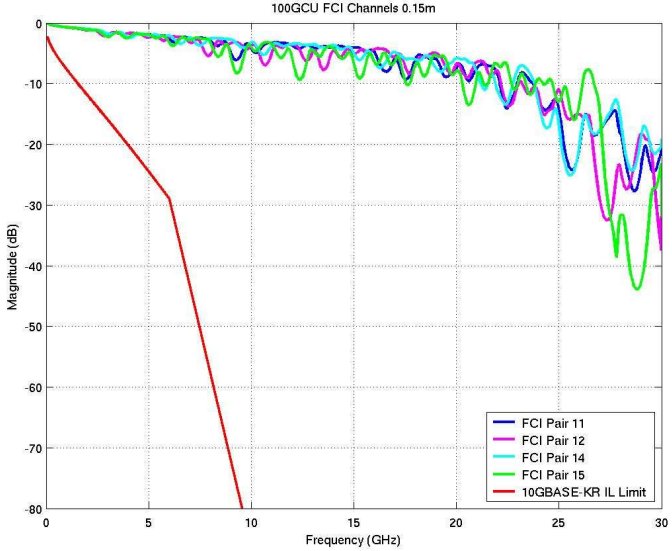


100GCU FCI Channels: 6” – 27”





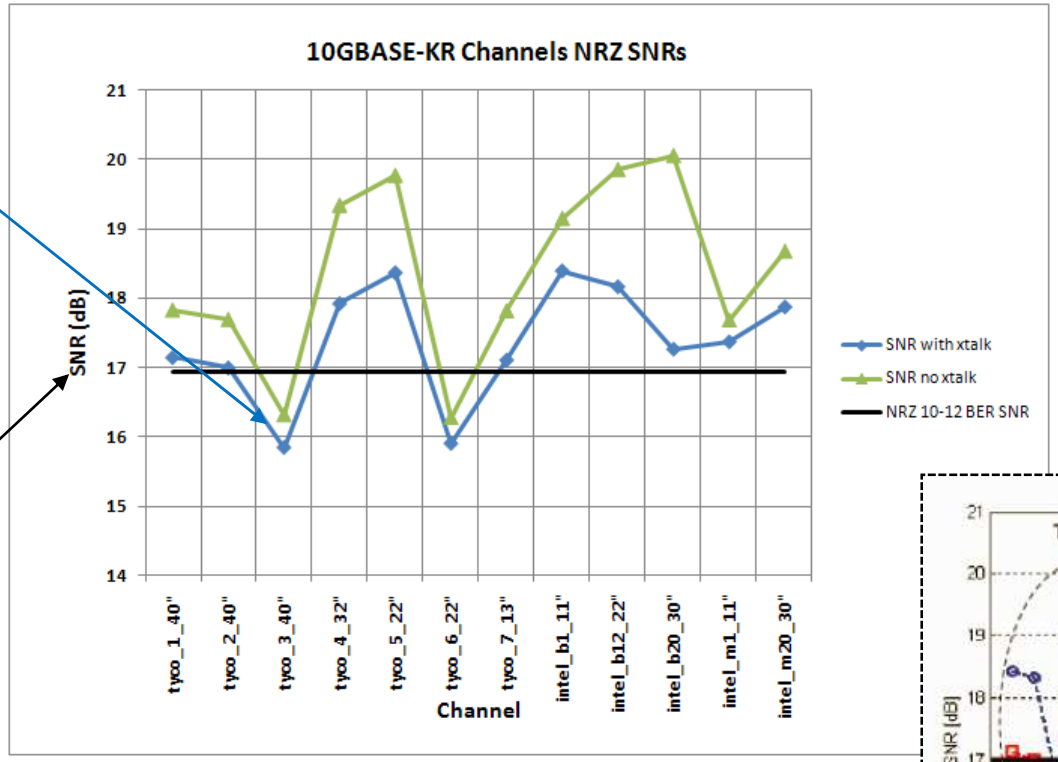


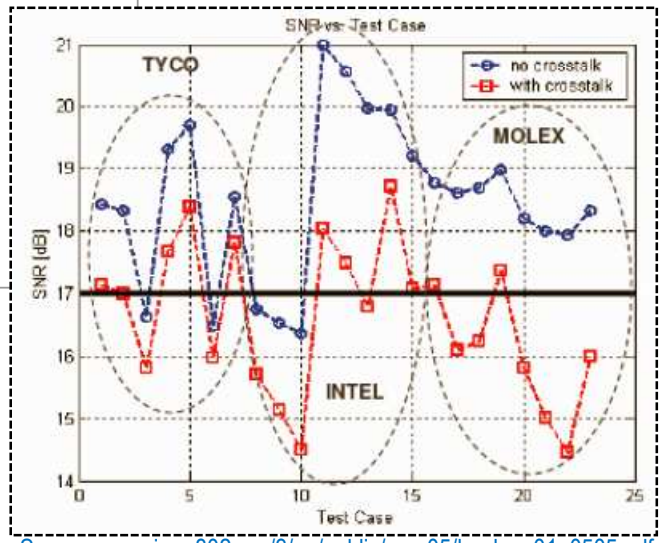


10GBASE-KR Channels SNR Results at 10 Gb/s

10.3125 Gb/s
NRZ
Vpp = 1v
64B/66B
RJ = 6.6ps
PJ = 4.0ps
AWGN
1 NEXT (async)
1 FEXT (async)
Cap-Like Package
3 FFE symbol-spaced at Rx
5 DFE
LMS

$SNR = 10*\log_{10}(\sigma^2_S/\sigma^2_N)$
σ^2_S: signal variance
σ^2_N: noise variance
At optimal phase

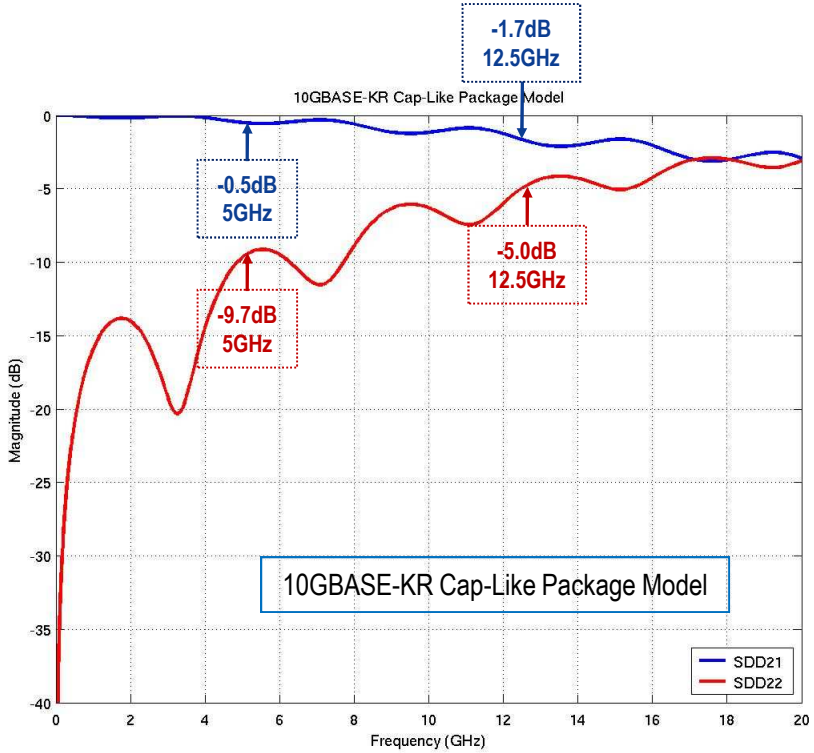


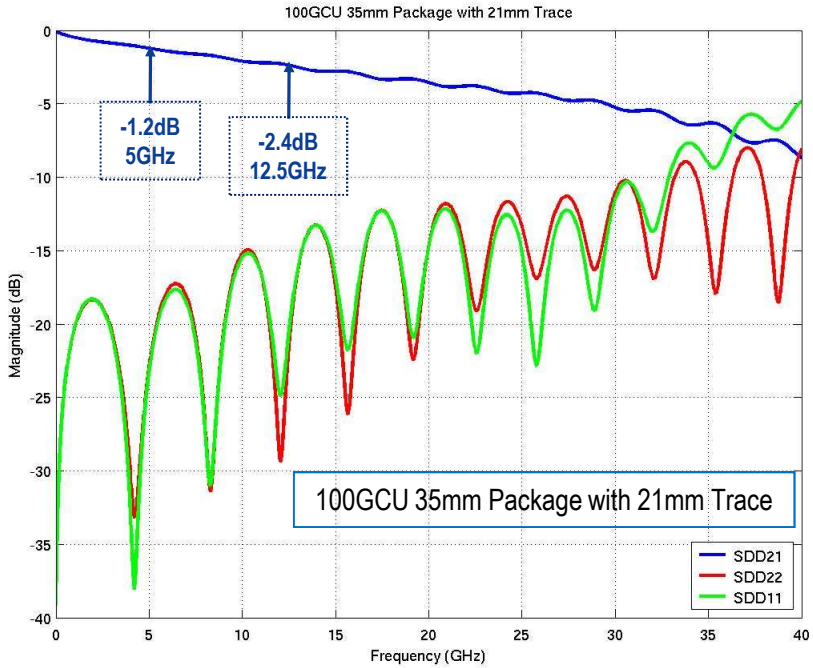


Source: www.ieee802.org/3/ap/public/may05/healey_01_0505.pdf

- Good correlation with "healey_01_0505.pdf" for Tyco channels.
- Some mismatch for Intel channels:
  - Intel channels were updated on June 2005.
  - Left out the T channels due to poor performance even at 10Gb/s.
- (2112,2080) FEC NCG of 2.5 dB allows all channels to meet 10^{-12} BER target

Package Models

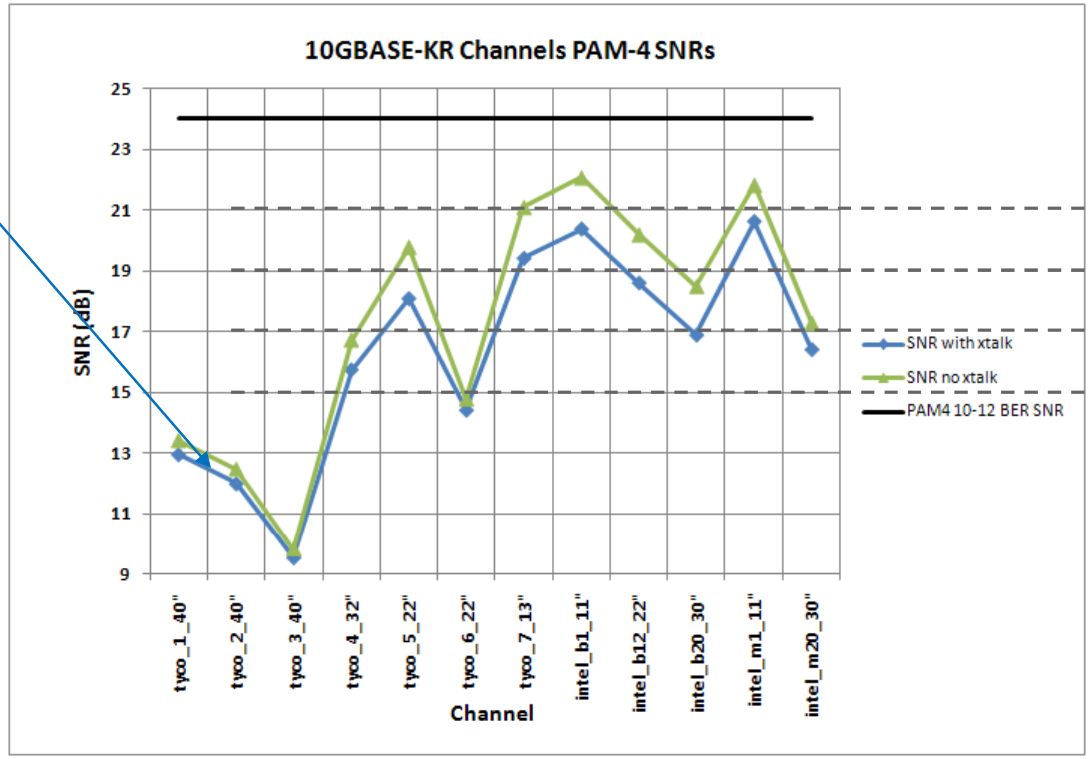




- Very large RL at high frequencies for 10GBASE-KR package model.
- In following simulations, use 100GCU 35mm/21mm package model.

10GBASE-KR Channels SNR Results at 25 Gb/s

25 Gb/s
PAM4
Vpp = 1v
64B/66B
RJ = 6.6ps
PJ = 4.0ps
AWGN
1 NEXT (async)
1 FEXT (async)
35mm/21mm Package
8 FFE symbol-spaced at Rx
12 DFE
LMS



≈ 10": requires FEC NCG 3dB – 5dB

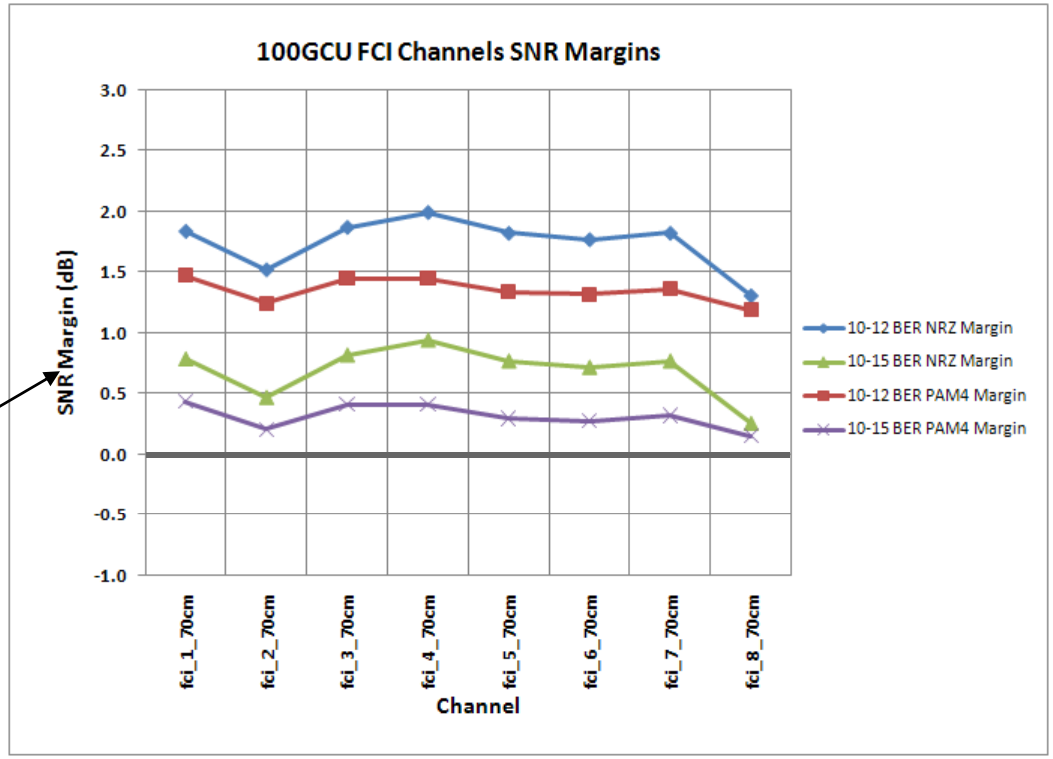
≈ 20": requires FEC NCG 5dB – 7dB

≈30": requires FEC NCG 7dB – 9dB to meet 10^{-12} BER target

- At 25Gb/s:
  - Increase equalizer size by factor of 2.5:
    - Proportional to increase in baud rate: (25GHz/10GHz)
  - SNR margin analysis using PAM-4 only :
    - PAM-4 to outperform NRZ: IL at $f_{Nyquist\text{-}PAM4} - f_{Nyquist\text{-}NRZ} > 10$ dB
    - Channels measured f_{max} = 15GHz and NRZ $f_{Nyquist}$ = 12.5GHz → potentially unreliable results

100GCU FCI 0.7m Channels SNR Results at 25 Gb/s

25 Gb/s
NRZ and PAM4
Vpp = 1v
64B/66B
RJ = 6.6ps
PJ = 4.0ps
AWGN
1 NEXT (async)
1 FEXT (async)
35mm/21mm Package
8 FFE symbol-spaced at Rx
12 DFE
LMS



10^{-12} NRZ BER SNR = 17dB
10^{-15} NRZ BER SNR = 18dB
10^{-12} PAM-4 BER SNR = 24dB
10^{-15} PAM-4BER SNR = 25dB

- At 25Gb/s and 0.7m (27”):
  - PAM-4 and NRZ have similar performance
    - IL at $f_{Nyquist\text{-}PAM4} - f_{Nyquist\text{-}NRZ} \approx 9$ dB
  - Little or no FEC needed

Solution Space Summary

Channel	Total Length (inches)	Materials (Line Card Backplane)	IL at 6.25 GHz (dB)	ILD	Required FEC NCG for 0 dB margin at 10^{-12} BER (dB)	Required FEC NCG for 0 dB margin at 10^{-15} BER (dB)
Tyco 4	32	Nelco 4000-13 Nelco 4000-13SI	-25.5	"Medium"	8.3	9.3
Intel B20	30	Nelco 4000-6 Nelco 4000-13	-21	"Low"	7.2	8.2
Intel M20	30	Nelco 4000-6 Nelco 4000-13	-22	"Medium"	7.6	8.6
FCI 1-8	27	Megtron-6 Nelco 4000-13SI	-10	"Medium"	0	0
Tyco 6	22	Nelco 4000-13 Nelco 4000-13	-29	"High"	9.6	10.6
Tyco 5	22	Nelco 4000-13 Nelco 4000-13	-19	"Medium"	6	7
Intel B12	22	Nelco 4000-6 Nelco 4000-13	-17	"Low"	5.4	6.4
Tyco 7	13	Nelco 4000-13SI Nelco 4000-13SI	-13.5	"High"	4.6	5.6
Intel B1	11	Nelco 4000-6 Nelco 4000-13	-13.5	"Medium"	3.7	4.7
Intel M1	11	Nelco 4000-6 Nelco 4000-13	-15	"High"	3.4	4.4

Remarks on SNR Margins

- We have presented preliminary high-level time-domain simulations intended to help with the reach and BER objectives:
  - Limited to 10GBASE-KR and 100GCU public channel data:
    - Data is consistent with proprietary customer channels.
  - Additional performance tweaking is possible through various parameters:
    - Tx Vpp
    - Number of FFE and DFE taps
    - Etc.
  - Additional level of simulation details and analysis will be incorporated in future presentations.
- At 25 Gb/s, there is a wide gap in channel quality between 10GBASE-KR and 100GCU channels:
  - 10GBASE-KR channels:
    - Multi-level line coding will be required even for short reaches of 11".
    - Support for compliant channels with reaches up to 30" appears very challenging.
    - FEC required.
    - No tolerance to ILD.
  - 100GCU FCI channels:
    - NRZ appears to be sufficient to support channels with reaches up to 27".
    - FEC optional.
    - Reasonable tolerance to ILD.

Reach and BER Objectives

- Support for 10GBASE-KR channels appears to be viable only for limited reaches and stricter ILD control:
  - Reaches up to ≈ 22”:
    - Multi-level line coding, e.g. PAM-4 will be required.
    - FEC with NCG of 6 dB will be required to achieve 10^{-12} BER
    - FEC with NCG of 7 dB will be required to achieve 10^{-15} BER
  - Reaches up to ≈ 13”:
    - Multi-level line coding, e.g. PAM-4 will be required.
    - FEC with NCG of 4.5 dB will be required to achieve 10^{-12} BER
    - FEC with NCG of 5.5 dB will be required to achieve 10^{-15} BER
- Support for 100GCU FCI channels:
  - Reaches up to 27”:
    - NRZ is sufficient
    - FEC optional
    - Positive SNR margins at 10^{-15} BER:
      - Possible to increase reach beyond 27”.