Study of 100 Gb/s on 40GBASE-KR4 channel

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Outline

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Past experience with scaling Ethernet

- Category 5 UTP cabling rapidly overtook Category 3 UTP (circa 1995)
  - Similar RJ-45 connectors
  - Comparable manufacturing process
  - Comparable installation process and cost
  - Originally installed for 10BASE-T, even though it was overkill
- 100BASE-TX was adopted very rapidly
  - “Hockey stick” growth in port shipments starting in 1995
  - Operated on Cat-5 UTP
- 1000BASE-T was adopted very rapidly
  - Adoption and growth were only a little slower than 100BASE-TX
  - Operated on Cat-5e UTP (same medium, added ACR and RL tests)
- “Triple speed” Ethernet (i.e. 10/100/1000BASE-T) is our greatest success

Lessons learned

- Silicon capability follows Moore's Law
- Upgrade paths are good
- Preserving the medium and improving the modulation can result in rapid adoption
  - *Exploit the Shannon capacity of the medium!*
- Key question: Can we provide an upgrade path from 10G to 40G to 100G on the same backplane medium?

Backplane specifications in IEEE Std 802.3

- The 10GBASE-KR backplane channel specification was published over three years ago in IEEE Std 802.3ap-2007
  - An important accomplishment, and not an easy undertaking
- IEEE Std 802.3ba referenced this specification for 40GBASE-KR4
  - Essentially 4 lanes of 10GBASE-KR
- Market acceptance of 10G-KR has been very rapid
  - Initial KR deployments began in 2008
  - Shipments of KR ports increased 10x in 2009 and doubled in 2010
  - KR port shipments to exceed 5M in 2011; strong growth to continue thru 2015
- 10GBASE-KR and 40GBASE-KR4 both demonstrated “Broad Market Potential”
  a) Broad sets of applicability
  b) Multiple vendors and numerous users
  c) Balanced costs (LAN versus attached stations)

Meeting the 5 criteria for 100GBASE-KR4

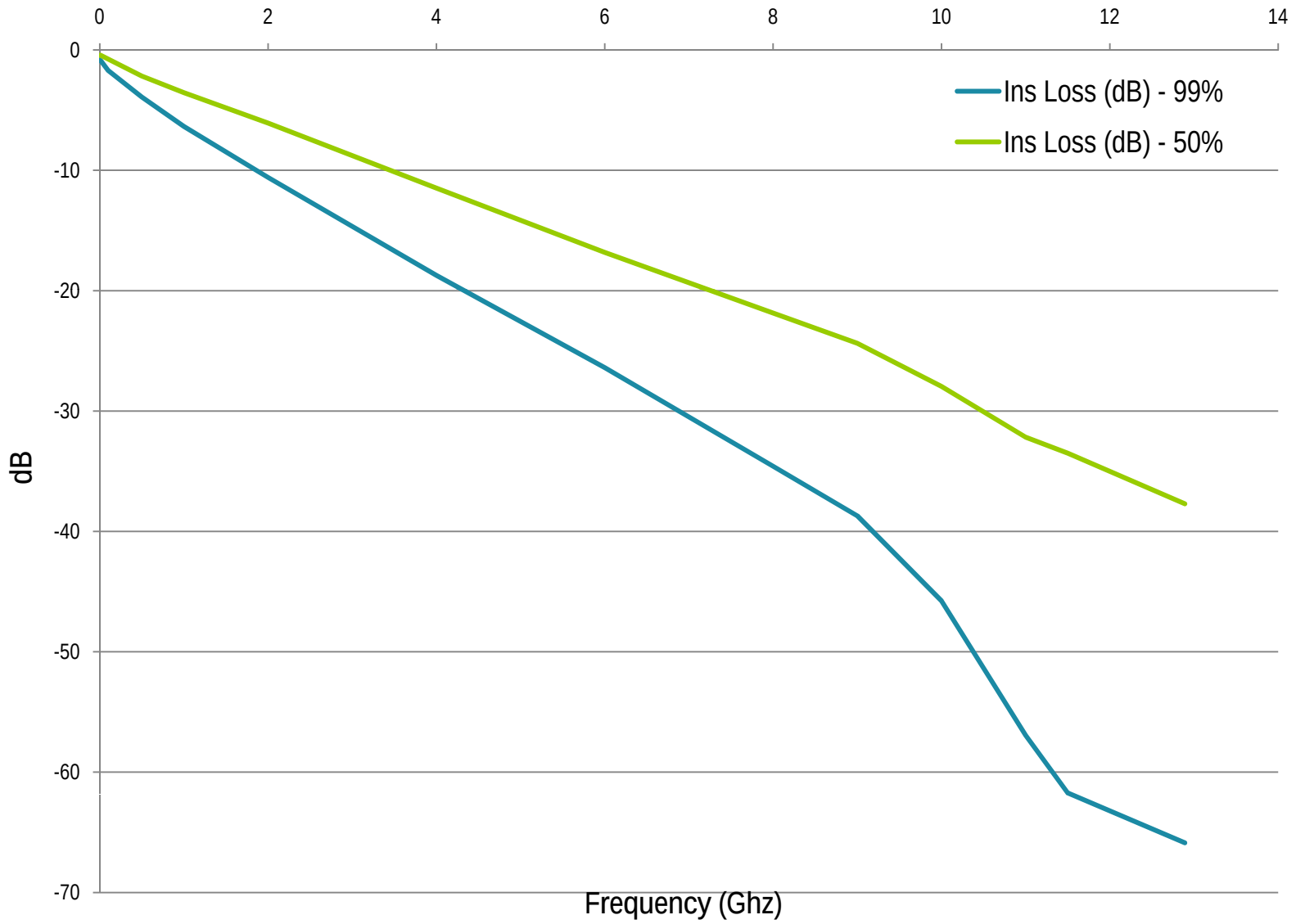
- 10GBASE-KR and 40GBASE-KR4 will become widely deployed
  - There is a significant and growing installed base of backplanes that meet the channel specifications
- It is technically feasible to build backplane channels that meet the 40GBASE-KR4 specifications
- It is economically feasible to build backplane channels that meet the 40GBASE-KR4 specifications
- 100GBASE-KR4 should achieve broad market potential if it can operate on backplane channels that meet the 40GBASE-KR4 specifications

Backplane database study

Background of backplane insertion loss/cross talk study

- Broadcom has collected significant backplane data over many years
- Backplane traces are from various customers all over the industry
- Backplane traces include FR4, Nelco and Megtron material
- S-parameters of traces provided by customers or in other cases measured at BRCM
- Total number of KR compliant backplane traces is 295 (from a database of 832 channels)
- Insertion loss/Cross talk (vs) frequency statistics were gathered to study what portion of frequency spectrum should be used

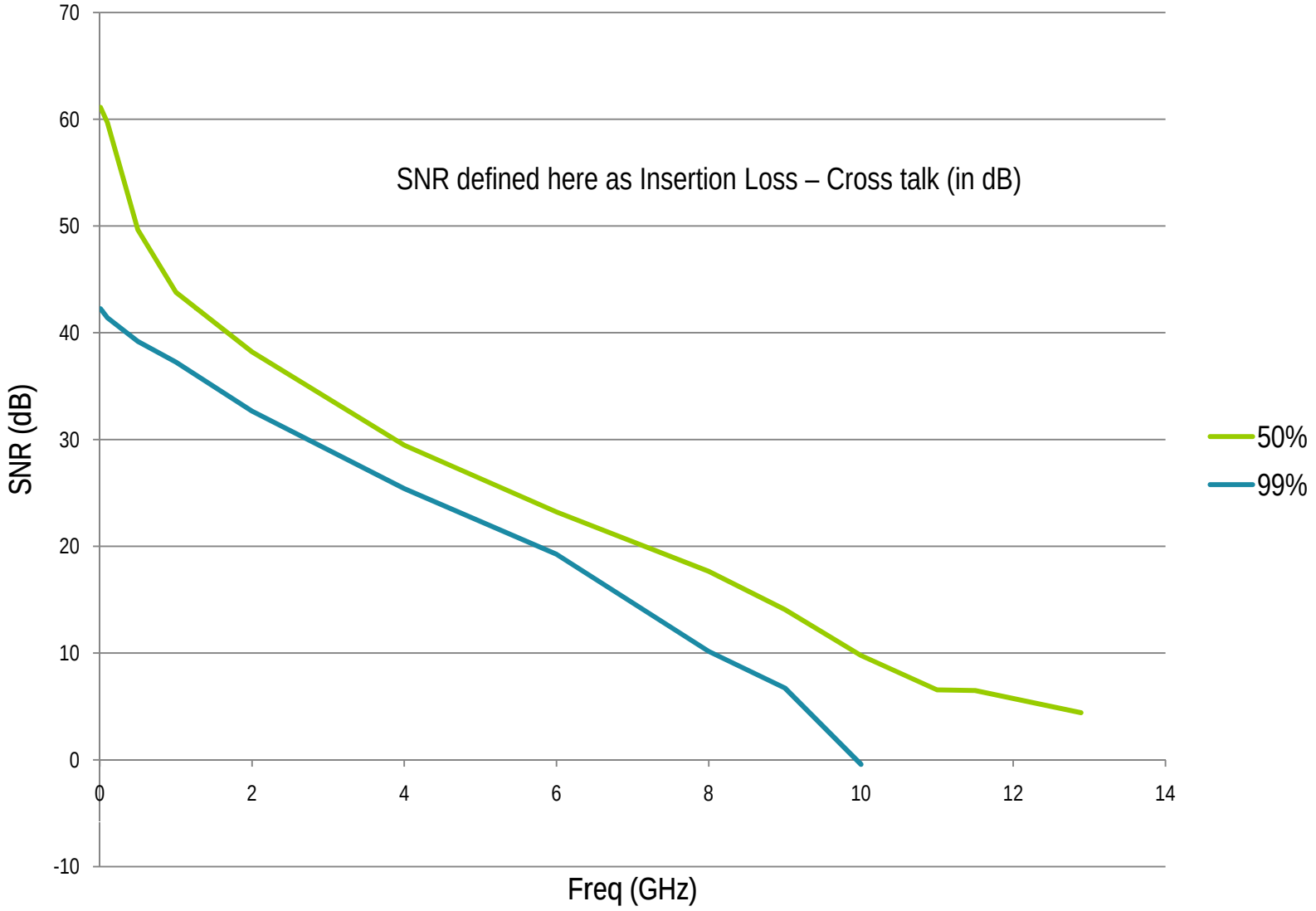
Insertion loss (dB) percentiles



Observations

- Around 6.5 GHz, insertion loss on full database (99%) is about 30 dB
- Insertion loss on full database (99%) is very poor (60 dB+) at a Nyquist frequency of ~12 GHz
- Around 12.5 GHz, roughly 50% of the installed base has an insertion loss of 40 dB
- Difficult to scale 10GBASE-KR insertion loss to ~12 GHz and cover the installed base of backplanes

Signal-to-Crosstalk ratio as a function of frequency



Observations

- Crosstalk noise swamps insertion loss for the full backplane dataset after a Nyquist frequency of ~10 GHz
- Around 6 GHz, performance will still be dominated by insertion loss for the full database
- Even for 50% coverage, margin (signal over cross talk) still degrades very rapidly around 12 GHz
- Constraining the Nyquist frequency by improving the modulation can provide an upgrade path from 10G to 40G to 100G on the same backplane medium
- Small changes in the backplane (e.g. length, humidity, dielectric, etc.) could affect coverage at a Nyquist frequency of 12.5 GHz because of the poor SNR margin

Summary

- Upgrade paths that increase the operating speed while preserving the medium can enjoy stellar success
- There is a significant and growing installed base of backplane channels that meet the 10GBASE-KR and 40GBASE-KR4 specifications
- The vast majority of these channels scale reasonably in terms of insertion loss and ICR out to ~ 8 GHz