‘Information’ on high speed data transmission on Cu links

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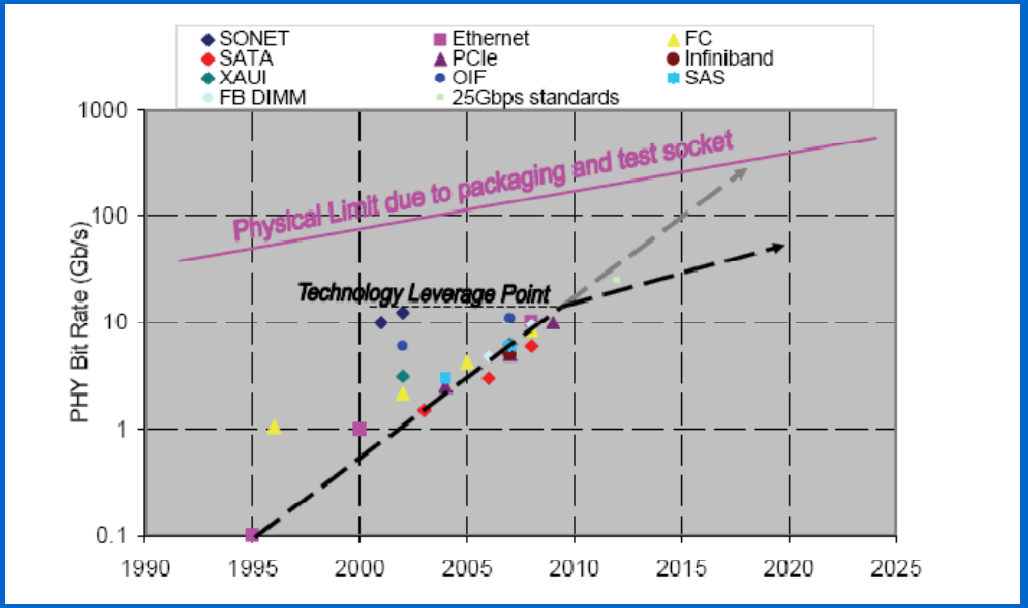
Where is industry on this ?

- Cu is still alive, despite optical boom:
  - "The *rumors* of my *death* have been greatly *exaggerated*" (Mark twain)
- great (economic) interest to transmit 10+ Gbit/s on Cu to 'avoid' short distance optical links.

Infiniband, sata, FibreChannel, 10Gbe, XAUI, SONET,… still some room for improvement.



(from Altera whitepaper)

Cu links on printed circuit board and cables.

- 1. On pcb,
  - largely driven by FPGA : require very high speed serial I/O to match ‘gigantic’ internal processing power.
  - mostly using conventional FR4 : avoid cost of special dielectric laminates.
  - ‘extreme’ : 10Gbits/s over 80 cm is achievable on FR4 with equalizing technique.
- 2. Cu on cable.
  - driven by ‘datacenter’ applications: board interconnections in large servers or switches/routers and data disk I/O …
  - ‘extreme’ : 10Gbit/s over 8m is achievable on fairly normal cables cat6e, with equalizing techniques.
  - this is of most significance to our ‘40MHz readout’.

Our interest: Cu on cable !

- just VELO will use at least 1500 x 5 Gbit/s links for readout (double ATLAS upgraded tracker):
  - 'preferred scenario' is to have the electro-optical transition outside vacuum tank, leaving on initial distance of 1m on Cu.
- all LHCb detectors might need 'some' distance of Cu links.
- Maybe the connection from Tell40 to DAQ switch could be Cu ?
  - if Tell40 mounted close to DAQ switch instead of being in sub-detector racks.

Cu on Cable: distortion

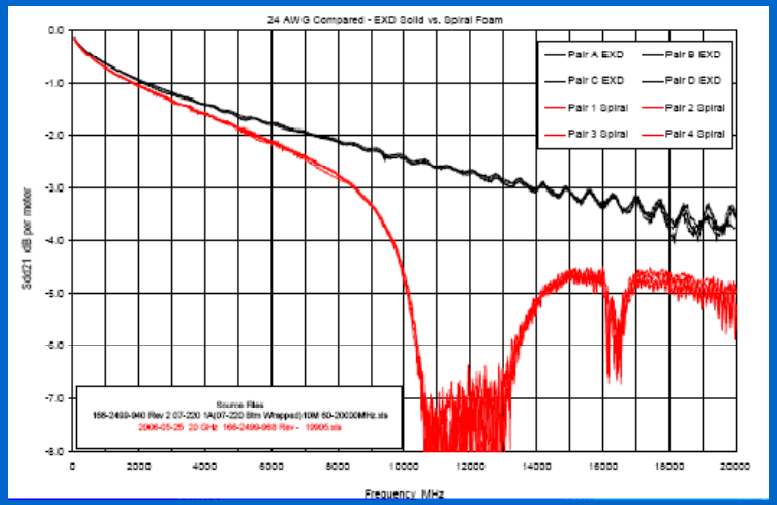
- signal distortion is due to dispersive nature of cable, originating from:
  - 'skin and proximity' effects of conductors.
  - dielectric properties of the cable insulation/isolation material.
- Skin effect:
  - starts at low frequencies : skin depth = 8.5 um at 100Mhz in Cu!
  - only tiny surface layer is 'in play'. Surface finish is important !
  - material budget :
    - 'Conductive cross-section efficiency' = 4 x (skin depth) / (wire-diameter)
    - only 8% for very thin cable (AWG36 diameter=127um) at 1GHz (skin depth in Cu = 2.7um). 92% is dead material in acceptance !
- proximity effect:
  - single strand cable is more efficient then multistrand (also least flexible…)

Cu on Cable: dielectric

- dielectric quality of insulator;
  - at low frequencies : value of dielectric constant must be small.
    - ideal ε_r=1 (air)
    - determines capacitance and consequently ‘low pass filter’ behavior of cable .
  - at higher frequencies:
    - dielectric constant increases and
    - becomes lossy : ‘loss’ or ‘dissipation’ factor (tanδ)
  - Often ‘foam’: air lowers effective dielectric constant and loss !
  - lots of information available on materials on habia.com ! Best materials are ptfe (teflon), polyethylene (PE) ,etfe (tefzel), fep, polyolefin …
  - polyimide (kapton) is quite bad for very high frequencies (current flex cables inside VELO vacuum tank)

Cu on Cable: types

- **Coax, twisted pair, twinax :**
  - coax is excellent , but not ‘differential’ (needs common ground reference).
  - twisted pair suffers ‘intra-pair skew’ : different physical length of wires in a pair, causes distortion at high frequencies (10 ps transition time ~ 4mm cable length)
  - twinax is popular:
    - vendors: Samtec, Amphenol (spectrastrip) , Gore, Radiall,
    - custom cables: e.g. Habia Cable, Draka, AXON
    - no cancelling of pickup from external e.m. fields …?
- **Shields:**
  - individual shields absolutely necessary for limiting pair crosstalk !
  - spiral wrapped Al foil creates strong attenuation at a 12GHz
  - replaced by longitudinal wrapped foil .



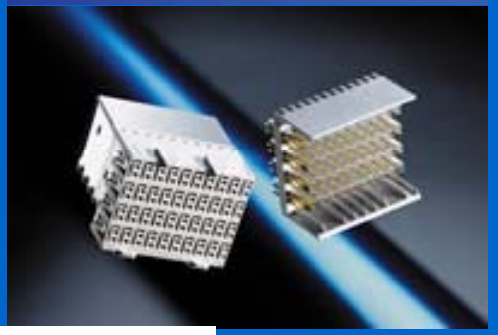
from Amphenol, spectrastrip

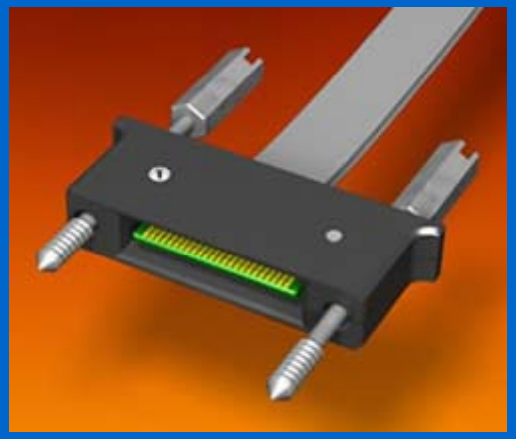
Cu on Cable: environment

- **Velo specific:**
- **Radiation hardness: (VELO 10+kGy total dose)**
  - ptfe only upto 10kGray
  - PE and etfe upto 1Mgray !
- **Vacuum compatible:**
  - insulation ‘foam’ is excluded , must be solid.
  - no air pockets trapped in shields. Puncture foil?

Cu on Cable : connectors

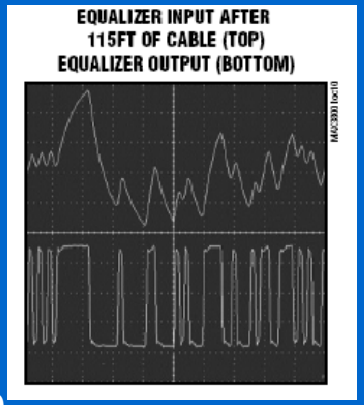
- impedance controlled
- extensive shielding for crosstalk !
- Many types and vendors
  - GBx (Teradyne & Molex&Gore)
  - Z-pack HM-Zd (Tyco & ERNI)
  - MicroGiga (Fujitsu)
  - EEDP/EQDP (Samtec)

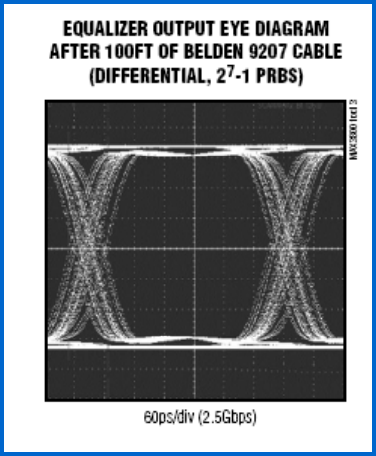




Cu on cable: equalization

- **Many cable compensation techniques and devices exist for digital transmission:**
  - **chip vendors (TI, Maxim, …) and even built-in in recent FPGA's.**
- **pre or de-emphasis**
  - **same performance if on Tx or Rx side (linear system)**
  - **but : pre-emphasis generates more emi emission !**
  - **de-emphasis: can adapt to existing length (adaptive equalization, e.g Maxim 38xx). Easier to install/tune (no need for a communication channel to configure driver side !)**
  - **de-emphasis circuit could be in a lesser radiation environment (commercial radtolerant devices ?)**





Plan in VELO

- Purchase some standard (hi speed) cable/connector and construct testbed (join with existing ?)
- Measure reference performance and explore datarate, distance, stability, connector insertion loss, emi …
- Then look for cable with low mass, radiation hard dielectric and vacuum compatible shield for VELO.