# Select SMF & Link Specifications Review

P802.3cu 100 Gb/s and 400 Gb/s over SMF at
100 Gb/s per Wavelength Task Force

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# Outline

- SMF Model
- Dispersion
- Loss
- Penalty Addition
- BER

# 802.3cu Draft 1.0

## 140.9 Fiber optic cabling model

*Change Table 140-11 and Table 140-12 as follows:*

**Table 140–11—Fiber optic cabling (channel) characteristics**

| Description | 100GBASE-DR | 100GBASE-FR1 | 100GBASE-LR1 | Unit |
|---|---|---|---|---|
| Operating distance (max) | 500 | 2 000 | 10 000 | m |
| Channel insertion loss[a,b](max) | See Table 140–12 | 4 | 6.3 | dB |
| Channel insertion loss (min) | 0 | 0 | 0 | dB |
| Positive dispersion[b] (max) | 0.8 | 3.2 | 16 | ps/nm |
| Negative dispersion[b] (min) | –0.93 | –3.7 | –18.6 | ps/nm |
| DGD_max[c] | 2.24 | 2.3 | 5 | ps |
| Optical return loss (min) | 27 | 25 | 22 | dB |

[a]These channel insertion loss values include cable, connectors, and splices.
[b]Over the wavelength range 1304.5 nm to 1317.5 nm

# Dispersion

- No SMF exists that has such extreme Dispersion values
- Dispersion in practice, i.e. in the field in Ethernet applications, is ~50% of that listed in table 140-11
- This has significant cost implications for the design and testing of Ethernet optics
- This has been known for the past decade, so why has nothing been done?
- 802.3 SMF specs. use ITU-T G.652 Application code
- ITU-T has been asked over the past decade to reduce the ~20 year old zero dispersion range of 1300nm to 1324nm.
- In practice, SMF delivered for Ethernet applications is 1310nm +- ~0.5nm

# Dispersion, cont.

- At C-band, the zero dispersion range makes a tiny difference to the Dispersion value
- ITU-T has no incentive to change the zero dispersion range because the primary applications are transport in C-band
- In future projects, IEEE should stop using ITU-T G.652 SMF dispersion values based on worst case 1310nm to 1324nm dispersion range, and use typical values representative of actual SMF deployment by volume Ethernet users
- This will enable realistic penalties for longer reaches like 10km and 40km
- This will enable realistic testing without contortions of searching for SMF that doesn't exist

# G.652 SMF Model Values

| λ | A&B loss | C&D loss | Worst Case Dispersion | Realistic Dispersion |
|---|---|---|---|---|
| nm | (dB/km) | (dB/km) | (ps/nm.km) | (ps/nm.km) |
| 1270 | 0.47 | 0.46 | -5.35 | -3.92 |
| 1290 | 0.44 | 0.44 | -3.29 | -1.92 |
| 1310 | 0.41 | 0.41 | 1.73 | 0.81 |
| 1330 | 0.42 | 0.41 | 2.70 | 1.80 |
| 1350 | 0.45 | 0.40 | 4.40 | 3.54 |
| 1370 | 0.90 | 0.38 | 6.03 | 5.21 |
| 1390 | 1.20 | 0.37 | 7.59 | 6.81 |
| 1410 | 0.80 | 0.35 | 9.09 | 8.34 |
| 1430 | 0.41 | 0.34 | 10.54 | 9.82 |
| 1450 | 0.35 | 0.32 | 11.93 | 11.24 |
| 1470 | 0.32 | 0.31 | 13.27 | 12.61 |
| 1490 | 0.30 | 0.30 | 14.57 | 13.93 |

# Loss

- No SMF exists that has 0.5dB/km (max) O-band loss, as per ANSI/TIA 568
- Typical loss is 0.3dB/km, with 0.4dB/km O-band limit
- The consequences are not significant for most IEEE specs
- What matters are the total loss and power budget values
- However, there are instances where this causes a problem
- In 802.3cn, 40km reach objective has required an 18dB loss, using “engineered link” 0.4dB/km loss value
- This is unsupported by existing RX technology so the yield of the specified PMD will be grim
- In reality, a 15dB loss, with 0.33dB/km loss value would work over modern deployed SMF

# Penalty Addition

- The 802.3 power budget methodology is to add up all the "worst case" losses and penalties
- No modern manufacturing specs are calculated this way
- The only virtue of adding worst case values is to make the math simple and avoid understanding the underlying yield distributions
- At lower rates, where there was margin to spare, such an approach was OK
- As rates increase, and available optics margin shrinks, this approach does not work
- There is no such thing in the real world as flat or truncated distributions for large manufacturing volumes

# Penalty Addition, cont.

- The notion that adding up “worst case” values leads to a total spec. value which is not exceeded is an illusion based on not understanding manufacturing statistics
- The correct approach is to separately add up nominal losses and penalties and their variances, and chose a % yield to set the spec. limits
- The next best thing is to add up nominal losses and penalties, and add a dB margin to the total number based on prior experience.
- SPC was invented in the ’30s, widely used since the ‘50s
- Every manufacturing facility uses it, including all the ones that make Ethernet optics
- Let’s bring our spec. methodology into the 20$^{th}$ century

# 802.3cu Draft 1.0

### 151.1.1 Bit error ratio

The bit error ratio (BER) when processed according to Clause 120 shall be less than $2.4 \times 10^{-4}$ provided that the error statistics are sufficiently random that this results in a frame loss ratio (see 1.4.275) of less than $1.7 \times 10^{-12}$ for 64-octet frames with minimum interpacket gap when processed according to Clause 120 and then Clause 119. For a complete Physical Layer, the frame loss ratio may be degraded to $6.2 \times 10^{-11}$ for 64-octet frames with minimum interpacket gap due to additional errors from the electrical interfaces.

If the error statistics are not sufficiently random to meet this requirement, then the BER shall be less than that required to give a frame loss ratio of less than $1.7 \times 10^{-12}$ for 64-octet frames with minimum interpacket gap.

# BER

- End users require “error free” operation
- Because the 802.3 specs are for a finite BER or FER, each end user changes the 802.3 specs based on their understanding of what is required to get to “error free”
- Ex. 1:  100x BER margin on top of 100x manufacturing margin
- Ex. 2: 1dB BER margin on top of 1dB manufacturing margin
- The end result is unique spec. for each end user
- 802.3 needs to bite the bullet and write specs. with useful BER criteria to match optics use
- David Ofelt is the One to be coaxed into doing this

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Thank You