MPN Theory Predictions vs. Measurements

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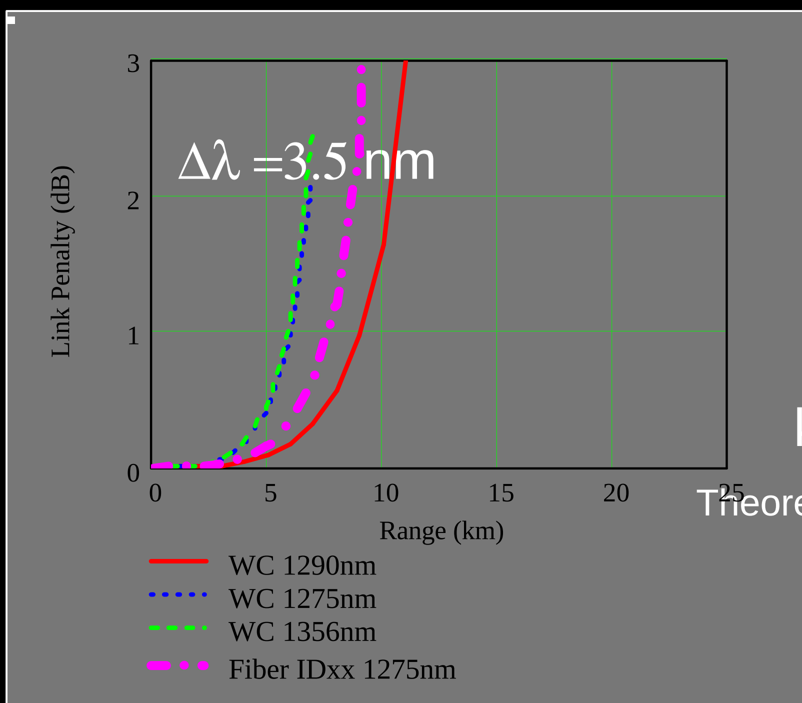
IEEE 802.3 ah interim
January 2002
Raleigh, NC

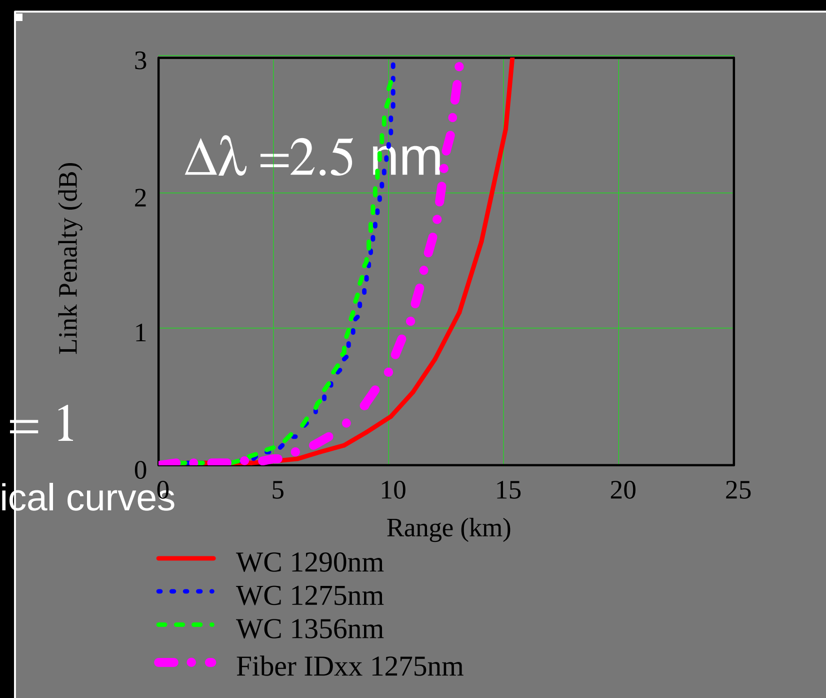
MPN theory predictions and test results

- MPN theory predictions at 1.25 Gb/s (see Appendix 1 for equations and details. WC stands for worst case for G.652 (SM28) fiber. Different plots for different emitter wavelength.
  - k = 1 , $\Delta\lambda$ is rms –20 dB



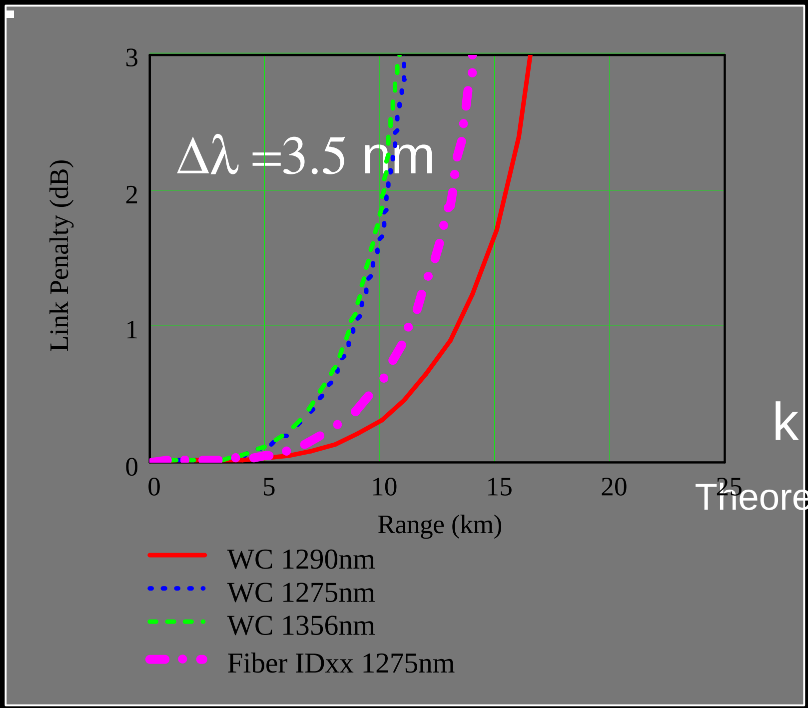
k = 1

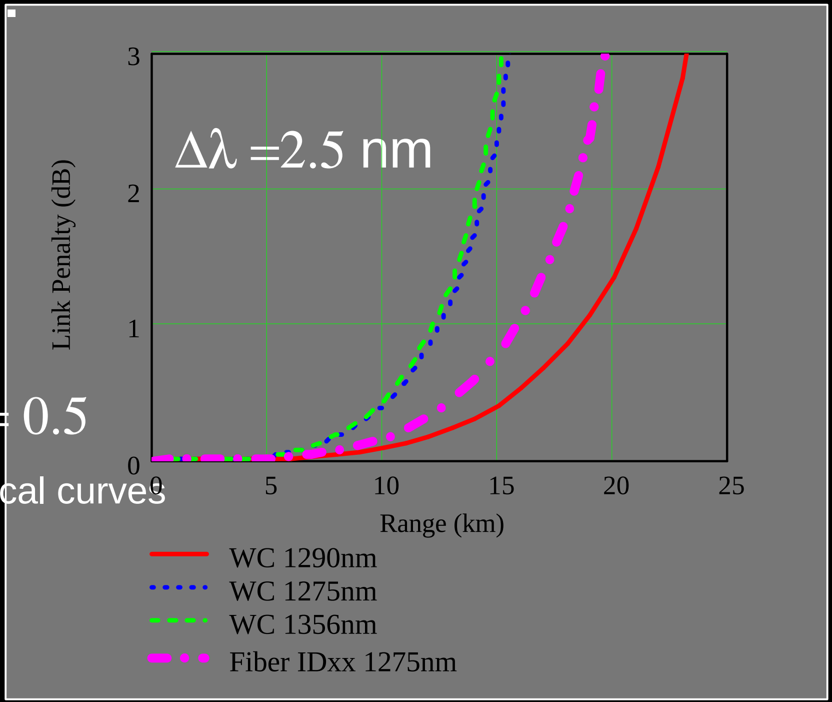
Theoretical curves



MPN theory predictions and test results

- MPN theory predictions (see Appendix 1)
  - k = 0.5

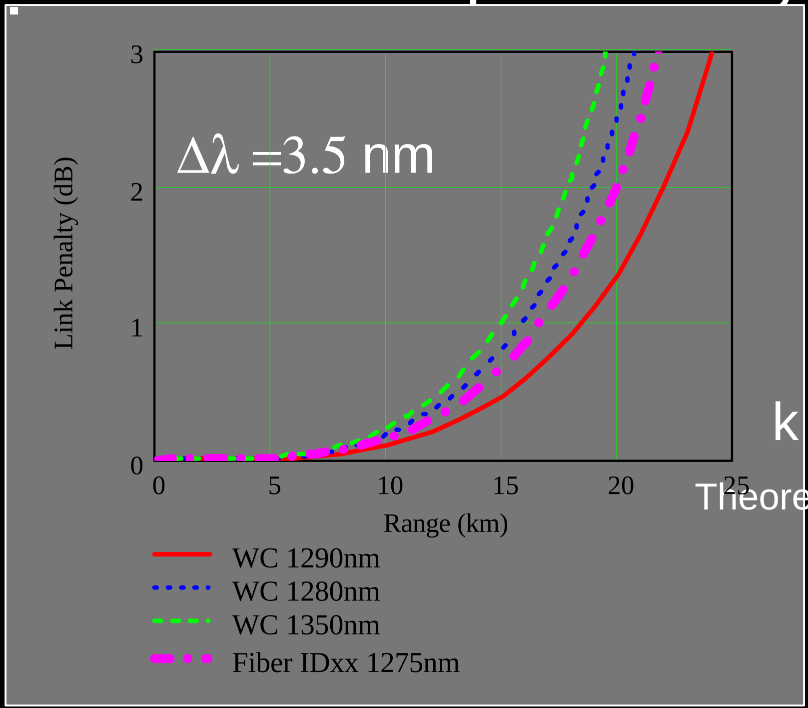




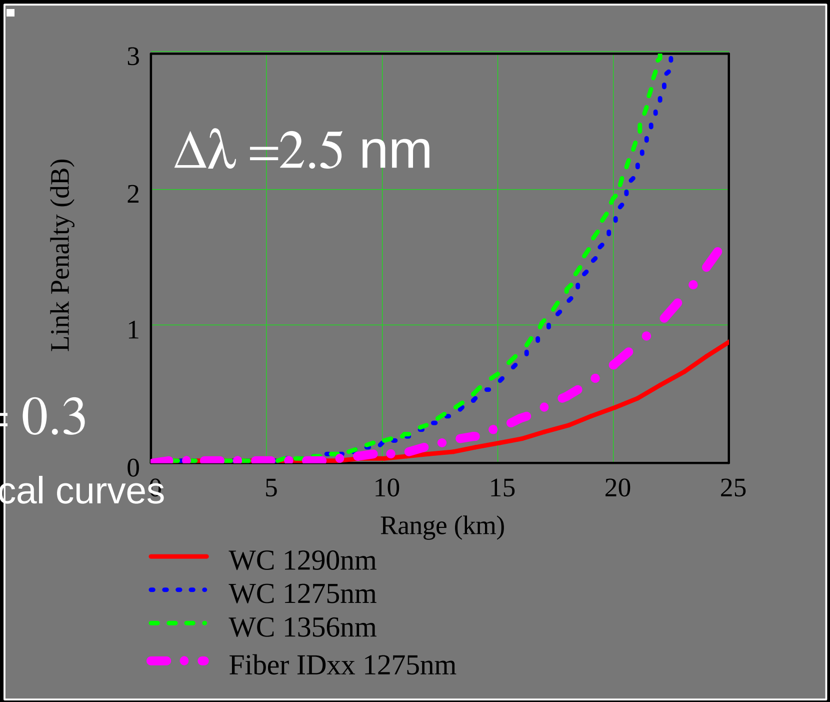
k = 0.5
Theoretical curves

MPN theory predictions and test results

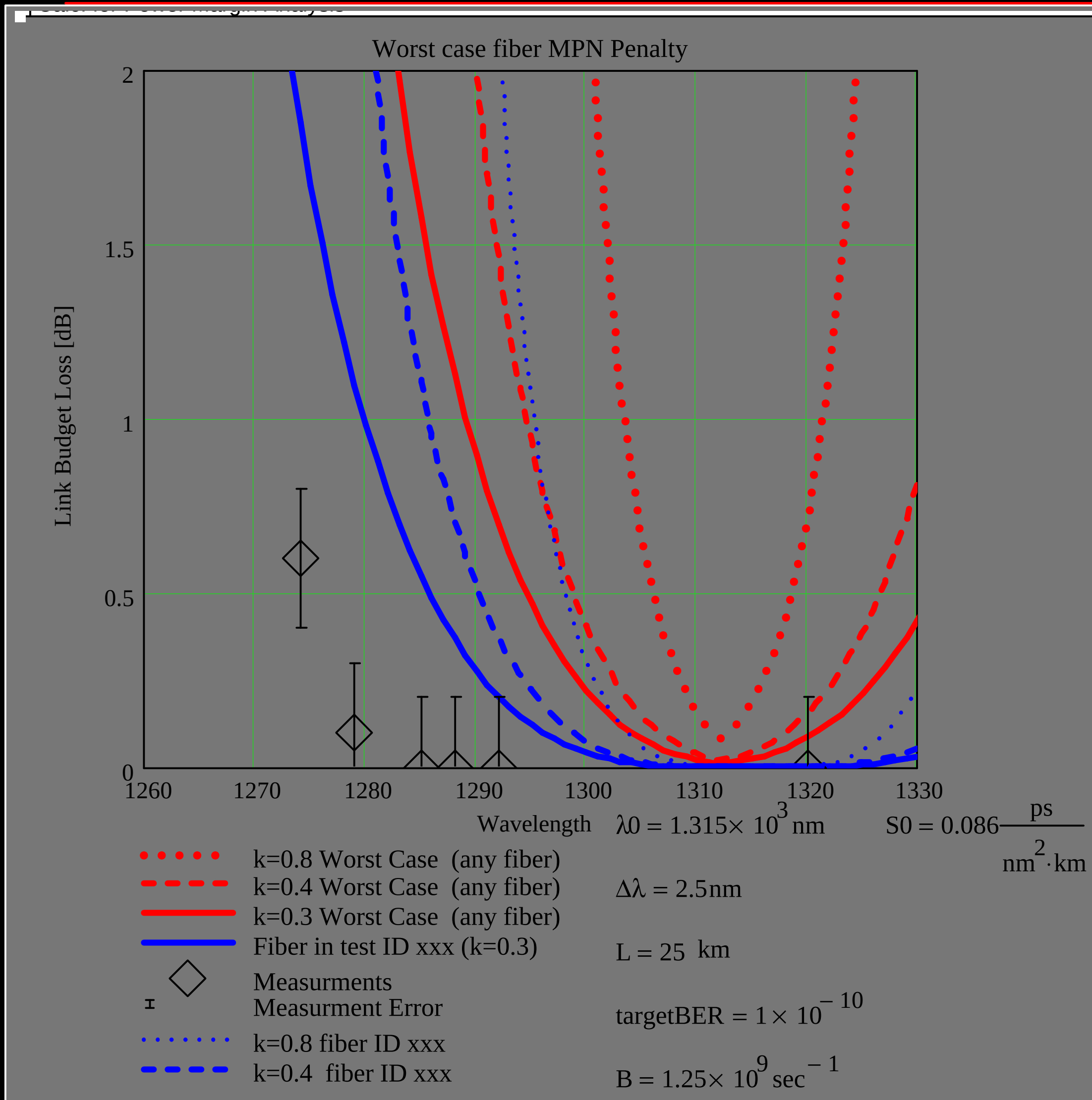
- MPN theory predictions (see Appendix 1)
  - k = 1 (Telcordia) is too "pessimistic"
  - "Others" recommend 0.4 to 0.5
  - Our preliminary measurements k < 0.3



k = 0.3
Theoretical curves



MPN test results – 25 km (see Appendix 1 for additional conditions)



Worst case assume:

1302nm < λo < 1322nm

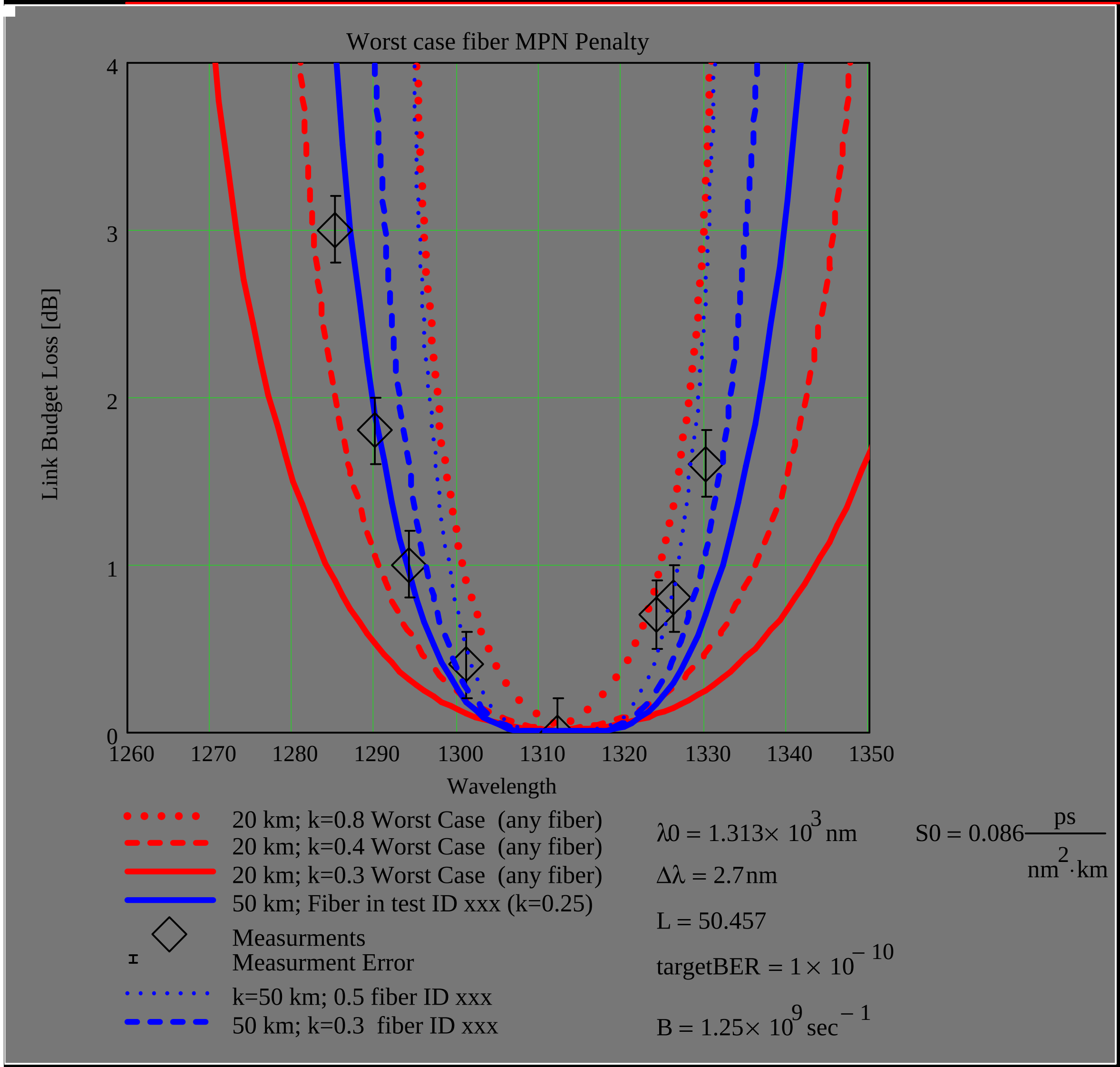
So = 0.092 ps/nm²/km.

Three k values 0.8,0.4,0.3

Measured data (25 km known fiber)

k < 0.3

MPN test results – 50 km (see Appendix 1 for additional conditions)



Worst case assume:

1302nm < λo < 1322nm

So = 0.092 ps/nm²/km.

Three k values 0.8,0.4,0.3

Measured data (50 km fiber) k < 0.3

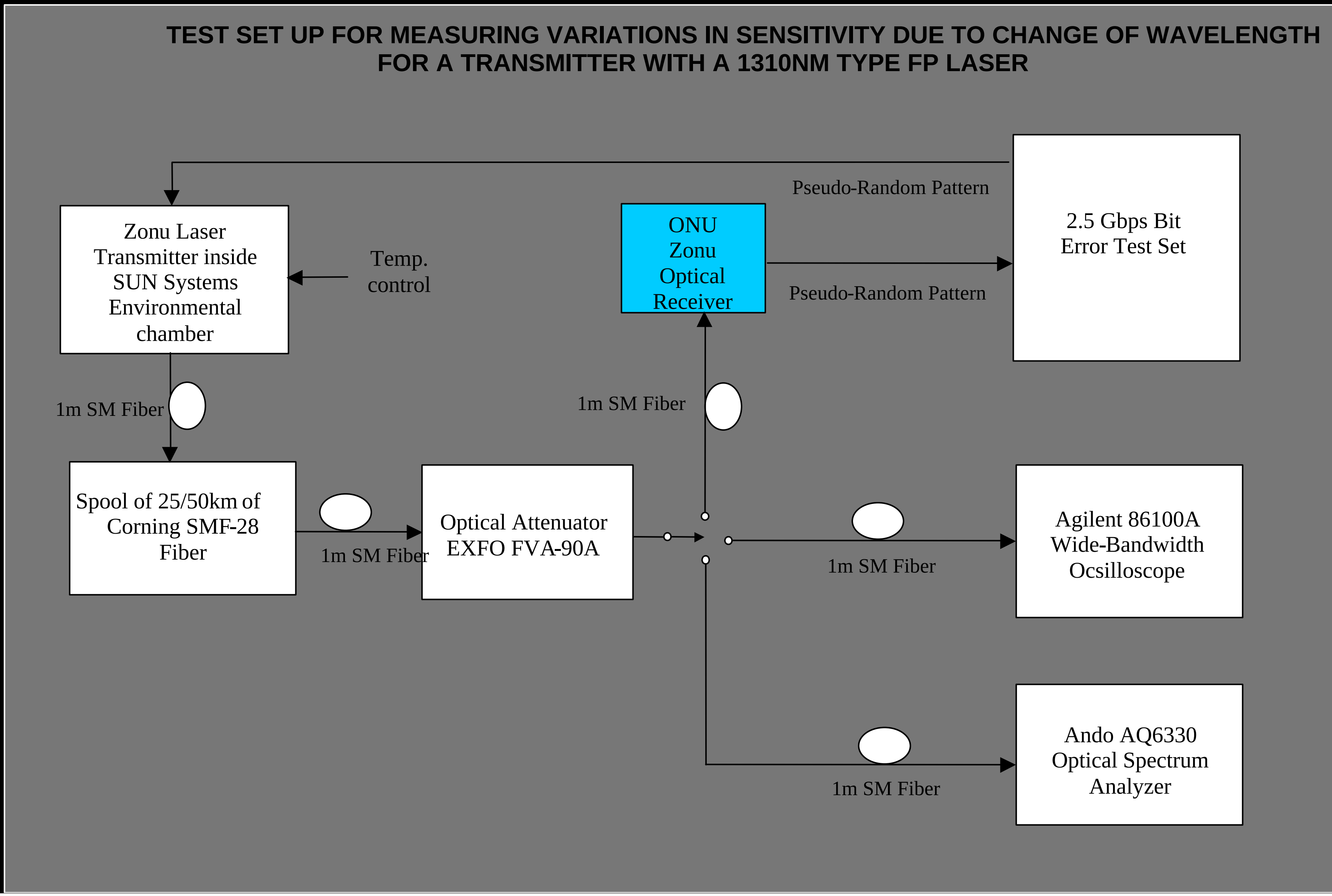
LEAST SQUARE FIT:

K = 0.255

Observations

- Using worst case k for FP all laser diodes (different manufacturers) is misleading
  (Power, wavelength, and spectral width are not enough for FP characterization)
- Need for test methodology, to be used in production, to ensure utilization of FP fo range >10 km
  - For “long reach” optics test with 20km spool of “extreme fiber” (λo = 1322nm for –40C and λo = 1302nm for 85C) will work. Is it practical?

Appendix 1: Dispersion penalty test setup



Appendix 1: MPN penalty model equations

Basic MPN equations

$$BER(Q) := 0.5 \cdot \mathrm{erfc}\left(Q \div \sqrt{2}\right)$$

Fiber dispersion

$$D(\lambda) := \overrightarrow{\left[\frac{So}{4} \cdot \left[\lambda - \frac{(\lambda o)^4}{(\lambda)^3}\right]\right]}$$

$$Q := \mathrm{root}\left(\mathrm{targetBER}^{-1} \cdot BER(Q) - 1, Q, 3, 10\right) \qquad Q = 6.361$$

$$\beta(L,\lambda) := \pi \cdot B \cdot D(\lambda) \cdot \Delta\lambda \cdot L \cdot km \qquad \sigma_{mpn}(L,\lambda,k) := \frac{k}{\sqrt{2}} \cdot \left(1 - e^{-\beta(L,\lambda)^2}\right)$$

Agraval et.al.

$$\varepsilon(L,\lambda) := B \cdot D(\lambda) \cdot \Delta\lambda \cdot L \cdot km$$

$$\alpha(L,\lambda,k) := 5 \cdot \log\left(\frac{1}{1 - Q^2 \cdot \sigma_{mpn}(L,\lambda,k)^2}\right)$$

$$\alpha_{wc}(L,\lambda,k) := \mathrm{if}\left[(\lambda) > 1312 \cdot nm, \alpha(L,\lambda,k)_0, \alpha(L,\lambda,k)_4\right]$$

Basic MPN equations

Agraval et al, "Dispersion Penalty for 1.3um Lightwave Systems," IEEE Journal of Lightwave Technology, Vol.6, No. 5, pp 620-624, May 1988

Appendix 1: Dispersion test conditions

- Known fiber (25 km for slide 5, 50km for slide 6)
- Heat/Cool transmitter (the 25 km measurements were done on the cold side only, RT to –70C. The 50 km measurements were done –40C to 70C no corrections to other loss penalty from jitter and rise/fall time – all sensitivity losses attributed to dispersion).
- Test conditions (see also slide 6):
  - 3 different LD (MQW FP lasers) different lots
  - ER constant
  - $\Delta\lambda$ 2.3 – 2.8 nm rms (only one point < 2.5 nm)
  - 1.25 Gb/s
  - BER < 5×10^{-11}
  - Pattern $2^7 - 1$
  - Known parameters fiber