ECE 5411 - Optical Communication Systems
Final Exam - Part I

Please pay attention to units and the reasonableness of your answers. This part is worth 40 points.

Problem 1 (10 pts)

An optical fiber has a core diameter of 15 μm and core index of $n_1 = 1.465$ at $\lambda = 850$ nm. What is the minimum cladding index for which this fiber is single mode?

We have to consider the V number for the fiber

$$V = \frac{2\pi a}{\lambda}\sqrt{n_1^2 - n_2^2} \leq 2.405.$$

Note that 2a is the diameter. Plugging in the numbers, we get

$$\frac{\pi \times 15\ \mu m}{0.85\ \mu m}\sqrt{1.465^2 - n_2^2} = 2.405,$$

resulting in $n_2 = 1.4644$.

Problem 2 (10 pts)

An optical communication link is designed to transmit data over a (single-mode) optical fiber of 100 km, with fiber loss of 0.2 dB/km, six splices with 0.05 dB per splice loss, and two connectors with 0.2 dB per connector. The receiver sensitivity is 20 μW. What is the minimum transmitter power (express in both mW and dBm)?

You can express the loss budget of the system (in dB) using

$$P_{tr,dBm} - P_{rec,dBm} = -\gamma L + L_{fixed},$$

where L_{fixed} *represents the fixed losses in the system (i.e. losses that do not depend upon fiber length). Remember that* $\gamma = -0.2\ dB/km < 0$ *for loss.*

From the problem statement, the fixed losses add up to

$$L_{fixed} = 2 \times L_{connector} + 5 \times L_{splice} = 2 \times 0.2\ dB + 6 \times 0.05\ dB = \underline{0.7\ dB},$$

and the fiber loss

$$-\gamma L = 0.2\ dB/km \times 100\ km = \underline{20\ dB}.$$

Now, we need to express the receiver sensitivity in dBm, which we do by

$$P_{rec,dBm} = 10 \log\left(\frac{20\ \mu W}{1\ mW}\right) = \underline{-17.0\ dBm}.$$

Solving for the transmitter power, we get

$$P_{tr,dBm} = P_{rec,dBm} - \gamma L + L_{fixed} = -17.0\ dBm + 20\ dB + 0.7\ dB = \underline{3.7\ dBm}.$$

Expressed in mW, $\underline{P_{tr} = 2.34\ mW}$.

Problem 3 (20 pts)

For the system of Problem 2, the transmitter operates at 2.5 Gb/sec at a central wavelength of 1550 nm, with a spectral linewidth of $\Delta\lambda = 0.5$ nm.

a) If the fiber has a dispersion parameter of $M = -20$ ps/nm·km, then will the system work?

At this bit-rate, the maximum pulse spread is limited to

$$\Delta\tau = \frac{0.7}{B_{NRZ}} = \frac{0.7}{2.5\ Gb/sec} = 280\ ps.$$

The pulse spread due to chromatic dispersion is

$$\Delta\tau_{chrom} = -M \times L \times \Delta\lambda = 20 \times 100 \times 0.5 = 1000\ ps,$$

so the system will not work.

b) If not, then what is the minimum length of dispersion compensating fiber with a dispersion parameter M =100 ps/nm·km needed at the end of the link to achieve the intended bit rate?

To achieve the bit rate, the pulse spread needs to be reduced by 720 ps. With the dispersion compensating fiber,

$$\Delta\tau_{chrom} = -720\ ps = -100 \times L \times 0.5,$$

so that the distance is $L_{comp} = 14.4\ km$.