Course of Optical Communications – Telecommunication Engineering

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Practice Work n°8 – 08/06/2006

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PROBLEMS

8.1 In an optical fiber receiver, assume the received optical power is P Watts and the bit rate is R bits/s.

a) Find the number of received photons per bit.

b) Show that for a constant number of photons per bit, the required received optical power is proportional to the bit rate.

c) Find the received optical power necessary to receive 100 photons per bit at a wavelength of 1.5 μm and a bit rate of 1 Gb/s.

d) For the same conditions as c), assume you can launch 1 mW power into the fiber, and that the fiber loss at that wavelength is 0.2 dB/Km. What is the distance that we can transmit?

8.2 A typical direct detection optical receiver requires about N = 2000 photons per bit in the notation of problem 8.1.

a) derive the following formula for the required received power at an optical detector at a wavelength of 1.5 μm for this value of N,

$$P_{dBm} = -65.8 + 10\log_{10}\left(R_{Mb}\right)$$

where P_{dBm} is the received power in dBm required and R_{Mb} is the bit rate in Mb/s.

b) Assuming 0 dBm launched power into the fiber, and 0.2 dB/Km loss in the fiber, what is the allowable distance between repeaters at bit rates of 100 and 1000 Mb/s? You can assume that loss is the dominant impairment limiting repeater spacing.

8.3 Suppose we have a system requirement that a total bit rate of R_T must be transmitted over a distance of L_T using a set of parallel repeatered transmission lines in fiber. In each repeater span we have as design parameters the bit rate R of each line and repeater spacing L. Show that the total number of repeaters is minimized when the product $R \cdot L$ is maximized. Thus, if the repeaters are the dominant transmission cost, we want to maximize the product of the bit rate and the distance.

8.4 Let us consider the system described in problem 8.3 with the following characteristics:

Parameter	**Value**
Transmitted power in each span P_{TdBm}	0 dBm
Number of photons per bit needed at the receiver N	2000
Transmission wavelength λ	1.5 μm
Spectral width Δλ	30 nm
Attenuation factor γ_0	0.2 dB/Km
Chromatic dispersion factor D	4 ps/Km·nm
Total bit rate R_T	20 Gb/s
Total length L_T	2300 Km

Table 8.1

a) Derive the following relationship between repeater spacing L in Km (L_{Km}) and bit rate R in Mb/s (R_{Mb}):

$$L_{Km} = \frac{65.8 - 10\log_{10}(R_{Mb})}{\gamma_0}$$

b) Determine the admissible values for R and L in a graph having on the *y* axis the length L_{Km} and on the *x* axis the rate R_{Mb}, taking into account both attenuation and chromatic dispersion. In plotting the curves, assume that R can only take one of the following values: 1 Mb/s, 10 Mb/s, 100 Mb/s, 1 Gb/s, 10 Gb/s.

c) For the same possible values of R, determine the optimal couple (R, L).

Hint: For determining the impact of dispersion on distance, assume that the condition to be met is $\Delta\tau < T/2$, where T is the bit time.