ECE228B Term Project

Objective: To simulate a WDM transmission link and assess its performance characteristics.

Introduction:
In this project you will design and implement a time-domain simulator for data transmitted over the point-to-point fiber links. The links consist of a digital NRZ transmitter transmitting at λ_1, a wavelength multiplexer with 200GHz channel spacing, two interfering channels at λ_{N-1} and λ_{N+1}, an optical amplifier, a transmission fiber of length L, an optical de-multiplexer and a receiver connected to λ_1.

Your simulation will cover two cases
      (I)   A WDM link with optical booster amplifier (Figure 1a) and two interfering channels
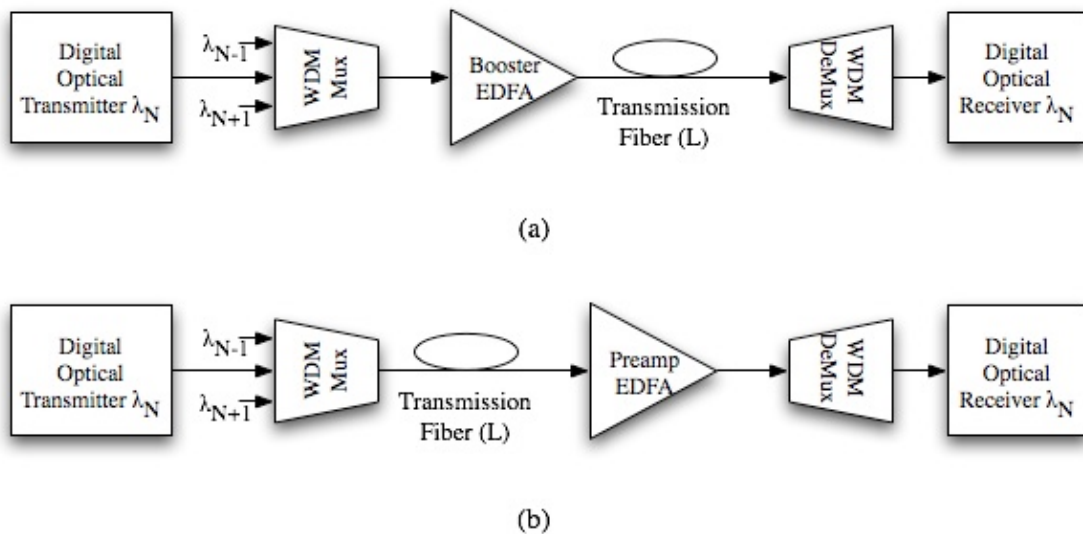   (II)   A WDM link with Preamp EDFA (Figure 1b) and two interfering channels.

(a)

(b)

Figure 1

Transmitter:
In each case, a data source generates a fixed binary non-return-to-zero (NRZ) intensity on-off modulated bit sequence that is electrically filtered, drives an optical current source and then direct drives a single mode semiconductor laser. Let the electrical filter 3dB bandwidth be 0.8 times the NRZ bit rate. Assume the single mode laser relaxation oscillation frequency is 10GHz and in response to being driven with the filtered current source, there is a 10% overshoot in the optical output that decays to steady state after 5 oscillations (e.g. the 1/e point of a decaying exponential envelope). The single mode laser source operating at 1550 nm with a 100 MHz linewidth is injected into the modulator that is then coupled to an optical fiber. All components are inter-connected by fiber splices with 0.1dB loss each.

Interfering Sources:
Assume that the interfering sources are identical to the primary transmitter in all ways, including the bit sequences transmitted and phase relation between bits. For example assume that the same simulator for your primary source can be duplicated exactly for the interfering sources.

Optical Multiplexer:
The transmitter and two similar interfering sources are connected to a WDM multiplexer. The multiplexer has an excess loss of 4dB for each input to the multiplexed output.

Fiber:
A standard single mode fiber of with nominal attenuation of $\alpha = .2$ dB/km. For this problem, assume negligible effects due to dispersion.

Optical Amplifier:
An EDFA with 10dB gain and 5dB noise figure is used. Assume the output saturation power of the EDFA is 10dBm.

Optical De-Multiplexer:
Assume the excess loss from the input to each output is the same as the multiplexer. Also assume the de-multiplexer has -10dB out-of-band power crosstalk (i.e. -10dB of each interfering channel leaks into the primary channel port).

Optical Receiver:
The output of the de-multiplexer is terminated with an optical connector to a photodetector with unity efficiency and 0.05nA dark current. A transimpedance preamplifier with 3 dB Noise Figure is used and followed by a low pass filter with electrical bandwidth of 1/2 the bit rate. Use the same technique to add electrical noise at the receiver (via the NF) that you used on the optical signal with the EDFA.

Simulation:
1) Operate your system at 2.5 Gbps (OC-48).
2) First generate a pseudo-random number generator that outputs a series of 10 bits.
3) Next create an output rise and fall waveform that represents the laser optical output in response to a bit as it turns on and off. You should sample each bit with at least 100 data points to get high enough resolution.
4) Use your laser rise- and fall-patterns combined with the binary pseudo-random number generator to create a simulated optical output data stream. Use this stream for your primary and interfering transmitted streams and normalize the peak to your transmitted optical power.
5) First assume a fiber length of 10km. Operate on this data stream with each element in the system including each loss element and each gain element. Make sure to generate input and output data streams in order of the elements they pass through and create a new data output file for each element.
6) For the optical amplifier, add random noise to your data stream at each time sample using a Gaussian random number generator with variance chosen based on the noise figure. Make sure you add in power.
7) At the receiver, make sure you add the three channels taking into consideration the level of de-multiplexer crosstalk.
8) Plot a series of received output bit patterns while varying the transmitter optical power from –20 dBm to +20 dBm in steps of 5 dBm. Make sure you take into account the optical amplifier output saturation power. Also make sure the interfering channels are increased in power the same as your primary channel.

9) Choose a transmitter power that gives you the best received bit pattern in terms of a signal to noise ratio measurement. Fixing the laser output power at this value, now perform the same simulation as in as in (9) varying the fiber length from 10 km to 80 km in increments of 10 km.

In your writeup, use the following outline. Limit the total length to no more than 15 pages.

(I)   Problem statement: Setup the problem in your own words.
(II)   Approach: Describe in your own words the high level approach you are using to solve this problem.
(III)   Simulation Tool: Describe how you designed the simulation, what assumptions and tools you used.
(IV)   Results: Summarize your results. Use representative bit patterns but not all that were generated. Here is where you plot the end results, for example the SNR as a function of transmitted power and the SNR as a function of fiber length for fixed transmitter power.
(V)   Questions:
   a. What can you say about the behavior of the link in terms of loss and the placement of the optical amplifier as a booster and pre-amp?
   b. What is the effect of electrical and optical amplifier noise figure?
   c. How did the amplifier output saturation power affect the system design?
   d. What is the effect of the interfering channels and the level of de-multiplexer crosstalk?
   e. What overall conclusions can you draw from your simulations?