King Abdulaziz University
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THE DISPERSION EFFECT ON AN OPTICAL FIBER LINK

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ABSTRACT:

This lab assignment studies the dispersion effect on an optical fiber link. The study is made on simulated system using the VPI software. The simulated system contained of transmitter, optical fiber and receiver. It was tested at different optical fiber lengths with fixed attenuator at 4dB. The system performance was measured by studying the system figures that show the optical, electrical signals and the corresponding eye-patterns.

INTODUCTION:

As it mentioned in the assignment sheet, there are three kinds of fiber dispersions waveguide dispersion ($D_{waveguide}$) , material dispersion, or chromatic dispersion ($D_{material}$) and modal dispersion or inter-modal dispersion.

The summation of the first two types is referred to as intra-modal dispersion.

The third type of dispersion is due to the dependence of the propagation velocity on different propagation modes. Single mode fiber has only intra-modal dispersion.

Total fiber dispersion is

$$D^2_{total} = D^2_{intra}\, \Delta\lambda^2 + D^2_{modal} \quad (sec/km)^2$$

$\Delta\lambda$: is the line-width of the light spectrum.

In this lab assignment a single-mode fiber will be used, so the modal dispersion equals 0. Based on the given specifications, D_{total} can be calculated using the above equation.

The total dispersion affects the bit rate, B, explicitly and the link length, L, implicitly; so there is a trade-off between these parameters in designing any fiber link. The relationship can be defined as:

$$L \leq \frac{1}{4D_{total}B}$$

To analyze the effect of dispersion and/or attenuation on the performance of an optical fiber link, the received power has to be fixed during all the simulation steps.

The equipment will be used in this assignment is the VPI toolbox only.

The study in this lab assignment, focused on studying the eye diagram for the system. The eye pattern superimposes the waveform in each signaling interval into a family of traces in a single interval (0,T). Below figure demonstrate it for binary antipodal signaling. The width of the opening indicates the time over which sampling for detection might be preformed. The optimum sampling time corresponds to the maximum eye opening.

D_A, is the range of amplitude differences, is a measure of distortion caused by intersymbol interference (ISI).

J_T, is the range of time differences of zero crossings, is a measure of the timing jitter. S_T is the sensitivity-to timing error; M_N is the measure of noise margin.

The most frequency use is for ISI qualitative assessment. As the closes, ISI is increasing, as the eye opens, ISI is decreasing.

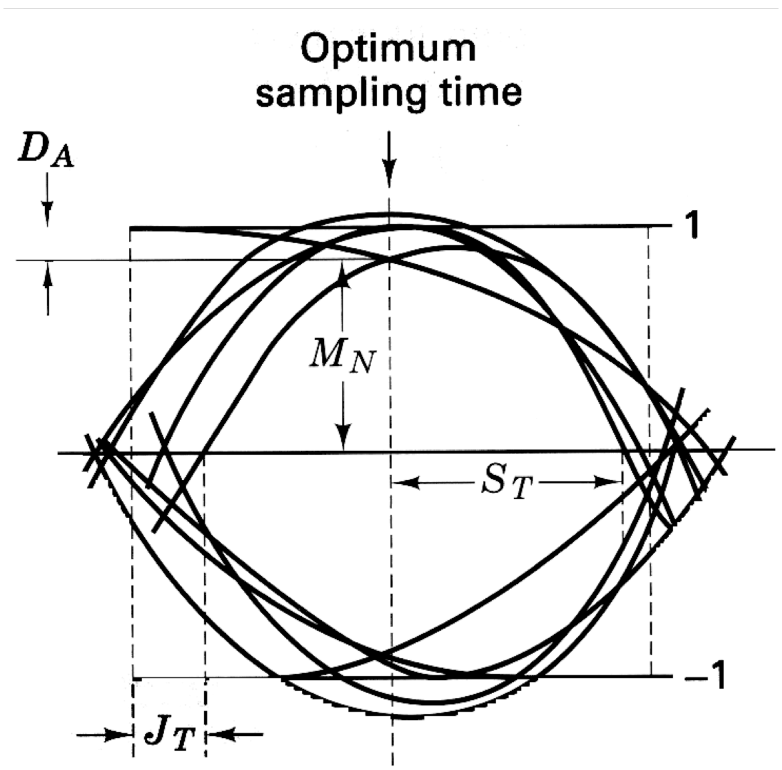
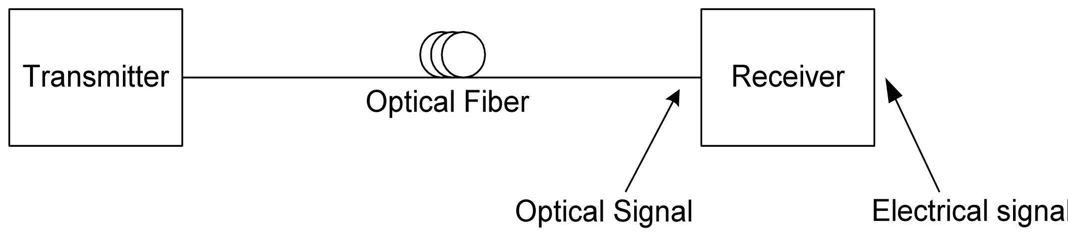


Figure # Eye Pattern

Procedure:

Using the VPI software, these are the steps followed in this lab assignment:

Step1: Constructing the fiber optic link shown in the following figure based on the following specifications.



The system has to be constructed for 10 Gbps at a wavelength of 1552.5 nm and an operating band of the system of 1550nm. An NRZ encoding scheme of the signal is used; this means that the average power is half of the peak power.

TX-OOK.Vtmg is used as a transmitter. The operating frequency of this transmitter is 193.1 THz (wavelength of 1552.5 nm); the laser-transmitted power is 1mW peak (-3 dBm average power) and the laser line width is 12.5 GHz ($\Delta\lambda$ = 0.1 nm at reference frequency).

RX-OOK-BER.Vtms is used as a receiver. The thermal noise for the receiver is assumed to be 10^{-12} (A/Hz$^{1/2}$), and the shot noise of the receiver is kept on. 1 nA is used for the dark current of the photodiode inside the receiver.

The standard single-mode fiber, *FiberNLS.Vtms*, is used to make the connection between the components; the attenuation factor of it is equal to 0.2dB/km and the dispersion factor is 16×10^{-6} s/m^2 (16 ps/nm/km).

To take into account the connector losses and excess loss of other devices in the link, an attenuator with 4.0 dB attenuation is added in front of the receiver.

The transmitted power is kept at a constant value of 1 mW (or 0 dBm) for all of the following steps.

Step2: Running the simulation with the fiber length of 1m and adjust the attenuator at 4dB.

Step3: Measuring the optical power at the receiver side using the simulation. The *Vipowermeter* module will display the results in watts, not in dBm.

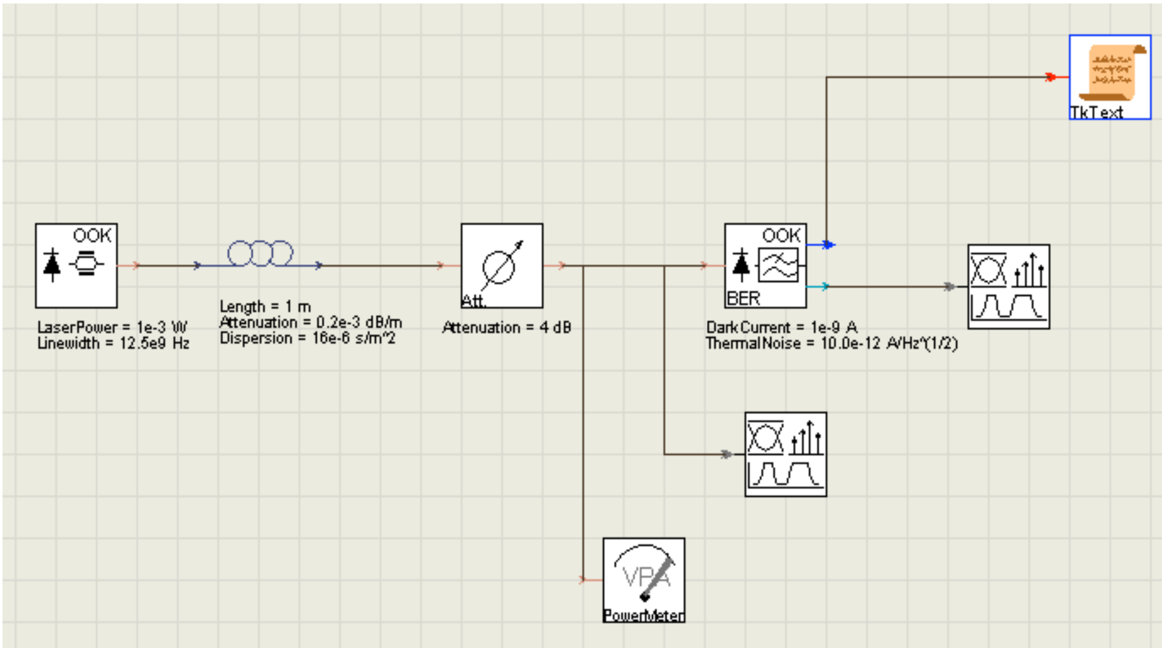
Step4: Using the *Viscope* to display the signal at both the optical and electrical sides of the receiver; for all signals, examine their corresponding eye-patterns. Include those signals and a plot of their corresponding eye-patterns in the report.

Step5: Repeating steps 1 through 4 after adjusting the length of the fiber to 5 km and leave the attenuator at 4dB.

Step6: Repeating steps 1 through 5, but in this case change the length of the fiber to 10 km.

Step7: Increasing the length of the fiber to a point where the eye-diagram is 90% closed.

Results:

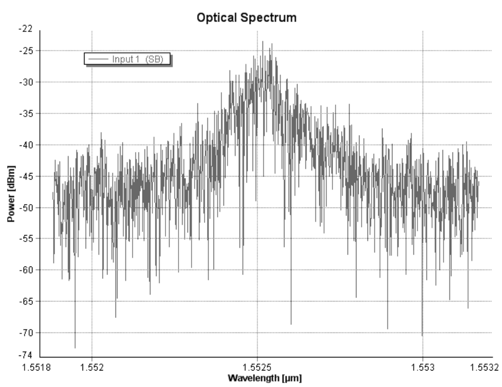


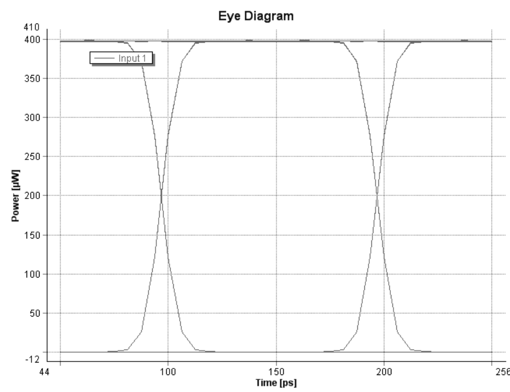
The constructed fiber optic link block diagram on VPI software

Viscope display signal at both the optical (before receiver) and electrical signal (after receiver)

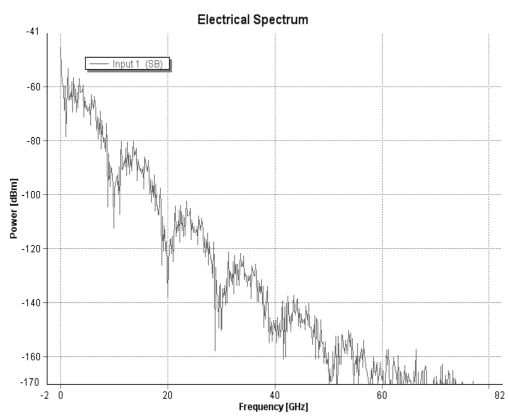
After running the simulation with fiber length of 1 m and adjusting the attenuator at 4dB, yielded the flowing results:

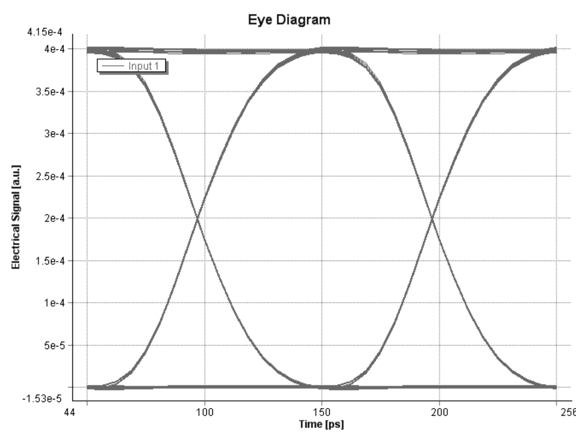
For 1m fiber length:





Eye Diagram before





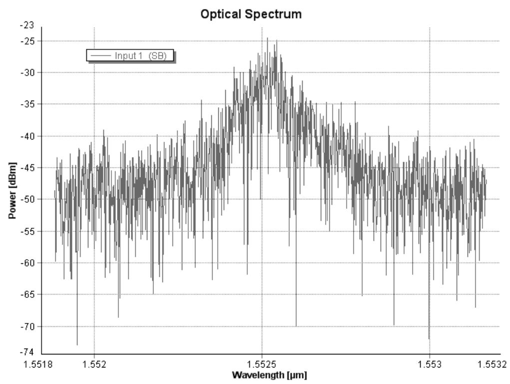
Eye Diagram after

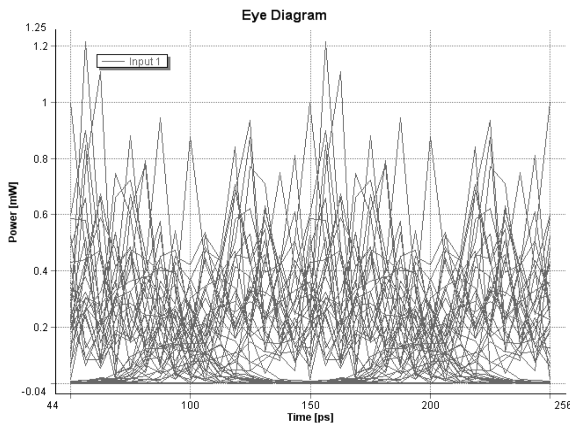
Bit Error Rate = 0.0

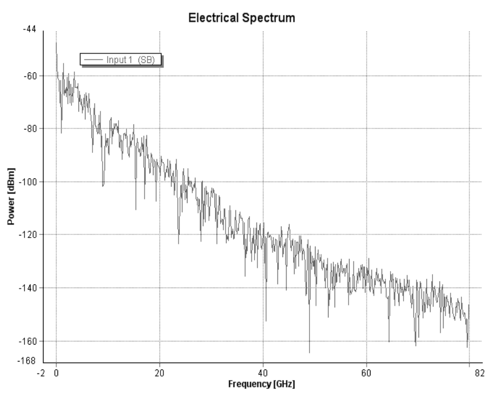
Output Optical Power=0.000168005992011613 W = -7.72 dBm

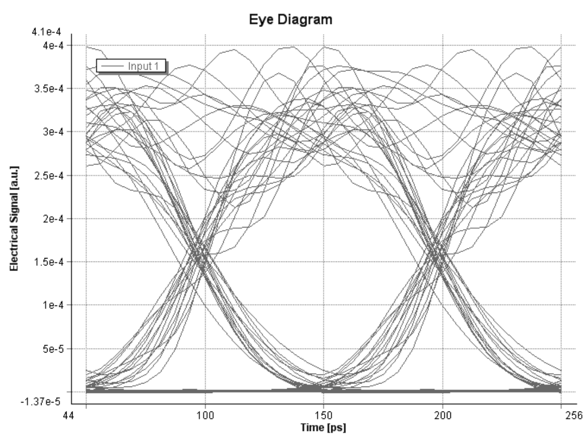
After running the simulation with fiber length of 5k m and adjusting the attenuator at 4dB, yielded the flowing results:

For fiber length 5km:







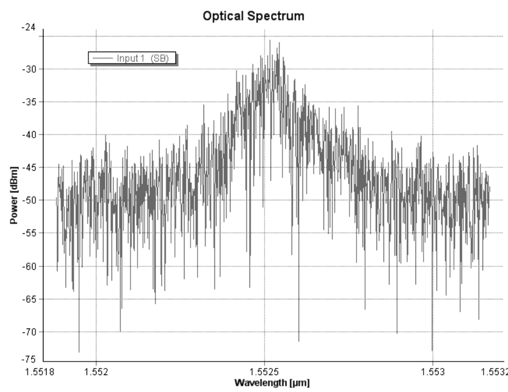


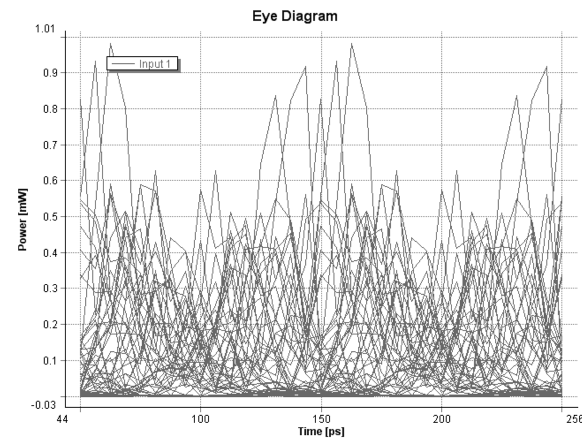
Bit Error Rate = 7.42785787894811 x 10^{-15}

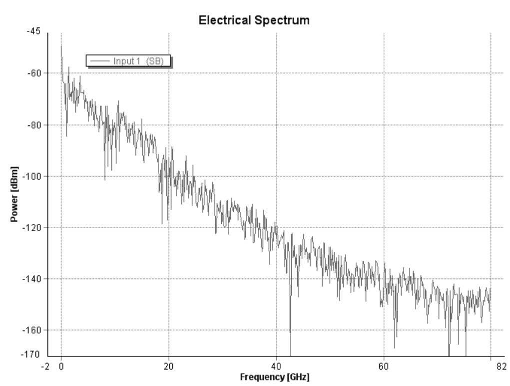
Output Optical Power = 0.000133458048886452W= -8.74 dBm

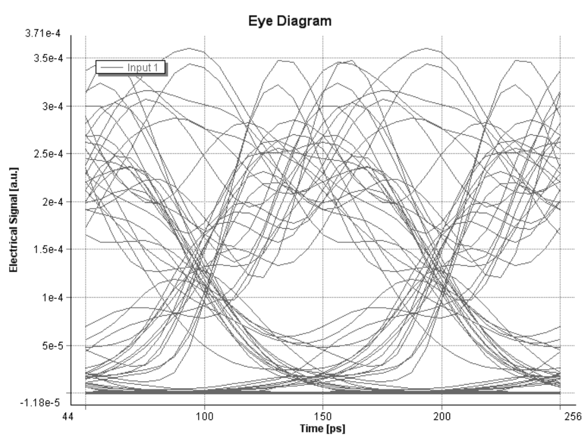
After running the simulation with fiber length of 10 km and adjusting the attenuator at 4dB, yielded the flowing results

For fiber length 10km:









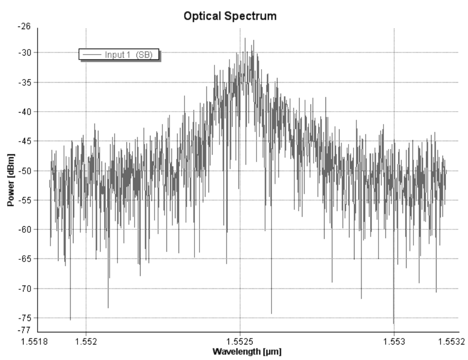
Bit Error Rate = 9.73423972985413 X10^{-5}

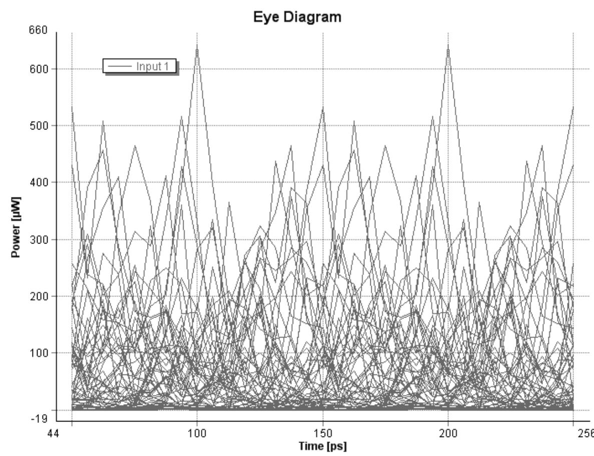
Output Optical Power = 0.000106009496381723=-9.74 dBm

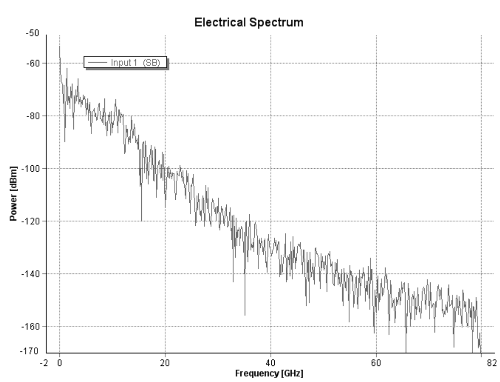
To make eye 90% closed

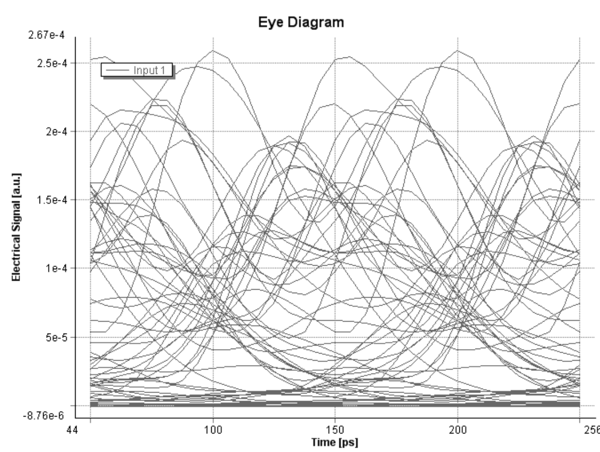
Running the simulation with fiber length of 20 km and adjusting the attenuator at 4dB, yielded the flowing results

20km:







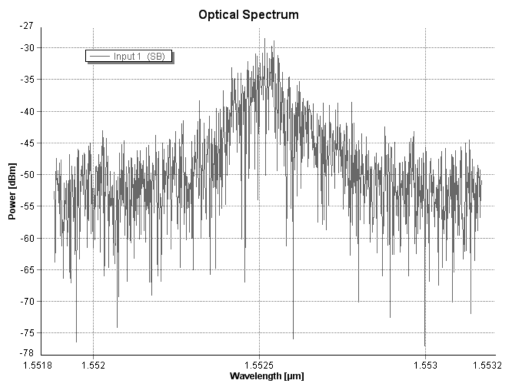


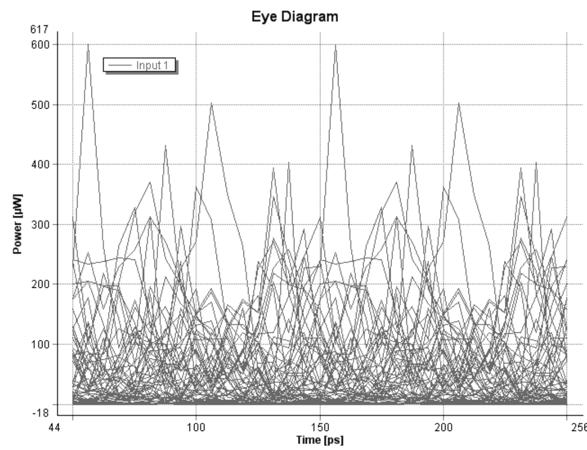
Bit Error Rate = 0.0163745136238897

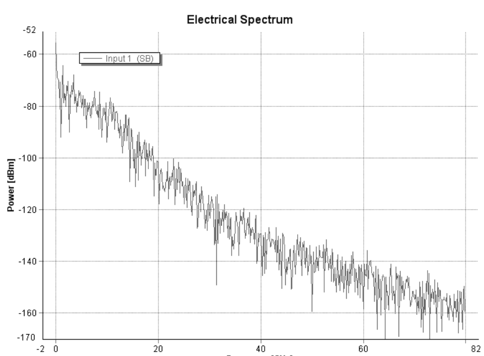
Output Optical Power =6.6887470326695 X10^{-5} W = -11 dBm

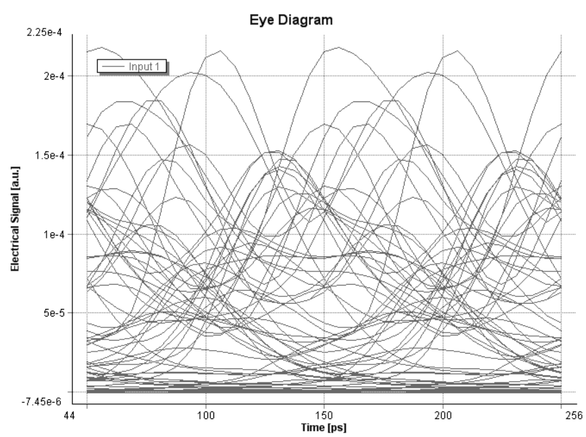
After running the simulation with fiber length of 25 km and adjusting the attenuator at 4dB, yielded the flowing results

25km:









Bit Error Rate = 0.0400560313048051

Output Optical Power =5.31306062297763 X10^{-05} W = -12.7 dBm

Putting all the results together for comparing, yield the following

Optical Fiber length (meter)	Bit Error Rate	Output Optical Power
1	0	-7.72 dBm
5k	$7.42785787894811 \times 10^{-15}$	-8.74 dBm
10k	$9.73423972985413 \text{X} 10^{-5}$	-9.74 dBm
20k	0.0163745136238897	-11 dBm
25k	0.0400560313048051	-12.7 dBm

From the first result for the fiber length at 1 meter, was observed that how the eye diagrams are wide open, which imply no intersymbol, would occur. This explains the zero bit error. Also the electrical spectrum showed that the transmitted information would recover with the least noise from all the other fiber lengths. Which the output optical power value confirm that.

At 5k-meter fiber length, the system eye diagrams started to show some noise and the width of the opening decreases. The noise will cause some error and the decreases in the optical power. That would cause less information transmission.

At 10k-meter fiber length, the length got doubled and the bit error rate increased in great deal, but it still acceptable. The eye diagram at this length is still noticeable that is open, implies the error bit rate is tolerable as well as the attenuation in the output optical power.

At 20k and 25k-meter fiber length, error bit rate is extremely high and the output optical power are low. The eye diagram at 20k meter is almost close explaining the high error bit rate. At 20k-meter assumed the point where eye diagram is is about 90% closed. The electric spectrum shows many noises that the differences to the electrical spectrum for the 1-meter fiber length are observed.

At 25k-meter the eye diagram closed more than eye diagram at the 20k-meter length. From the observation between the two eye diagrams it was assumed the 25k-meter eye diagram closed by more than 90%.

Conclusion:

By studding the attenuation on the performance of an optical fiber length, it is important to decide what is the acceptable error bit rate in the optical fiber communication system. From this experiment, the relationship between eye diagrams and the error bit rate was observed. As much the eye in an eye diagram opens as less error bit rate show and vise versa.

Fiber optical length has a wide effect on the information transmission, by affecting the error bit rate. From the assignment the length effect on the total dispersion was confirmed.

From comparing all the results for the different fiber lengths in this practical application, optical fiber length at 10k-meter gave the most acceptable error bit and output optical power.

Works Cited

- Introduction to Analog & Digital Communcations, by Haykin, Moher, second edidtion