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Performance Analysis of fibre Channel Dispersion and its effect on Optical Communication

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Abstract—***the bandwidth that an optical fiber can support is limited by the dispersion in an optical fiber. As the demand of bandwidth increases, the spacing between successive pulses and the pulse duration of the signals have to decrease to meet the demand. However, the short optical pulses used may not necessarily be monochromatic, in another words they often contain more than one frequency components. In this case, chromatic dispersion in the optical fibre is the dominant factor limiting the transmission rate of nowadays telecommunication systems. Dispersion limits the length of fibre and effect on inter symbol interference (ISI) of the signal. The primary dispersion in a multi-mode step index fiber is the intermodal dispersion caused by different modes in the fiber traveling different distances to reach from one point to another a narrow pulse at the input divides its energy into different modes which now take different lengths of time to reach the detector. The result is a broadening of the pulse. In the graded index fiber, the intermodal dispersion is greatly reduced and is eliminated in a single mode fiber. The pulse broadening may cause overlapping of neighboring pulses. To avoid this, dispersion compensation techniques are used to make sure long and error free transmission. In this paper the effect of dispersion and the method to compensate it using MATLAB coding and SIMULINK modeling of the optical communication system are shown***.

Keywords—* Dispersion, Inter symbol Interference, Chromatic Dispersion, Polarization Mode dispersion, optical fibre*

Introduction

The demand for the bandwidth of nowadays telecommunications grows exponentially each year. For high speed communications, data (bits) are converted to optical pulses and sent through optical fibres. Single-mode optical fibres have been laid underground and on the ocean floor to provide high speed telecommunication pathways throughout the globe. As the demand of bandwidth increases, the spacing between successive pulses and the pulse duration of the signals have to decrease to meet the demand. However, the short optical pulses used may not necessarily be monochromatic, in another words they often contain more than one frequency components. In this case, chromatic dispersion in the optical fibre is the dominant factor limiting the transmission rate of nowadays telecommunication systems. Dispersion defined as the signal broadening or spreading while it is propagates inside the fibre. It is most often described in light waves, but it may happen to any kind of wave that interacts with a medium or can be confined to a waveguide, such as sound waves. As a pulse of light proceeds through the fibre, it widens in the time domain. This spreading is caused by dispersion [1]

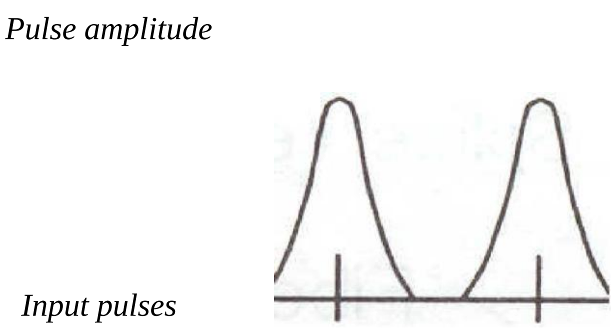


Figure 1(a) Well-resolved pulses at input

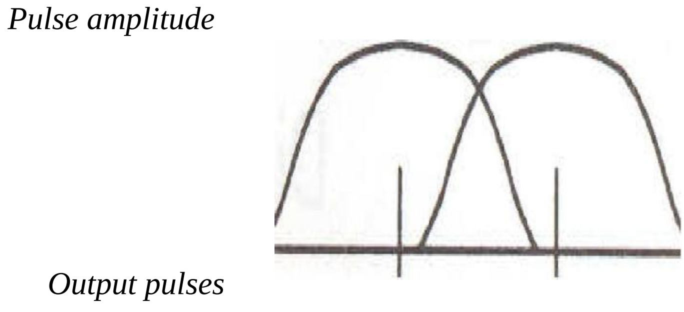


Figure 1(b) Unresolved (overlapping) pulses at output [2].

The amount of pulse spreading determines how close (in time) two adjacent output pulses are. For any given receiver, there is a minimum spacing required between output pulses, since the receiver must be able to resolve the two separate pulses.Hence, the amount of pulse spreading in the fiber limits the maximum rate at which data can be sent (or, the spreading determines the maximum length of the fiber, if the data rate is fixed). Low dispersion means a high data rate, since pulses can be transmitted closer together with less overlap at the output[3].

There are many different types of dispersion in optical fibres. These types are:

1. Intermodal, or modal, dispersion occurs only in multimode fibbers.

2. Intramodal, or chromatic, dispersion occurs in all types of fibbers, but the main concern is in the single mode fibres where intermodal dispersion is not present. The causes of chromatic dispersion are Material dispersion and Waveguide dispersion.

3. Polarization mode dispersion PMD.

Each type of dispersion mechanism leads to pulse spreading. As a pulse spreads, energy is overlapped. This condition is shown in figure 1(b). The spreading of the optical pulse as it travels along the fiber will affect the whole system where dispersion will cause the signal to spread out, lose it's shape and become difficult to detect by receivers at the end of a fiber span, thus dispersion will causes bit error rates (BER) to increase to unacceptable levels. The spreading of the optical pulse as it travels along the fiber limits the information capacity of the fiber. Dispersion results in inter symbol interference (ISI) and hence power penalty[4]. Dispersion induces coherent cross-talk between channels in multiplexed transmission systems. Dispersion causes pulse spreading and distortion and thus can lead to system penalties. There are several methods being developed to compensate the dispersion of optical fibre. However, to compensate the dispersion correctly, an accurate method to measure the dispersion of the optical fibre is essential. The main purpose of this project was to analyse the dispersion in the fibre accurately in order to compensate the pulse broadening effect caused by dispersionis a template. An electronic copy can be downloaded from the Journal website. For questions on paper guidelines, please contact the journal publications committee as indicated on the journal website. Information about final paper submission is available from the conference website.

I. CHROMATIC DISPERSION

Chromatic, or Intramodal, dispersion occurs in both single mode and multimode optical fibers. It is the main cause of dispersion in the single mode fibers, in which only one mode that is the lowest order mode HE11 propagates. Chromatic dispersion is the term given to the phenomenon by which different spectral components of a pulse travels with different velocity [5].

Chromatic dispersion occurs because different colors of light travel through the fiber at different speeds. Since the different colors of light have different velocities, some colors arrive at the fiber end before others. This delay difference is called the differential group delay. This differential group delay leads to pulse broadening. In actuality, the chromatic dispersion is caused by the same physical effect of the dependence of the index of refraction of glass on wavelength. Chromatic dispersion arises for two reasons. The first is that the refractive index of silica, the material used to make the optical fiber, is frequency dependent. Thus different frequency components travel at different speeds in silica. This component of chromatic dispersion is termed as material dispersion. Although this is the principal component of chromatic dispersion for most fibers, there is a second component, waveguide dispersion[8].

II. MATERIAL DISPERSION

Material dispersion is caused by the velocity of light (or, equivalently, the index of refraction) being a function of wavelength as the figure 2 shows the variation of refractive index n(λ) in silica with respect to wavelength.

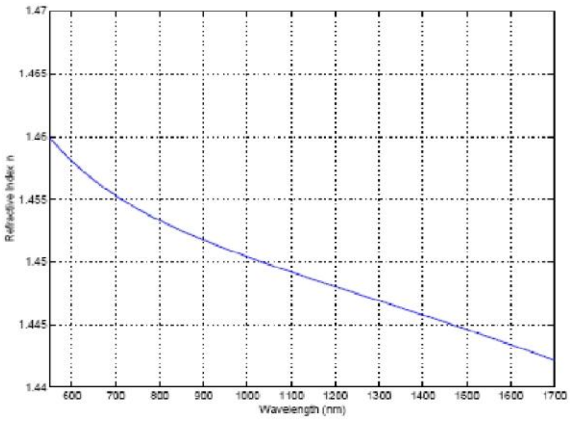


Fig 2 Variation of refractive index with the wavelength

In single-mode fibers operating at shorter wavelengths (i.e., 800-900 nm), this will be the dominant source of dispersion. All sources of light have some degree of spectral width to their output. (A laser source has a considerably narrower spectral width than an LED.) This nonzero spectral width implies that, even with single-mode propagation, the longer wavelengths with their faster velocities will arrive at the receiver before the shorter wavelengths, thereby stretching the pulse. The pulse spreading due to material dispersion is given by [6]

$$T = \frac{L}{V_g} \qquad (2.1)$$

III. POLARIZATION MODE DISPERSION

Polarization Mode Dispersion (PMD) has increasingly attracted the attention of the researchers due to several reasons. Different techniques have been emerged to mitigate the effect of chromatic dispersion and chromatic dispersion compensating modules have become commercially available, making the PMD a dominating factor. The introduction of optical amplifier has allowed a considerably increase in the length of the communication link before electronic regeneration of the signal is required. This however also allowed the PMD effect to accumulate even to a longer distance. PMD has its significant effect in the multi gigabit per second optical communication system. Polarization Mode Dispersion (PMD) is a broadening of the input pulse due to a phase delay between input polarization states. Single-mode optical fibre and components support one fundamental mode, which consists of two orthogonal polarization modes. Ideally, the core of an optical fibre is perfectly circular, and therefore has the same index of refraction for both polarization states[7]

IV. RESULTS AND DISCUSSION

A. Measurement of Inter Symbol Interference (ISI) Using Eye Diagram

In order to obtain an impression as well as a quantitative measure of the quality of a received data signal an eye diagram can be taken. It consists of many overlaid sections of the data signal, one or several bit periods long and triggered to the bit rate. The pattern received in this way looks like an eye which is more or less open[9]. The wider the opening, in particular the vertical opening, the better is the signal quality and the lower is the bit error ratio. The decision level on whether a “1” or a “0” has been received is located in the middle between the upper and the lower boundary of the eye. The opening is affected by timing jitter, by noise, by pulse distortion caused by dispersion effects, and by nonlinear effects[10].

In this exercise the impact of chromatic dispersion (CD) and 1st order polarization mode dispersion on the eye diagram is studied by numerical means by writing and applying a simple code in MATLAB.The pulses under consideration are Gaussian pulses (as shown in the figure 3) with a sinusoidal carrier.

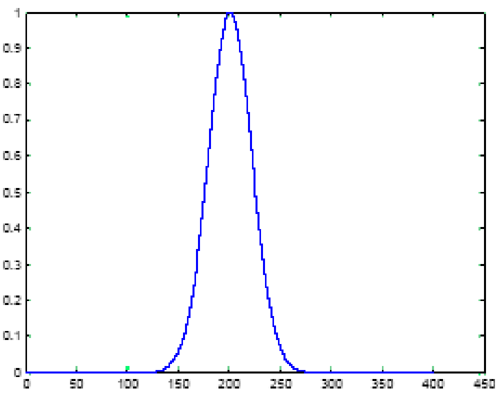
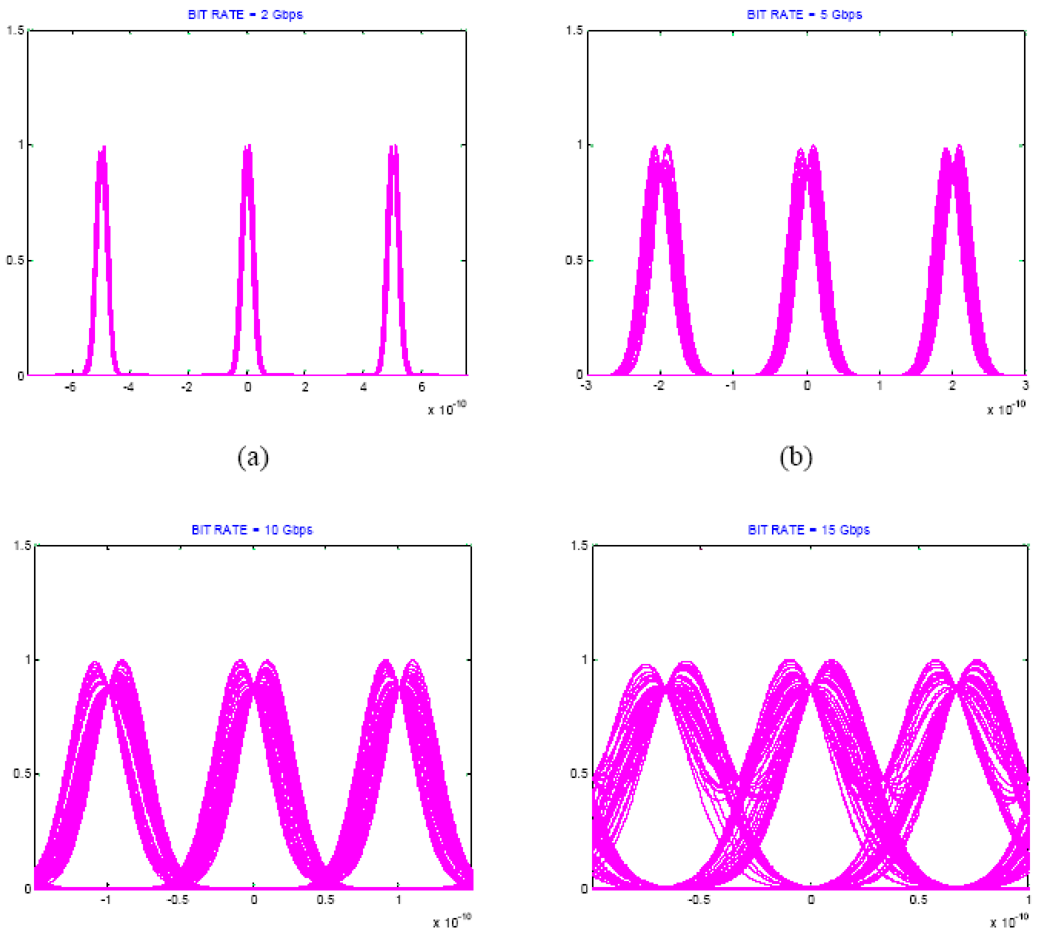


Fig 3. Gaussian pulses

The transmission system and the optical source are characterized by the bit rate, the pulse form, the mean wavelength and the input pulse width (FWHM) while the fiber is characterized by its length, dispersion coefficient D (in ps/km/nm), PMD coefficient (in ps/km1/2) and the Attenuation (in dB/km). Since eye pattern is used to note the effect of inter symbol interference due to dispersion and the nonlinearity present in the optical fiber.

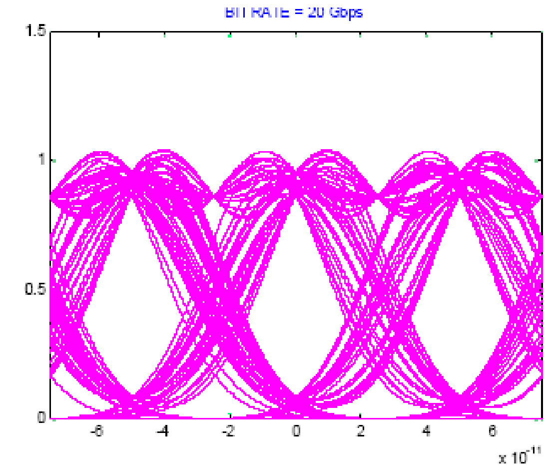
B. Effect of Bit Rate on the ISI.

Effect of the bit rate on the system performance can be seen by plotting different eye plots for different value of bit rate keeping the dispersion, length, PMD, attenuation and all other parameters under consideration to be constant. The simulation result is as shown in the figure 4 (a)-(h) with varying value of bit rate 2, 5, 10, 15, 20, 25, 30 and 35 Gbps respectively.

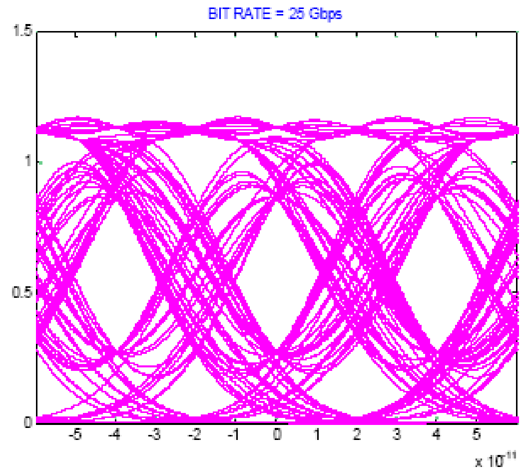


(c) (d)

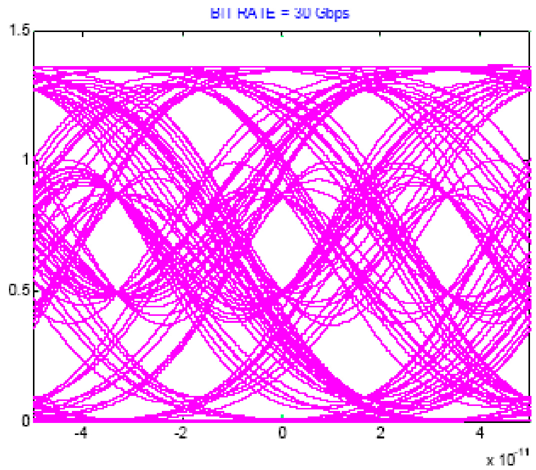
Fig.4(a) –(d) Effect of bitrate on performance of the system



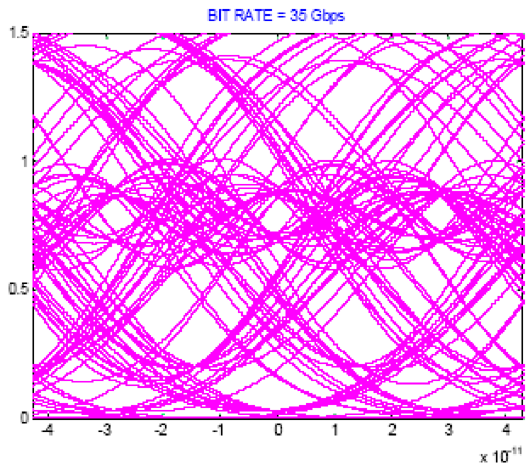
(e)



(f)



(g)



(h)

Fig.4(e) –(h) Effect of bitrate on performance of the system

It is clear from the figure 4.2, that as the bit rate of transmitting signal increases the effect of ISI gets pronounced. From the figure it (a) when the system is operated at 2 Gbps which is optimum for the given parameter the bits are easily distinguishable from each other with substantial spacing between them. In fig (b) although broadening do get occur in the pulse width but the pulses are still easily distinguishable from each other. But as the bit rate keeps on increasing the point is reach fig (g), where it is impossible to distinguish between the “1’s” and “0’s” bits from each other. Thus at higher data rate the effect of dispersion gets pronounced, leading to ISI. The relation between relative increases in the chromatic dispersion with the increasing data rate is shown in the figure 5.

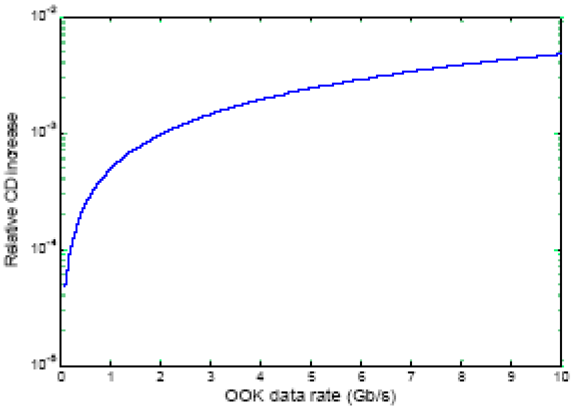


Fig 5 relation between relative CD increases with the Bit rate

V. CONCLUSIONS

We perform the analysis of pulse dispersion phenomenon in optical fiber communication. During the project work we analyse the different factors responsible for the pulse distortion in optical fiber communication and the methods to resolve them. The factors on which the pulse dispersion depends includes spectral width of the source, operating wavelength, bit rate of the data transmission, length of the optical fibre used. We perform the various simulations which include MATLAB coding, MATLAB SIMULINK modelling of the optical communication systems. We demonstrated that as the bit rate of transmitting signal increases the effect of ISI gets pronounced. Results show that as the bit rate increases, the relative chromatic dispersion also gets increased.

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