Analysis of Pulse Dispersion and effects of differential group delay and length of optical fibre

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ABSTRACT *In current era, Optical fibre communication is used to transmit data with high speed and for requirement of high data rate. In optical communication we can transmit data in terabit range. Data accuracy is very important in case of optical communication. Signal distortion due to pulse broadening is leads inter symbol interference of the optical signal which is called pulse dispersion. Analysis and compensation of pulse diapersion is necessary. In today's optical communication pulse dispersion will be managed by using some advanced optical amplifiers and wavelength division multiplexing technique. In this paper we analyse the difference types of pulse dispersion like polarization mode dispersion and chromatic dispersion. We have also proved in this paper that the differential group delay effects on ISI of the signal and Signal ISI limits the length of optical fibre. In this paper we analyse the effect of pulse dispersion in form of DGD and fibre length because of pulse dispersion.*

Keywords: *Pulse dispersion, Differential Group delay, optical fibre, Group velocity dispersion.*

1. INTRODUCTION

The total dispersion of single-mode fibres is the combination of material and waveguide dispersion[1]. It can be taken into account mathematically by using the Taylor series expansion about the centre frequency ω_0 of the mode-propagation constant $\beta(\omega)$

$$\beta(\omega) = \beta_0 + \beta_1(\omega - \omega_0)\frac{\beta_0}{2!}(\omega - \omega_0)^2 + \ldots\ldots \quad (1)$$

$$\beta_m = \frac{d^m \beta}{d\omega^m}\bigg|_{\omega=\omega_0}$$

Where, (2)

The parameter β_1 is the reciprocal of the group velocity vg and is related to the group index ng, where the group velocity represents the velocity of the envelope of the optical pulse[2]

$$\beta_1 = \frac{1}{v_g} = \frac{n_g}{c} \quad (3)$$

On the other hand, β_2 represents the change in group velocity of the envelope as a function of frequency and is the main factor that is responsible for pulse broadening effects.

$$\beta_2 = \frac{d\beta_1}{d\omega} = \frac{d}{d\omega}\frac{1}{v_g} = -\frac{1}{{v_g}^2}\frac{dv_g}{d\omega} \quad (4)$$

The pulse broadening effect is called the group-velocity dispersion (GVD), and β_2 is generally referred to as the GVD parameter which is the most interesting parameter in this paper.

The unit of β_2 is ps2/km which is equivalent to ps/ (THz·km), and it can be easily understood as if there are two pulses separated by 1THz entering a 1km fiber with β_2 = 20ps2/km, they will have a 20ps delay between them when they exit at the other end. The dispersion parameter D is commonly used in engineering literature in place of β_2 and it has the units of ps/(nm· km), which has the same meaning of the β_2 parameter but the unit of the pulse separation is in wavelength (nm). It is related to β_2 by the relation

$$D = -\frac{2\pi c}{\lambda^2}\beta_2 \quad (5)$$

There are two different dispersion regimes in fibers, normal dispersion regime and anomalous dispersion regime. In the normal dispersion regime, longer wavelength components in the pulse travel faster than shorter wavelength components, resulting in different frequency components arriving the receiver at different times. In the an ormolus regime, the exact opposite will occur in comparison to normal dispersion, that the longer wavelength components travel slower then the shorter wavelength components.

A very important feature of chromatic dispersion is that different wavelength components of the pulse propagate at different speeds inside an optical fiber, this leads to pulse broadening, and in the worst case inter-symbol interference (ISI) will occur. Figure 1 below shows how ISI may occur at the fiber end if chromatic dispersion is present.

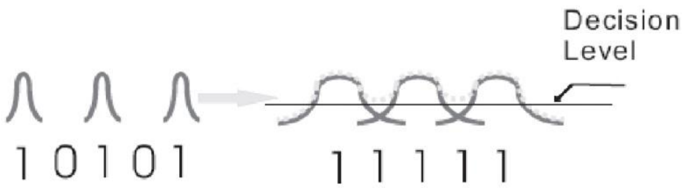

Fig 1 Inter-symbol interference (ISI) caused by chromatic dispersion.

2. WAVEGUIDE DISPERSION

In monomode fibre another cause of dispersion becomes important. This is **waveguide dispersion**. It arises because the way in which the waves match the boundary conditions at the core-cladding interface depends on their frequency. As a result, their propagating phase velocity is a function of frequency, independent of any material effects. Another way of understanding this is to recognize that, in monomode fibres, a significant fraction of the optical power propagates in the cladding. In the single mode fibers as the frequency varies, so the proportion of the power traveling in the cladding changes, and so the average refractive index experienced by the wave also changes.

Although the relationship between material dispersion and waveguide dispersion is quite complex, to a first approximation they may be added algebraically.

3. CHOROMATIC DISPERSION

The resulting total dispersion is perhaps best called **chromatic dispersion[3]**. For a standard monomode fiber with a core diameter of about 8 um and an index difference of about 0.005, the wavelength of minimum chromatic dispersion, λ_0 is shifted to about 1310 or 1320 nm by the combined effects of the germanium dopant in the core and the waveguide dispersion[4]. This is shown in Figure 2

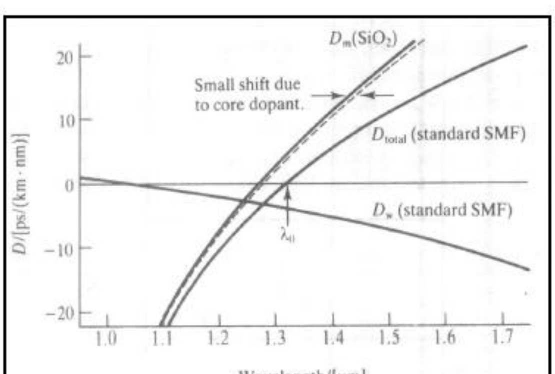

Fig 2 Dispersion characteristic of standard single mode fiber.[3]

Standard single fiber is often referred to as G.652 fiber from the number of the CCITT Recommendation specifying its characteristics. It is required to have a total R.M.S. Dispersion not exceeding 6 ps/ (nm~km) over the wavelength range 1270—1340nm. To minimize the total dispersion of a single mode fiber, it is necessary to operate at a wavelength longer than 1.27 microns to allow the small positive dispersion to cancel the small negative waveguide dispersion, causing a net dispersion of zero, as shown in the figure 2.. This zero dispersion occurs near 1320 nm approximately

4. MODAL DISPERSION

Optical signal wavelength travels with different speed in different mode of optical fibre. Due to speed variation different signal arrive at different time in multi-mode fibre. So that signal is spreaded due to varios mode this is called modal dispersion. This modal dispersion is shown in figure 3.

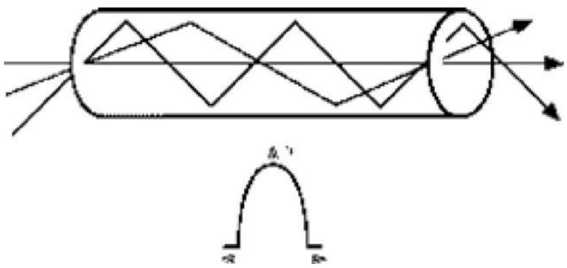

Fig 3 multiple modes in a fiber [7]

As disused above due to velocity difference in various modes creates group delay of the light in the fibre. This situation creates the pulse to broaden. This intermodal dispersion increases with the length of the fibre. Modal scattering is the main cause of distortion of the signal in multimode fibres. This dispersion occurs in multimode fibre only. In single mode fibres signal travels in same velocity so that single mode fibre propagate only the fundamental mode. Therefore, single mode fibres show the lowermost quantity of total dispersion [7]. Lower dispersion provides more bandwidth in optical communication so that single mode fibre shows the highest possible bandwidth. In graded index fibre the effect of this dispersion is less than the step index fibre. So to optimize the optical communication we can use ingle mode fibre or graded index fibre in comparison with step index fibre.

5. RESULTS AND DISCUSSION

5.1 Effect of Differential Group Delay (DGD) on the ISI

Broadening of the input pulse due to a phase delay between input polarization states is called as Polarization Mode Dispersion (PMD)[8]. Single-mode optical fibre and components support one fundamental mode, which consists of two orthogonal polarization modes. Due to fiber birefringence the mode which consist of horizontally as well vertical polarized mode will travel at different velocity and emerges out of the fiber with different times, resulting in the distortion of the optical pulse The difference in the transmission time of two signals polarized along the state of polarization producing the shortest and the longest propagation times is known as Differential Group Delay. By using MATLAB simulation we can generate the differential group delay. The simulation result of the dependence of DGD parameter on the ISI is shown in the figure 4(a)-(f)

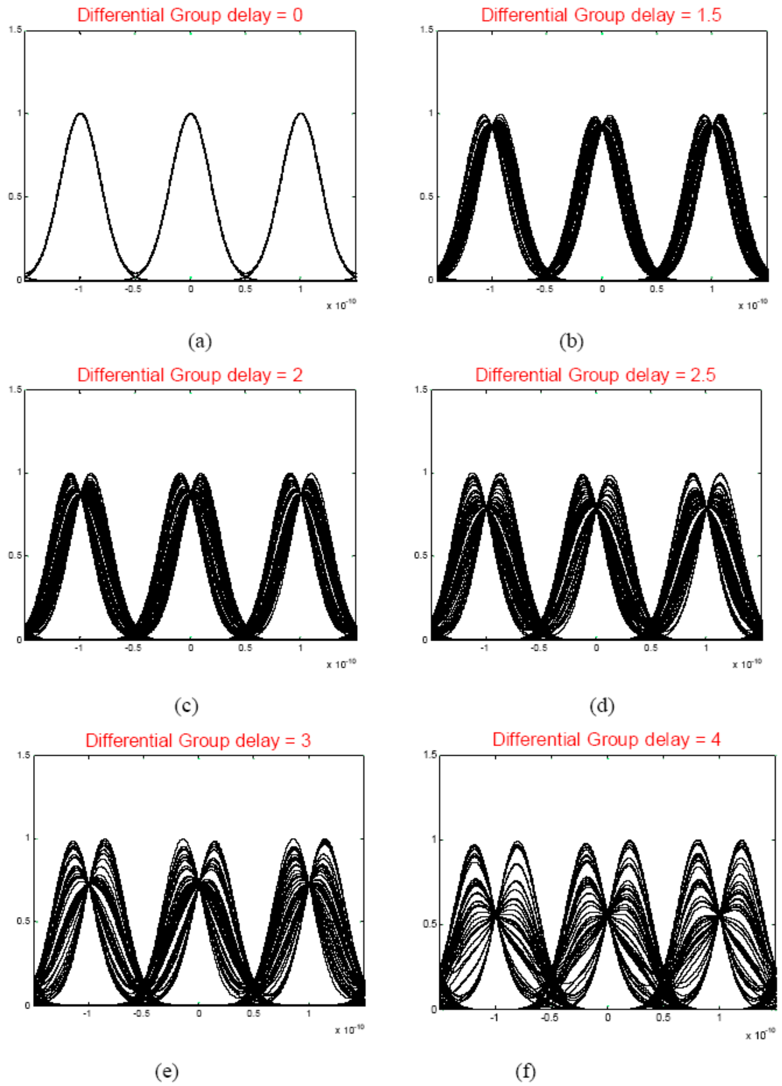

Fig 4(a) to 4(f) effect of DGD parameter on ISI

We have seen the effect of PMD on the pulse transmission. It is clear from the figure (a) that in the absence of PMD there is no time difference in the arrival of the pulses, all pulses arrived at the same time. But as the value of DGD parameter increases the arrival time for different pulses differ from each other, resulting in the spreading as shown in the subsequent figures from fig 4(b) to fig 4(f) thus increase in the DGD will leads to the ISI.

5.3 Effect of Length of the fiber on the ISI

By keeping all the mentioned parameters constant and changing the length of the fiber we can find effect of the length of fiber on ISI[9]. The simulation result is shown in the figure 5 (a)-(h)

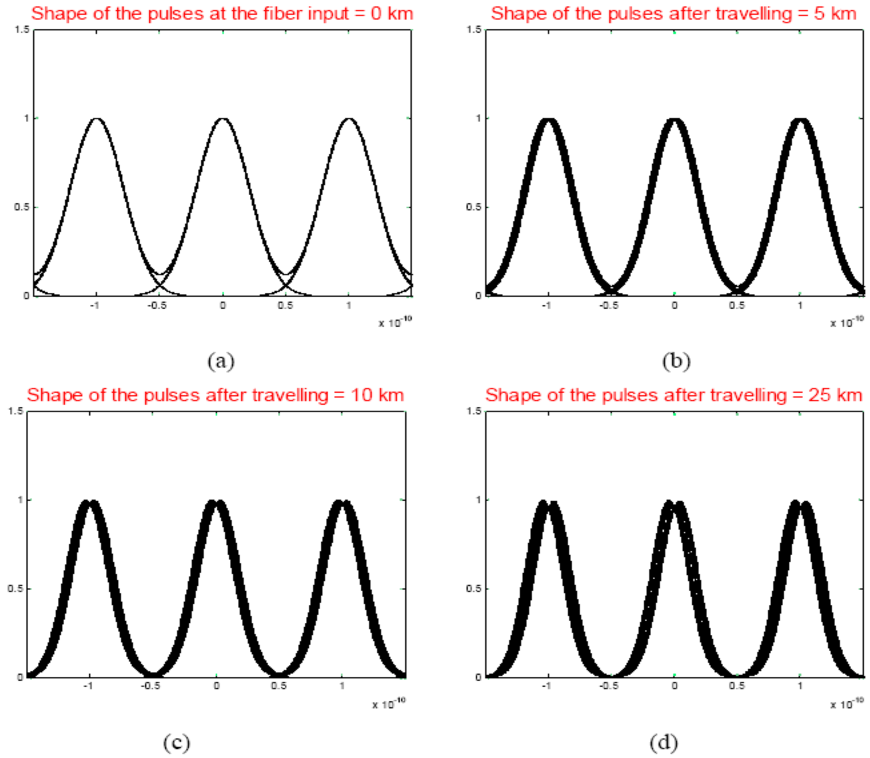

Fig 5(a) to 5(d) effect of ISI on length of fibre

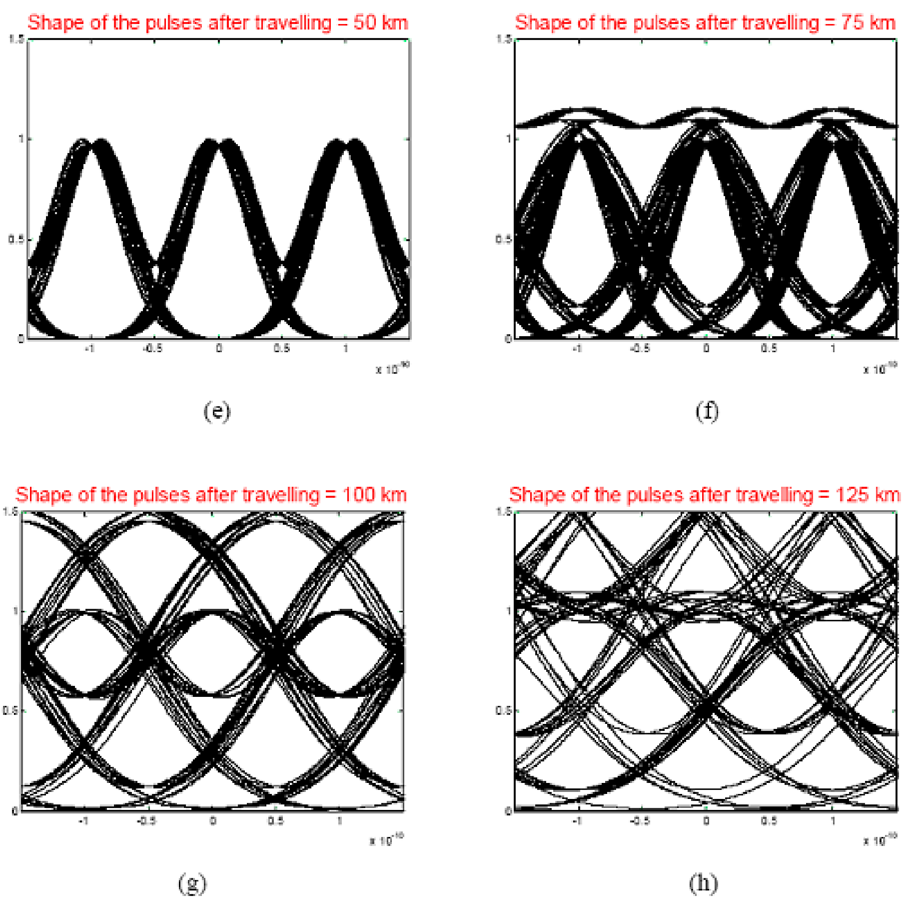

Fig 5(e) to 5(h) effect of ISI on length of fibre

It is clear from the simulation result that as the pulse propagates in the fiber it tends to get broadened and distorted. More the distance it travels more is the distortion in the shape of the pulse. It is clear from the figure 6.4 that initially the eye diagram is perfect. The eye was open perfectly but as the distance of propagation increases the eye opening becoming narrower. It is impossible to distinguish between the “1”and”0” of the data signal.

6. CONCLUSIONS

We have been studied different parameters of pulse dispersion. We have seen that different types like chromatic dispersion, wave guide dispersion and modal dispersion affect the strength of optical signal. From results shown in results section we can conclude that DGD lead the Isi and ISI limits the length of the fibre. We have seen the effect of phase mode dispersion and length of the fibre on the transmission of the pulse. We have also seen that there is no time difference of the incoming pulses in the absence of PMD an seen the effect of PMD on the pulse transmission. If we reses the value of differential group delay we can see time difference between different arrival pulses and due to this time difference dispersion occurs.. It is clear from the results that as the pulse propagate in the fibre it inclines to get widened and inaccurate. More the distance it travels more is the distortion in the shape of the pulse.

REFERENCES

1. A Selvarajan, Optical Fiber Communication Principles & System, McGraw- Hill ,1999
2. Ajay Ghatak, K. Thygrajan, Introduction to Fiber Optic Communication, Cambridge University press ,2001
3. John Powers, Introduction to Fiber Optic System, McGraw Hill, 2nd Edition ,2001
4. Mankei Tsang and Demetri Psaltis,Dispersion and nonlinearity compensation by spectral phase conjuction, opt. letter/ vol. 28, No. 17/ September 1, 2003
5. chertkov, I. Gabitov, and J. Moeser, Pulse confinement in optical fibers with random dispersion, PNAS 2001; 98;14208-14211; Nov 20, 2001
6. K.S. Abedin, Rapid, cost effective measurement of chromatic dispersion of optical fiber using Sagnac Interferometer, Elect. Letter, 14th April 2005
7. K.C Byron and D.M. Ashworth, Intermodal dispersion measurement on 1.3 um single mode fiber for use at 0.85 um, IEEE Proceedings, Vol. 135, Pt. J, No. 3, June 1988
8. T. Dennis and P.A. Williams, Chromatic dispersion measurement error caused by source ASE, IEEE Photonics Technology Letter, Vol. 16, No. 11, November 2004
9. Goel and R. K. Shevgaonkar, Wide band dispersion compensating optical fiber,