THE EFFECT OF DISPERSION ON OPTICAL FIBER

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I declare that this project report entitled "*The Effect Of Dispersion On Optical Fiber*", is the result of my own research except as cited in the references.

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SUPERVISOR VERIFICATION

"I hereby declare that I have read this project report and in my own opinion this project report is sufficient in terms of the scope and quality for the award of Bachelor of Electronic Engineering (Electronics Telecommunication) With Honors."

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Dedicated to my beloved family especially my parents, supervisor, lecturers and all my friends who helping me whether directly or indirectly.

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ABSTRACT

Optical fibre can be used as a medium for telecommunication and computer networking because it is flexible and can be bundled as cables. It is worth used for long-distance communications because light propagates through the fibre with little attenuation compared to electrical cables. This allows long distances to be spanned with few repeaters. However, in order to extend the higher bit rate of optical transmission, there have some impairment arise and needs to be improve or eliminate. Generally, the transmission impairment will affect optical transmission and will decrease the quality of the optical signal along the propagation path. Dispersion is one of the transmission impairment which have severe effect on optical network. In this investigation, other transmission impairment regarding noise and interferences also need to be considered such as multi-access interference (MAI), optical beat interference (OBI) and receiver's noise. In this project Optisystem is used as simulation tools. The system performance is evaluate by using negative and positive dispersion fiber. The pre-, post- and symmetrical dispersion compensation by using DCF and also chirp grating dispersion compensation were also used and simulate in this project to get the better performance of the signal pulse. By using the suitable parameter for the component in the circuit, the different result can be seen and analyze whether it is acceptable or not. The result from Optisystem simulation shows that for single-mode fibre (SMF) under impact of chromatic dispersion, the number of supportable users is extremely decreased and the transmission length is remarkable shortened.

ABSTRAK

Gentian optik boleh digunakan sebagai medium untuk telekomunikasi dan komputer rangkaian kerana ia adalah fleksibel dan boleh digabungkan sebagai kabel. Gentian optik perlu digunakan untuk komunikasi jarak jauh kerana cahaya merambat melalui gentian dengan sedikit pengecilan berbanding dengan kabel elektrik. Hal ini membolehkan jarak yang jauh untuk menjangkau dengan beberapa pengulang. Walau bagaimanapun, untuk melanjutkan kadar bit yang lebih tinggi penghantaran optik, terdapat beberapa kemerosotan timbul dan perlu diperbaiki atau menghapuskan. Secara umumnya, kemerosotan penghantaran akan menjejaskan penghantaran optik dan akan mengurangkan kualiti isyarat optik di sepanjang gentian optik. Serakan adalah salah satu kemerosotan penghantaran yang mempunyai kesan yang teruk pada rangkaian optik. Dalam penyelidikan ini, pengurangan berlaku pada nilai pemindahan lain berkenaan dengan bunyi bising dan gangguan juga perlu dipertimbangkan seperti gangguan pelbagai akses (MAI), gangguan denyutan optik (OBI) dan bunyi penerima. Dalam projek ini Optisystem digunakan sebagai alat simulasi. Prestasi sistem adalah menilai dengan menggunakan negatif dan positif serat penyebaran. Pra, pasca dan simetri pampasan serakan dengan menggunakan DCF dan juga kedengaran pampasan penyebaran parutan juga digunakan dan simulasi dalam projek ini untuk mendapatkan prestasi yang lebih baik daripada nadi isyarat. Dengan menggunakan parameter yang sesuai untuk komponen dalam litar, hasilnya berbeza boleh dilihat dan menganalisis sama ada ia boleh diterima atau tidak. Hasil daripada simulasi Optisystem menunjukkan bahawa untuk gentian mod tunggal (SMF) di bawah kesan serakan kromatik, bilangan pengguna dikekalkan adalah amat menurun dan panjang penghantaran adalah luar biasa dipendekkan.

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LIST OF ABBREVIATIONS

1.	SMF	-	single-mode fiber
2.	MMF	-	multi-mode fiber
3.	DCF	-	dispersion compensating fiber
4.	MAI	-	multi-access interference
5.	OBI	-	optical beat interference
6.	CWDM	-	Coarse Wavelength Division Multiplexing
7.	DML	-	direct modulated laser
8.	NRZ	-	nonreturn-to-zero
9.	GVD	-	Group Velocity Dispersion
10.	PMD	-	polarization mode dispersion
11.	SPM	-	self-phase modulation
12.	XPM	-	cross-phase modulation
13.	FWM	-	four wave mixing
14.	DSF	-	dispersion-shifted fibers
15.	NZ-DSF	-	non-zero dispersion shifted
16.	WDM	-	wavelength division multiplexing
17.	EDFA	-	Erbium doped fiber amplifier
18.	LAN	-	local area networks
19.	MAN	-	metropolitan area networks
20.	ISI	-	intersymbol interference
21.	CW	-	continuous wave
22.	FBG	-	fiber bragg grating

CHAPTER 1

INTRODUCTION

1.1 PROJECT INTRODUCTION

With the growing needs for ultrahigh transmission speeds, optical fibre technology is becoming the replacement technology for the copper cable. The past 30 years have seen enormous strides in the fields of fibre optics and various device integrations. Many fibre optic devices are ready today for use in system applications and as commercial products within communication networks. However, extending the reach of optical transmissions at higher bit rates becomes a major challenge. Transmission impairments will generally affect optical transmission and decrease the quality of the optical signal along the propagation path.

1.2 PROBLEM STATEMENT

Transmission impairments generally have severe effect on optical transmission. Such linear impairment not only limited to noise, attenuation and interference but also dispersion. The effect of chromatic dispersion to the optical transmission is very significant especially for the long distance transmission. Therefore the fundamental study on this impairment is important in order to understand the problem, then find solution and improve the optical transmission system for better system performance. To be more specific, the intermodal dispersion which in different propagation can limit the possible data rate of a system for optical fiber communications and the attenuation of an optical signal would be limiting the availability of optical power along the transmission path. When the distance of the transmission increases it will cause more dispersion through the fibers.

1.3 OBJECTIVE OF THE PROJECT

There are several objective aim to be achieve in this project :

i. To study the performance of the optical fiber based on different distance.
ii. To study the effect of dispersion on optical fiber.
iii. To design and simulate the dispersion by using Optisystem software.
iv. To analyze the data taken from the simulation.

1.4 SCOPE OF THE PROJECT

In this project, the model of transmission system will be design and simulate by using OptiSystem Software. Then, the result of optical fibre signal will be recorded and comparing with the signal generated from input data. The output pulse will be monitored and analyzed from the result.

1.5 THESIS STRUCTURE

The thesis is organised with the project introduction and problem statement being discuss in the first chapter. This is to highlight the importance of this fundamental study. Project objective and scope of the project were also explain in this chapter.

Chapter two discuss about the background studies which including the literature review about the dispersion on optical fiber. Chapter three discuss about project methodology which there has a flow chart for explained about overall of the process take part for completing this thesis and also the software used during the project. Chapter four was discuss about results and discussion from the simulation. It shows the eye diagram to prove the signal was improved. In the Chapter five, it mention about the conclusion and recommendation for this thesis.

CHAPTER 2

BACKGROUND STUDIES

Fibres that support many propagation paths or transverse modes are called multi-mode fibres (MMF), while those that only support a single mode are called single-mode fibres (SMF). MMF generally have a wider core diameter and used for short-distance communication links and for applications where high power must be transmitted. SMF are used for most communication links longer than 1,000 meters. Chromatic dispersion is the phenomenon in an optical fiber which occurred due to dependence of group index (Ng) to wavelength. Dependence of Ng to wavelength in an optical fiber produces a time extension in propagated pulses. Extension of pulses after a distance leads to errors in receiver [1].

Erbium doped fiber amplifiers (EDFA) is an optical fiber communication system used in this project to compensate the losses while the dispersion compensating fiber (DCF) are extensively used to compensate the chromatic dispersion. This method was used because DCF is negative dispersion coefficient in a communication link in order to disable the effect of SMF which is positive dispersion in fibers. Fiber bragg grating (FBG) is a type of distributed Bragg reflector constructed in a small segment of an optical fiber that used in this project to reflect particular wavelengths of light and transmits all other. This can be achieved by producing a periodic variation in the refractive index of the fiber core.

Transmitted light in an FBG core which satisfies the Bragg conditions is resonated by grating structure and reflected. The FBG can also be used as an optical filter to block certain wavelengths. The reflected wavelength changes with the grating period and broadening of the reflected spectrum. The most important inclination of chirp FBG than other recommended types are small internal lose and cost efficiency [2].

2.1 Effect of The Fibre Optic Dispersion on Optical Transmission

Loss and dispersion are the major factors that affect optical fibre communication to develop in high capacity. Dispersion is defined because of the different frequency or mode of light pulse fibre transmits in different rates. At different time, the frequency components receive the fibre terminal and cause amount of distortion that will be lead to error. SMF performance is primarily limited by chromatic dispersion that occurs because of the glass index varies slightly depends on the wavelength of the light. Light from the real optical transmitters necessarily has nonzero spectral width [3]. If the dispersion getting too high, a group or pulses representing a bit-stream will spread in time make the bit-stream unintelligible. This is because of the length of the link limits or the information capacity of the fibre without regeneration [4].

2.1.1 Enhancing The Performance of Systems Using Negative and Positive Dispersion Fibers

The Coarse Wavelength Division Multiplexing technology (CWDM) enables carriers to transport more services over their existing optical fiber infrastructure by combining multiple wavelengths onto a single optical fiber. Technologically, CWDM is simpler and easier to implement and is a good fit for access networks and many metro/regional networks. ITU-T G.694.2 defines 18 wavelengths for CWDM, using the wavelengths from 1270 nm through 1610 nm with a channel spacing of 20 nm. This channel spacing allows using in CWDM systems, low-cost and uncooled lasers such as direct modulated laser (DML).

In this section, the transmission performance depends on strongly on dispersion fiber and DML output power. If the DML output power is properly chosen, the systems demonstrated by using SMF fibers can achieve a good performance. Finally, we have found a mathematical expression that makes estimation for a power value to fix the laser power output for each channel in WDM systems. Figure 2.1 shows a simple arrangement the CWDM system performance is proposed.

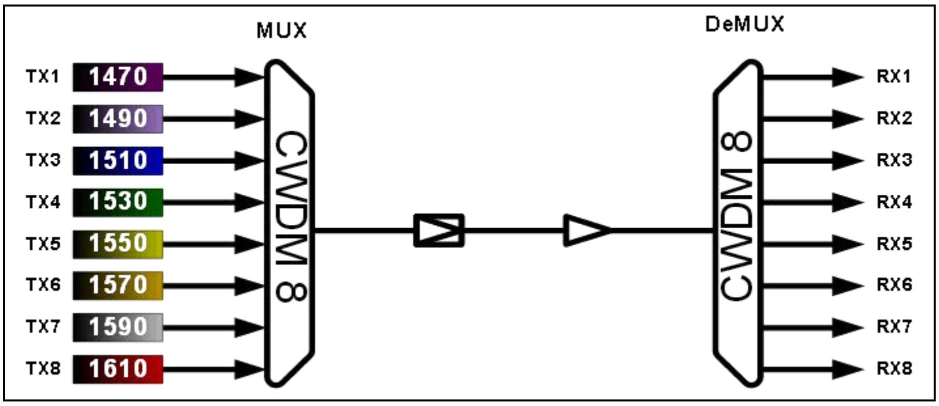


Figure 2.1 : CWDM system performance

By selected 16 output channels with wavelengths, in agreement with Recommendation ITU-T G. 694.2. The pulse pattern was a periodic 128-bit OC-48 (2.5 Gb/s) nonreturn-to-zero (NRZ). After transmission through 100 km of fiber, channels are demultiplexed and detected using a typical pin photodiode. In this part, using the two kinds of optical fibers which it already laid and widely deployed single-mode ITU-T G.652 fiber (SMF) and also the ITUT-T G.655 fiber with a negative dispersion sign around C band (NZ-DSF).

It is well known, SMF fiber dispersion coefficient is positive in the whole telecommunication band from O-band to L-band and the dispersion coefficient of the NZDSF fiber is negative in the optical frequency range considered. For the purpose, the same spectral attenuation coefficient of both fibers has been considered whose water peak at 1.38 µm is well suppressed. The dispersion slope, effective area and nonlinear index of refraction are compliant with typical conventional G.652 and G.655 fibers. Point out that the transmission performance of waveforms produced by directly modulated lasers in fibers with different signs of dispersion that depends strongly on the characteristics of the laser frequency chirp.

In this work, main purpose in comparing the system performance based on the type of fiber and DML used; for this reason, the rest of link components have been modelled by considering ideal behaviour [4].

2.2 Transmission Impairment

The effect of dispersion on the system bit rate, B_r is obvious and can be estimated by using the criterion in Eq.2.1,

$$B_r \cdot \Delta\tau < 1 \qquad (2.1)$$

Where $\Delta\tau$ = total pulse broadening

With the fiber length and the total dispersion $D_T(= M(\lambda) + D(\lambda))$; and the source linewidth, σ_λ it will become Eq.2.2 [5]:

$$B_r \cdot L \cdot |D_T|\sigma_\lambda \leq 1 \qquad (2.2)$$

For a total dispersion factor of 1 ps/(nm· km) and a semiconductor laser of linewidth 2-4 nm, the bit rate-length product cannot exceed 100Gb/s · km. That is if a a 100km transmission distance is used, then the bit rate cannot be higher than 1.0Gb/s. Figure 2.2 shows a block diagram of an optical fiber communication system from the transmitter to the fiber to the optical receiver. Photodetector is represented as the square of the magnitude of the optical field that to indicate the conversion of the optical power to the electronic current flowing out of the detector.

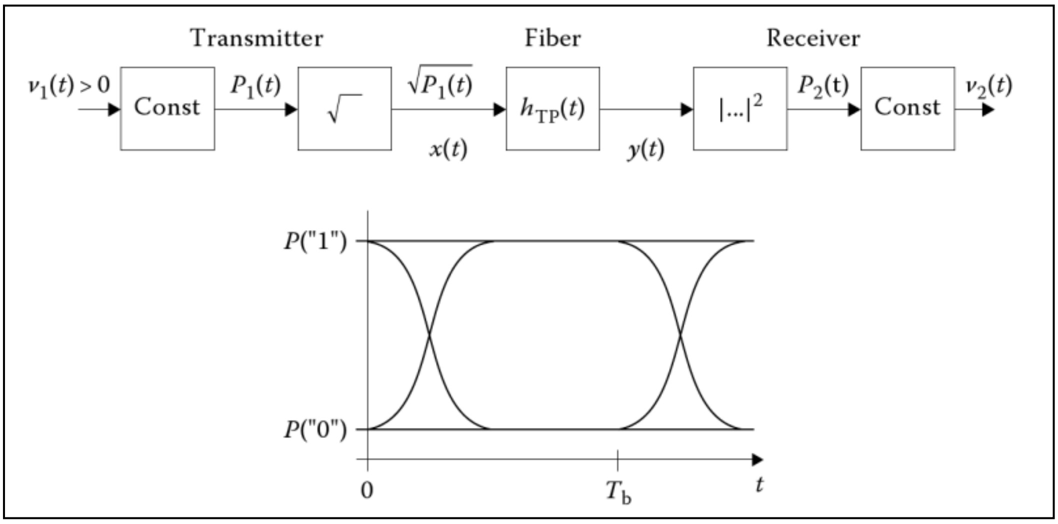
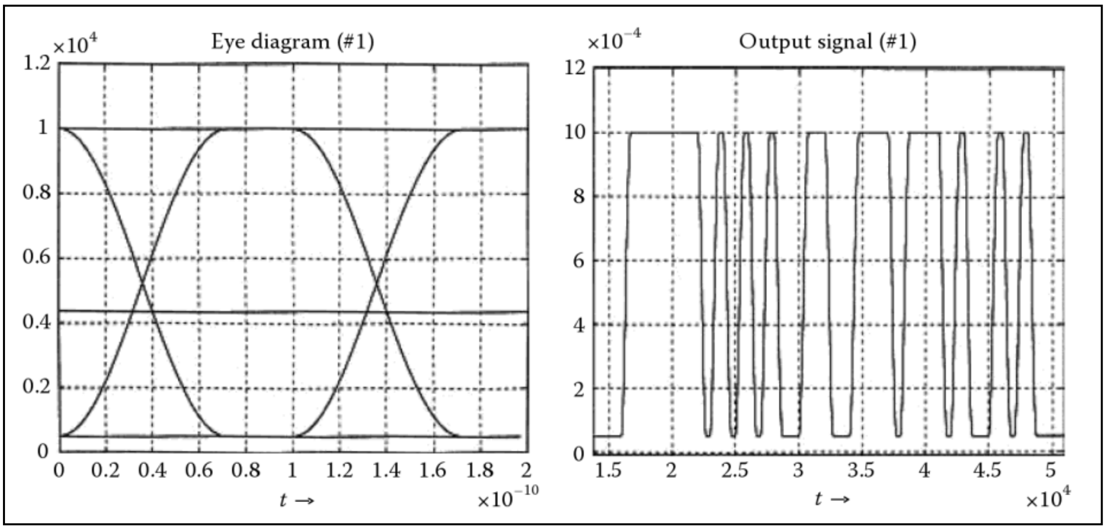
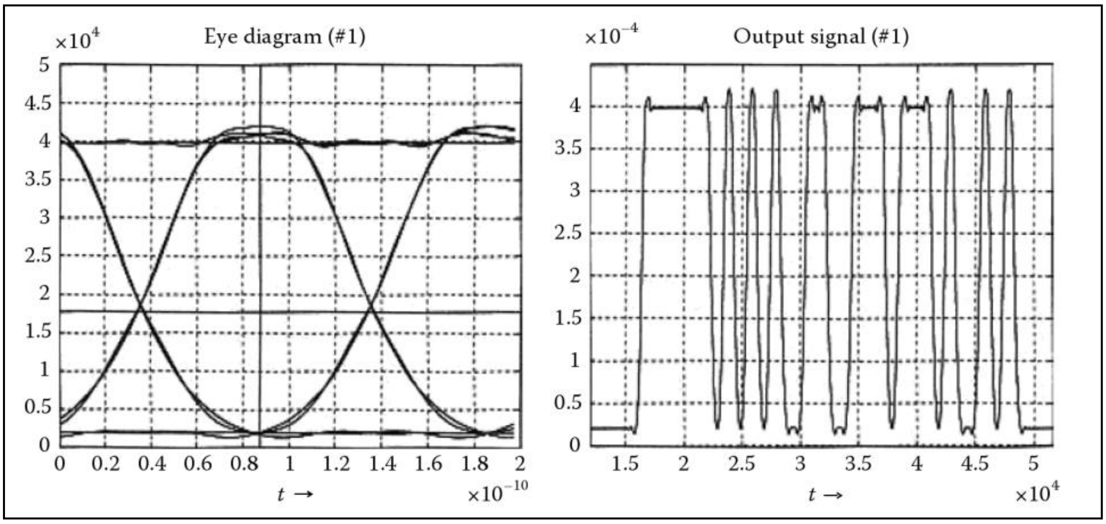


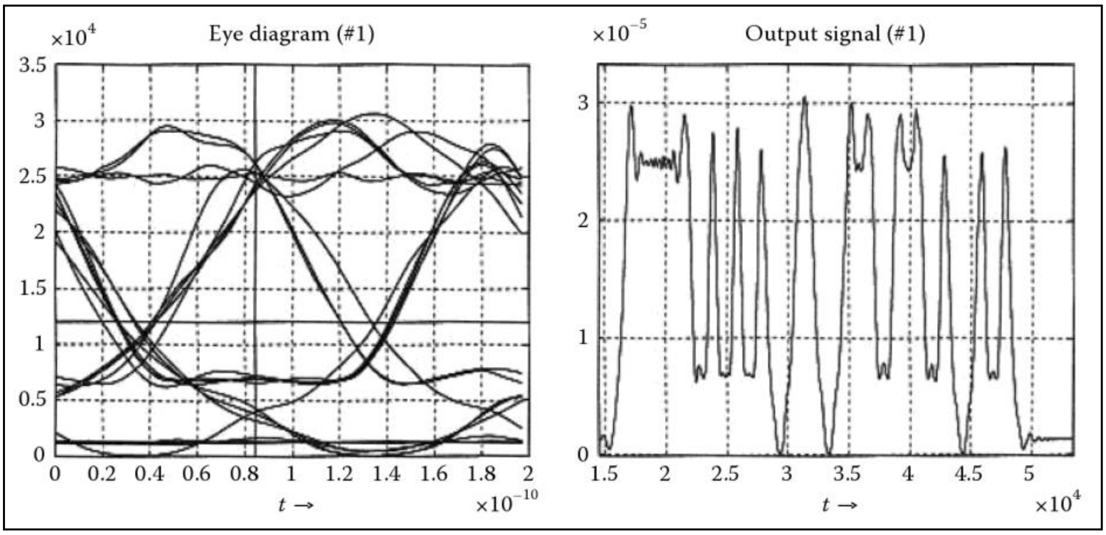
Figure 2.2 : Schematic of an optical transmission system and its equivalent transfer function.



2.3(a)



2.3(b)



2.3(c)

Figure 2.3(a)(b)(c) : Eye diagram of time signals at 10Gb/s transmission over an SSMF for 0, 20, 80km.

Figure 2.3 shows the evolution of the sequence of pulses (right column) and the eye diagram (left column) at the various distance from the launched input [5]. Dispersion is the broadening of light pulses that propagates through the fiber and increases with the length of the fiber. Excessive of the dispersion caused over-lapping of adjacent pulses or inter symbol interference so that, the dispersion has a negative effect on the bandwidth of the fiber. When the dispersion getting higher, the bandwidth getting lower of the system. Dispersion also decreases the peak optical power of the pulse and then increasing the effective attenuation of a fiber [6].

The dispersion divided into three types which are intermodal, chromatic, and polarization mode dispersion. Intermodal dispersion can getting from results of the different propagation characteristics of higher-order transverse modes in waveguides and can limit the possible data rate of a system for optical fiber communications based on multimode fibers. Chromatic dispersion is the result of the wavelength dependence of the group velocity, v_g. The most commonly used chromatic dispersion parameter is D, defined as Eq.2.3 [4] :

$$D = \frac{d}{d\lambda}\left(\frac{1}{v_g}\right) = -\frac{2\pi c}{\lambda^2}\beta_2 \qquad (2.3)$$