FIBER OPTIC DUPLEXER

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To my mother and father

&

My brother-in-law

For your infinite and unfading love, sacrifice, patience, encouragement and

Best wishes

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All praises and thanks be to Allah (S.W.T), who has guided us to this, never could we have found guidance, were it not that Allah had guided us!(Q7:43)

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ABSTRAK

Penghantaran dwiarah dalam komunikasi optik, secara tradisinya, dilaksanakan melalui dua fiber yang berasingan; satu fiber berfungsi sebagai penghantar, dan satu lagi berfungsi sebagai penerima. Namu begitu, dari segi ekonomi, sistem penghantaran gelombang pembahagi multipleks (WDM) dwiarah yang hanya menggunakan fiber tunggal adalah lebih menyenangkan. Oleh yang demikian penggunaan komponen dalam sistem WDM tersebut dapat dikurangkan. Seterusnya, transmisi dwiarah ini juga boleh menggandakan kapasiti fiber sehala yang sedia ada. Cakap-silang jalur-inter dan jalur-intra di model dan di analisa di dalam system ini. Keputusan yang diperolehi menunjukan cakap-silang jalur-intra tidak menganggu isyarat yang diterima selagi nilanya berada dibawah –25dB. Peningkatan nilai cakap-silang jalur-intra akan menyebabkan peningkatan dalam nilai kuasa tendangan. Sekiranya keadaan ini berlaku nilai kuasa tendangan akan dikira. Pengiraan juga dilakukan bilamana hingar didominasi oleh hingar terma. Keputusan yang diperolehi menunjukkan nilai kuasa tendangan merosot teruk. Keputusan eksperimen tersebut menunjukkan bahawa nilai minimum cakap-silang adalah –39dB dan nilai kuasa tendangan yang sepadan denganya adalah 0.513dBM. Untuk mencegah nilai cakap-silang daripada terakru, penambahan jalur diantara saluran yang hendak dihantar mestilah mematuhi ITU-T piawaian.

ABSTRACT

In traditional optical communication, duplexity is achieved by using two fibers, each having a transmitter and a receiver. Economically, bidirectional wavelength division multiplexing (WDM) transmission systems utilizing a single fiber will be more attractive not only reducing the use of the fiber by a factor of two, but also the number of components. Duplex transmissions over a single fiber can double the capacity of an installed unidirectional link. Optical fiber duplexer was implemented in this work, where two signals were carried over a single fiber. The interband and intraband crosstalk were modeled and analyzed. It was found that the intraband crosstalk did not affect the received signal as long as it is below -25dB. Increasing this value caused the power penalty to increase. The power penalty when the spontaneous beat noise of the received signal dominates was calculated. Calculation was also made in the case when the noise is dominated by thermal noise. It was found that the power penalty is worst for the thermal noise dominated case. From the experimental results, it was found that the minimum crosstalk was -39dB and the corresponding power penalty was 0.1513dBm. The case worsened when more than three signals had same wavelength, the gain band between the channels to be transmitted should be according to the ITU-T standards to prevent crosstalk from occurring.

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DWDM	-	dense wavelength division multiplex/multiplexing
BER	-	bit error rate
CWDM	-	course wavelength division multiplex/multiplexing
C-Band	-	Optical band from 1530 to 1570 nanometers long
dB	-	Decibel
ITU	-	International Telecommunications Union
APD	-	Avalanche photodiodes
AWG	-	Arrayed waveguide grating
Gb/s	-	gigabits per second
DS	-	dispersion shifted
LED	-	light emitting diode
LD	-	laser diode
SMF	-	single mode fiber
SONET	-	Synchronous Optical Network
FBG	-	Fiber Bragg Grating
PD	-	photodiode

CHAPTER 1

INTRODUCTION

In this chapter introduction is made on some general information about optical fiber communication technology, the basic blocks of fiber optic transmission link, wavelength division multiplexing, problem statement, research objectives and the scope of the project.

1.1 Optical Fiber Communication Technology

An optical communications system is similar to other communication systems in that it consists of the three main parts: Transmitter, Receiver and the Communication channel. In order for a fiber to guide the light signal, it must consist of a core of material whose refractive index is greater than that of the surrounding medium, which is called the cladding. Depending on the design of the fiber, light is constrained to the core by either total internal reflection or refraction.

In optical links the transmitter is a light source whose output acts as the carrier wave. Although frequency division multiplexing (FDM) techniques are used in longer broadcast systems, most optical communication links use time division multiplexing (TDM) techniques. The easiest way to modulate a carrier wave with a digital signal is to turn it on and off, where that is called on-off keying, or amplitude shift keying. In optical systems this is commonly achieved by varying the source drive current directly, so causing a proportional change in optical power.

The components that used to transmit or receive the optical signal are semiconductors devices. For transmitting the most common light source used are laser diode and light emitting diode (LED) where they have different specification according to power spectrum and fabrication. At the receiving end of the optical link a PIN photodiode or Avalanche photodiode (APD), converts the modulated light back into an electrical signal the photodiode current is directly proportional to optical power [10].

1.2 The Basic Blocks of Fiber Optical Transmission link

The basic block of an optical fiber transmission system is illustrated in Figure 1.1 consists of three main parts: The transmitter block “Laser Driver and temperature control”: the electrical signals will be transferred into optics. For long haul, laser diode is used for this purpose because of the narrow spectral width and high optical power that is used to carry data over long distance. The light is then coupled into the transmission channel, the optical fiber cable, where most of the dispersion and attenuation takes place. The receiver block which is the last part of the system converts the optical signal back into the replica of the electrical signal using the Avalanche photodiode (APD) or PIN-type photodiode then to the amplification stage before reaching the end user.

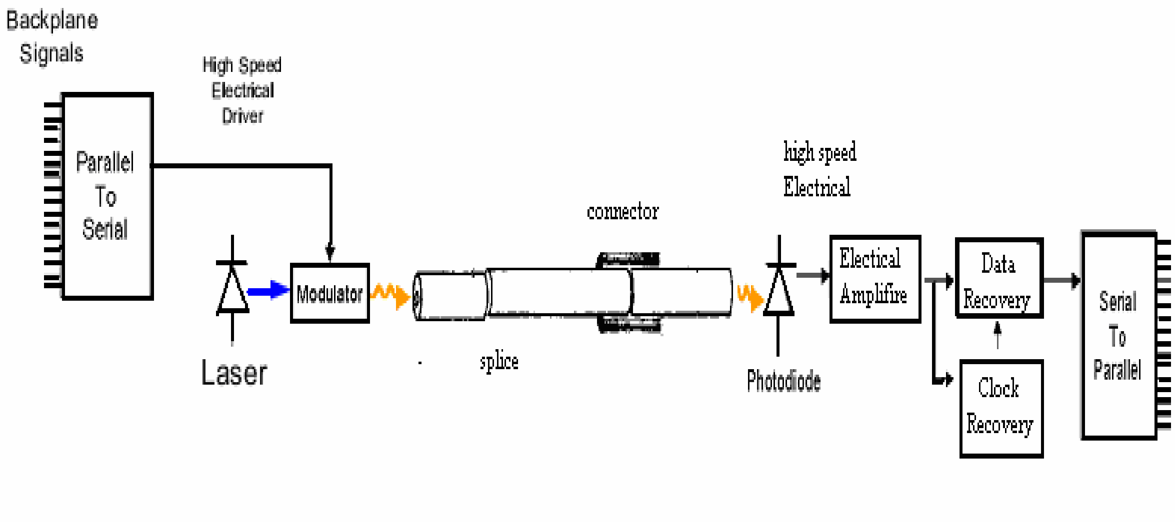

Figure 1.1: Basic block diagram of fiber optic communication

1.3 Wavelength Division Multiplexing (WDM)

WDM as shown in Figure 1.2, [1] combines multiple optical TDM data streams onto one fiber through the use of multiple wavelengths of light. Each individual TDM data stream is sent over an individual laser transmitting a unique wavelength of light. Wavelength division multiplexing was used with only two wavelengths 1310 nm and 1550 nm. However, this was suitable only for limited applications for example; applications in which analog optical cable television signals co-existed with digital optical telecommunication signals. WDM takes advantage of the fact that different wavelengths of light can be transmitted over a single fiber simultaneously. The light sources of different wavelengths can be combined using suitable components like couplers, splitters etc. the figure 1.2 shows the general structure of WDM system.

The ITU-T standard recommends 81 channels in C band with a constant spacing of 50 GHz and it is occupies wavelengths approximately from 1530 to 1560 nm which is the band around the minimum attenuation region among the other bands.

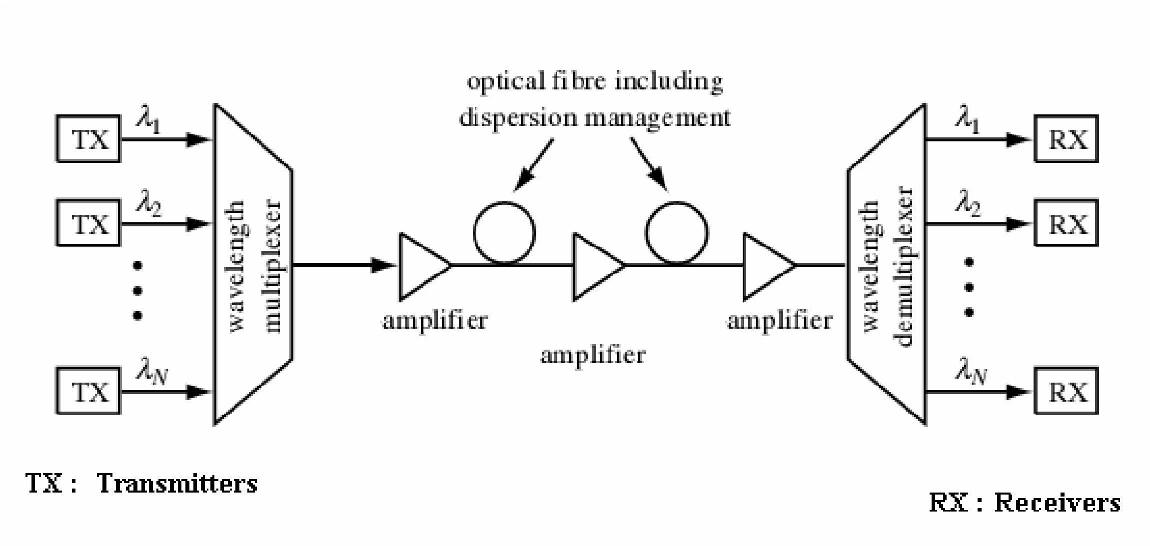

Figure 1.2: Wavelength Division Multiplexing

1.3.1 Different Wavelength Division Multiplexer

Early WDM systems transported two or four wavelengths that were widely spaced. WDM and the follow on technologies of CWDM and DWDM have evolved well beyond this early limitation.

1.3.1.1 WDM

Traditional, passive WDM systems are wide spread with 2, 4, 8, 12, and 16 channel counts being the normal deployments. This technique usually has a distance limitation of less than 100 km.

1.3.1.2 CWDM

Today, coarse WDM (CWDM) typically uses 20-nm spacing (3000 GHz) of up to 18 channels. The CWDM Recommendation ITU-T G.694.2 provides a grid of wavelengths for target distances up to about 50 km on single mode fibers as specified in ITU-T Recommendations G.652, G.653 and G.655. The CWDM grid is made up of 18 wavelengths defined within the range 1270 nm to 1610 nm spaced by 20 nm.

1.3.1.3 DWDM

Dense WDM common spacing may be 200, 100, 50, or 25 GHz with channel count reaching up to 128 or more channels at distances of several thousand kilometers with amplification and regeneration along such a route.

1.4 Problem Statement

The need of increasing the capacity of data transmitted within the fiber transmission links became the most attractive topic for researcher. Even though optical fiber communication is the best communication system in transmitting high data rate still the researchers are pushing to get the highest bit rate. One of the main concern in an optical network is the high cost of components. The global network is made of a large submarine cable network that is expensive to modify. An interesting and smart solution is to double the capacity of each fiber by using a duplexer. It is a system capable of duplex communication over a single fiber in contrast to two fibers required in the present scenario.

1.5 Research Objectives

Main objectives are:

1. Theoretical study and analysis of duplex optical communication.

2. Simulation of duplex optical communication utilizing single fiber.

3. Choosing the required components.

4. Implementation of the hardware.

5. Measurements and comparison of performance.

1.6 Project Scope

It is too vast for any single research work under a given time frame to cover all the topics related to Optical Fiber Duplexer system. This project will focus on a certain properties of the system.

1. To transmit two optical signals in opposite directions within one single mode fiber (SMF) simultaneously.

2. To realize wavelength division multiplexing using fiber duplexer technique.

3. To carry out performance analysis like:

i. Analysis and calculation of crosstalk and the power penalty.

ii. Comparing the power penalties for different crosstalk using the mathematical model (MATLAB).

1.1 1.7 Thesis outline

1.2 As an introduction (Chapter 1), the motivations of research the overview of fiber optic communication technology and the main block diagram of fiber optic link, introducing the fundamental work of WDM and including the problem statement, objectives, and the scope of the project.

Chapter (2) explains the basic concepts and the theory of bidirectional transmission systems and the characteristic of each system. Proposing the idea of implementing DWDM in full duplex system was at the end of the chapter.

Chapter (3) has been titled by the literature review, where the works that have been done and related works published by other researchers in this field and the results of each work explained and concluded

Chapter (4) studied the link design considerations, where the most important issues that might face the researcher whose is doing such kind of systems. The sections of the chapter were "crosstalk, dispersion, wavelength separation between channels and lastly the power penalty of the system".

Chapter (5) discussed the implementation of the project where it shows the general architecture of the system block diagram, then the components was used and their specifications after that the mathematical model used in the simulation part of the project then the operation of the first architecture of fiber duplexer and lastly the second architecture in fiber duplexer and its operation.

Chapter (6) was for the discussion and the analysis of measurements and results. First section in this chapter was introducing the first architecture of the system measurements. Then the second architecture came after that to introduce the results as the previous one. Analytical the results of the two architectures discussed in the third and fourth sections of the system.

Chapter (7) which is the last chapter in this work was written to be the conclusion and proposed future work in this filed. The conclusion part talked about the final analyzed results and the summarizing of the work while some recommendations or ideas proposed in future work section.

Comparison in power penalty between the received signal spontaneous beat noise dominated and the received signal thermal noise dominated and concluded that the power penalty is much higher in case of the received signal is thermal noise dominated than in case of the received signal spontaneous beat noise dominated.

7.2 Recommendation for Future Works

Fiber optical duplexer that has been achieved in this work must be completely done using WDM system to increase the capacity of transmitted data and more accurate results, the method of transmitting one group of channels at each transmitter can be done in two different ways. The first one is by sending the two groups in terms of odd and even wavelengths the odd wavelengths will be at one transmitter; the even group will be at the other transmitter as it was demonstrated in chapter (2) of this work. The interband cross talk in this case received between each two desired signals. The other method which is preferred to be done is by dividing the C band into two groups of wave length (up stream group and down stream group), where in this way the interband will be totally avoided and the probability of intraband to be happened is much lower, because the wavelengths separation will be much wider.

Fiber optical duplexer system is abroad topic for more works to be done. In this work, the optical signal transmitted is only the optical carrier one, which means this work, can be done for transmitting data that is modulated by the carrier wave and recording the transmitted signals in a form of eye diagram. From there some more properties can be focused on and studied such as SNR, BER and dispersion can be carried out.

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