UNIVERSITI PUTRA MALAYSIA

DESIGN AND DEVELOPMENT OF SIMPLEX-TO-FULL DUPLEX CONVERTER (SFDC)

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DESIGN AND DEVELOPMENT OF SIMPLEX-TO-FULL DUPLEX CONVERTER (SFDC)

By

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

DESIGN AND DEVELOPMENT OF SIMPLEX-TO-FULL DUPLEX CONVERTER (SFDC)

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Existing fiber optic network employ simplex transmission scheme where two fibers are needed, each to transmit and received signals between connecting points. The increasing demand has seen fiber, particularly in the metro area, are used up in no time. The conventional solution is to install new fibers to support new customers. However fiber installation are always expensive and fussy. Thus, a new approach is desirable in solving the problem. In this thesis, new technique is proposed to double the link bandwidth by fully utilizing the two fiber cores.

The technique is based on the basic ligthwave principle that two photons do not know each other. Therefore the optical signals, transmitted and received ones can be made to propagate in the opposite direction in the same fiber, as long as they can be split and isolated at the receiver side. The techniques proposed here in achieving the goal is simple but quite powerful. The components used in developing the device are all passive products. Each of them was characterized prior to developing them according to the design. Then the whole device was tested further both on its own, and in network environment.

From the tests conducted, it is important to reduce the reflection from transmitters to adjacent receivers, which is due to SFDC directivity. From the study it is found that the minimum isolation needed between actual and reflected signal to achieve good transmission quality is around 13 dB. Testing on SDH network was successfully conducted on over 50 km fiber link with zero errors. The test was conducted in both laboratory and testbed environment, with cooperation from Telekom Malaysia. Testing on WDM system was conducted in laboratory environment only. The test shows that no error is introduced. Finally it is concluded that SFDC is reliable to be used as a device to realize full duplex transmission, as its realization would result in huge increase in fiber bandwidth utilization with minimum installation and maintainance complexity and cost.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

REKABENTUK DAN PEMBINAAN SIMPLEX-TO-FULL DUPLEX CONVERTER (SFDC)

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Rangkaian fiber optik yang sedia ada menggunakan transmisi sehala di mana dua fiber diperlukan, masing-masing digunakan untuk menghantar dan menerima isyarat di antara dua terminal. Permintaan yang meningkat terhadap penggunaan fiber optik menyebabkan ia dengan cepat habis digunakan terutama di kawasan Metro. Penyelesaian yang ada adalah dengan memasang fiber baru untuk menampung pelanggan-pelanggan baru. Walau bagaimana pun pemasangan fiber baru selalunya melibatkan kos yang tinggi dan rumit. Oleh itu pendekatan baru diperlukan untuk menangani masalah ini. Di dalam tesis ini teknik baru dicadangkan untuk menggandakan peggunakan kapasiti fiber dengan menggunakan sepenuhnya fiber yang ada.

Teknik ini berdasarkan kepada prinsip asas gelombang cahaya yang menyatakan bahawa foton tidak dpat mengenali antara satu sama lain. Oleh itu isyarat optik , yang diterima dan dihantar, boleh merambat dalam arah yang bertentangan di dalam fiber yang sama, selagi isyarat-isyarat itu dapat diasingkan di terminal penerima. Teknik yang diperkenalkan di sini sangat ringkas tetapi amat berkesan. Komponen-komponen yang

digunakan dalam merekabentuk alat ini semuanya merupakan komponen pasif. Kesemua komponen ini menjalani proses pencirian berdasarkan kepada rekabentuk alat yang dibina. Kemudian alat yang dicipta diuji secara sendiri dan juga di dalam rangkaian fiber optik.

Daripada ujian yang dijalankan, dapat disimpulkan bahawa salah satu daripada parameter yang perlu diperhatikan adalah pantulan daripada terminal penghantar ke terminal penerima yang bersebelahan. Daripada kajian didapati pengasingan minimum yang diperlukan antara isyarat sebenar dan isyarat yang dipantulkan adalah dalam lingkungan 13 dB. Ujian di dalam rangkaian SDH juga telah berjaya berjaya dijalankan melebihi 50 km tanpa kesilapan data. Ujian dijalankan di makmal dan juga persekitaran sebenar, dengan kerjasama Telekom Malaysia. Walau bagaiman pun, ujian WDM dijalankan di dalam makmal sahaja. Ujian tersebut juga menunjukkan tiada kesilapan berlaku. Akhir sekali disimpulkan bahawa SFDC mampu untuk digunakan untuk merealisasi transmisi dua hala dalam satu fiber, dan membuka jalan kepada peningkatan besar penggunaan kapasiti fiber optik dengan kerumitan dan kos pemasangan dan penjagaan yang minimum.

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LIST OF ABBREVIATIONS

AIS	-	Alarm Indication Signal
BER	-	Bit Error Rate
BERT	-	Bit Error Rate Tester
CR	-	Coupling Ratio
DL	-	Directivity Loss
DWDM	-	Dense Wavelength Division Multiplexing
EL	-	Excess Loss
FEBE	-	Far End Bit Error
FERF	-	Far End Received Failure
FTTH	-	Fiber To The Home
I	-	Isolation
IL	-	Insertion Loss
LAN	-	Local Area Network
LCT	-	Local Craft Terminal
LOF	-	Loss of Frame
LOS	-	Loss of Signal
LSS	-	Loss of Sequence
MAN	-	Metro Area Network
O-E-O	-	Optical-Electrical-Optical Conversion
OOF	-	Out of Frame
Os-CDM	-	Optical Spectrum Code Division Multiplexing
OTDR	-	Optical Time-Domain Reflector meter
PAN	-	Personal Area Network
PDH	-	Plesiochronous Digital Hierarchy

PRBS	-	Pseudo Random Bit (Binary) Sequence
RDI	-	Remote Defect Indication
REI	-	Remote Error Indication
RFI	-	Remote Failure Indication
RL	-	Return Loss
SCM	-	Sub-Carrier Multiplexing
SDH	-	Synchronous Digital Hierarchy
SFDC	-	Simplex-to-Full Duplex Converter
SNR	-	Signal to Noise ratio
SONET	-	Synchronous Optical Network
STM	-	Synchronous Transport Mode
TDM	-	Time Division Multiplexing
U	-	Uniformity
VAR	-	Variable Optical Attenuator
WDM	-	Wavelength Division Multiplexing
XT	-	Crosstalk

CHAPTER 1

INTRODUCTION

1.1 Fiber Optic Communication System

Fiber optics communication is a light-based wire line data transmission. Several inadequacy in electrical-based wire line communication leads to the introduction and development of fiber optics communication. The increasing cost and demand for high data rate and long distance transmission are the reasons for the change-over [1,3,4,6,14]. This communication technique is also vulnerable to electrical and electromagnetic effect, which deteriorates the transmitted data in electrical communication. Moreover lightning strike against the communication link is another serious problem that has to be dealt with. All the mentioned problems motivates scientists, engineers, and telecommunications companies to come out with fiber optics communication as an alternative solution, which has now become the system of choice.

The basic particle of light is photon [1,4,14,28]. This explains the term 'photonics' that is used in fiber optics communication the same way as 'electronics', which refer to electron–based system. In fiber optics communications, the data carriers are wavelengths. These selected wavelengths are modulated with data and transmitted along optical fiber.

Modulation process is performed by using external modulator [31-34]. The selection of suitable carrier wavelength has to depend on the design of the system.

Presently, for long-haul communication, 1550 nm wavelength is used as the carrier [5,30,50] whilst 1310 nm is used for short distance [1-5]. Wavelength selection is performed based on the loss and dispersion characteristics.

In communication systems, suitable multiplexing techniques are another important issue to discuss. Currently, the multiplexing techniques used in fiber optics communication are Wavelength Division Multiplexing (WDM) [12,15,30,37,38,49], Time Division Multiplexing (TDM) [39,51,52,62], Sub-Carrier Multiplexing (SCM) [13,29,54,55] and Optical Spectrum Code Division Multiplexing (Os-CDM) [3]. Each used to increase the utilization of fiber capacity.

As time goes by, there is demand from the end users to switch from megabit networks into multi-gigabit networks as more and more data are transmitted via communication link. Then single mode fibers and the advanced opto-electronic component appeared to be the solution to solve this problem. They transformed many of the present networks to the Synchronous Optical Network (SONET) [39,42], and Synchronous Digital Network (SDH) [4,5,16] standard, which created an infrastructure in the telecommunications industry. The infrastructure will support future broadband services such as video conferencing, high definition television distribution, and advanced interactive image communications.

Beside SDH/SONET transport network, WDM is another good alternative with higher available bandwidth. It allows multiple wavelengths to be transmitted together in a single fiber instead of a single wavelength in SDH network. In this thesis the viability of the device developed is tested on both SDH/SONET and WDM network.

Photonics system involves the development of equipments, devices, communication medium, constructing materials, and the system itself. As the technology evolves, there are much more research and development needed in photonics world to fulfill the requirement. This thesis concentrates on the development of fiber optic device, namely SFDC.

1.2. Transmission Techniques

There are three basic modes of data transmission technique. They are Simplex, Half Duplex and Full Duplex [6-9]. This section is important because it gives us rough picture of transmission techniques available and its applications. Here, the working principles of those techniques are discussed.

1.2.1. Simplex Transmission

Simplex transmission is a one-way communication by using one channel [6-9]. The function of the transmitter and the receiver are fixed, and cannot be changed. The transmitter does all the talking, while the receiver only responding. This type of transmission is not frequently used because it is not a practical mode for communicating. The purpose is only to transmit data. The unique advantage of the simplex transmission is that it is cheap in term of manufacturing cost. Some examples of simplex transmission are sending data to printers and radio and television broadcasts. However many latest printers already have bi-directional communications to report status and problems. Similarly this phenomenon could also

being experienced by radio and television broadcast as Fiber To The Home (FTTH) architecture is applied.

Figure 1.1: Simplex Transmission from port A to port B

1.2.2. Half Duplex Transmission

In half-duplex transmission method, both participants take turns to transmit and receive data [6-9]. It is like a one-lane bridge where two-way traffic must give way in order to cross as depicted by Figure 1.2. When transmitter at one end is transmitting, transmitter at the other end is idle. This type of transmission is frequently used for transmissions over long distances, through commutated lines and modems. In some aspects, internet surfing could be an example of half-duplex, as a user issues a request for a web document, then that document is downloaded and displayed, before the user issues another request. Another example is the operation of walkie-talkie. After one person finished talking, he will say "over" to give way to the other person to talk. This is because at one time, only one person can talk.

Figure 1.2: Half Duplex transmission between port A and port B