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Implementation of Mach-Zehnder Modulation OTDM System

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***Abstract*— Optical fiber communications increase the rate of electronic communication. And the OTDM is one of the best schemes to achieve high–speed transmission of data over optical fiber. OTDM (Optical Time–Division Multiplexing) is a technique to overcome the electronic bottleneck and achieve a single channel system. In this paper, we simulate and design a point to point OTDM system with Mach–Zehnder modulation by using OptiSystem, and use DPSK (Differential Phase–Shift Keying) modulation format in this system.**

Keywords*— Optical Fiber; Mach–Zehnder; Optical Time–Division Multiplexing (OTDM); Differential Phase Shift Keying (DPSK);

I. INTRODUCTION

In computer networks and telecommunication, multiplexing of signals is process by which several signals are combined into a signal over shared medium. The reverse process is done to recover the multiplexed signal called De – Multiplexing.

Time–Division Multiplexing (TDM) is related to each signal appearing for each time in a alternating pattern by the means of synchronized switches. The time domain is divided into several time slots of fixed length, each foe a channel [1][5]. In this project, we use Optical Time–Division Multiplexing (OTDM). In OTDM, the optical signal from each channel are multiplexed over time domain and so multiplexed signal will be multiplexed optical signal.

Mach–Zehnder modulator is a special kind of electro–optical modulator which is used in the project for optical modulation. A signal controlled element exhibiting electro optical effect is used to modulate the light beam in waveguide. The Modulation is imposed on Amplitude and Frequency of the beam [2][4].

In this paper, we design and simulate a point to point OTDM (Optical Time–Division Modulation) system by using OptiSystem, and use DPSK (Differential Phase–Shift Keying) modulation format in this system. It achieves efficient and reliable transmission of data which satisfies high–speed optical fiber communications.

II. DESIGN FLOW

In this project, there are two major blocks A. Transmission block and B. Receiver block. In this project, we consider four input channels. Digital Signals from these channels are transmitted through a main channel that is Optical Fiber. These signals are recovered at the receiving end. The figure 1 show the complete block diagram of the DPSK Modulation OTDM System.

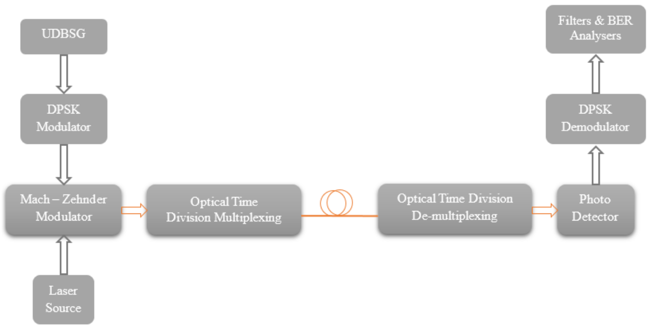

Figure 1 – Block Diagram of OTDM System.

A. Transmitter Block

As said earlier, in this paper we consider four channels which are modulated and multiplexed. These are done in transmitter block. Transmission block contains five sub–blocks. Namely – 1. UDBSG, 2. Differential Modulator, 3. Laser Source, 4. Mach – Zehnder Modulator and 5. Optical Time–Division Multiplexing. These five blocks are described as follows.

1) UDBSG

User Defined Bit Sequence Generator (UDBSG) which generates some predefined bit sequence at the rate of 30Mb/s. This is a bit sequence generator in which the user can define the sequence. The sequence length is defined by N, if the user–defined sequence is shorter than the N, the sequence will be repeated until the length is equal to N. The figure 2 Shows the layout diagram of User Defined Bit Sequence Generator.

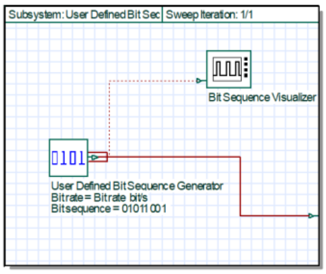

Figure 2 – UDBSG

2) *DIFFERENTIAL MODULATOR*

Differential Phase Shift Keying is a kind of high–speed transmission modulation format. DPSK modulation block consists of duo binary pre–coder and phase modulator. The coding rule of differential coder is as below.

$$b_n = a_n \oplus b_{n-1}$$

DPSK encodes two distinct signals that is the carrier and the modulating signal with 180^0 phase shift each. The serial data input is given to the XOR gate and output is again fed back to the other input through 1–bit delay. The output of the XOR gate along with the carrier signal is given to the balance modulation, to produce the DPSK modulated signal. Figure 3 shows the layout of DPSK Modulation.

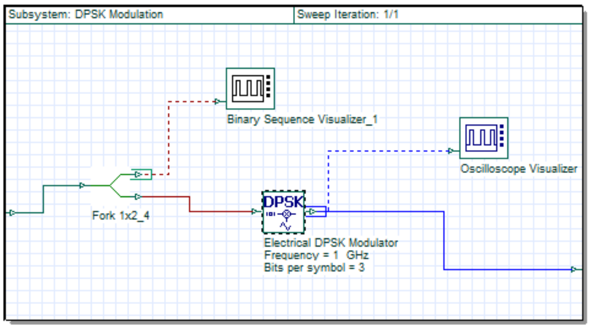

Figure 3 – DPSK Modulation

The figure 4 shows the waveform of binary input to the DPSK Modulation. And figure 5 shows the output of the DPSK Modulated signal.

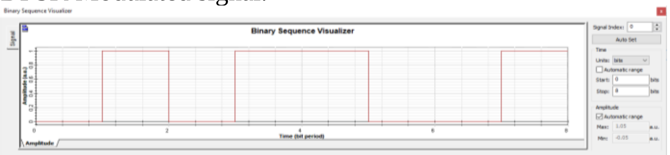

Figure 4 – Input Binary Signal

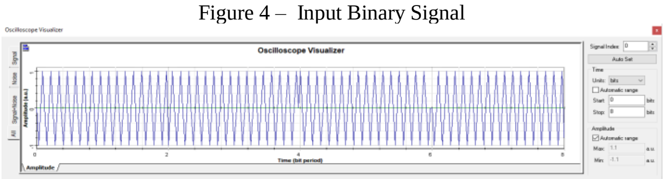

Figure 5 – DPSK Modulated output signal

3) *MACH – ZEHNDER MODULATOR*

The Mach–Zehnder modulator is a special kind of electro–optical modulator. The Modulation is imposed on Amplitude and Frequency of the beam. Waveguide LiNbO3 or Mach–Zehnder modulator which accepts optical carrier and electrical modulation signal and gives modulated optical signal. The output so produced is an optical signal with varying intensity which is in accordance with input electrical signal.

The Mach–Zehnder structure has an input branch, which splits the incoming optical signal into two arms. These two optical arms subsequently recombined by the output optical branch. Application of an electrical signal to one or both of the optical arms through electrodes controls the degree of interference of optical signals from two arms at the output optical branch the different paths can lead to constructive and destructive interference of signals at the output depending on the applied electric signal's voltage. Then the output intensity can be modulated according to the voltage.

In the above figure 6 shows the Mach–Zehnder Modulation technique. The laser source which acts as a carrier in the Optical System which is fed to waveguide. The signal is converted into Return to Zero (RZ) format. Then this signal is fed to electrode. The modulated signal will be optical wave.

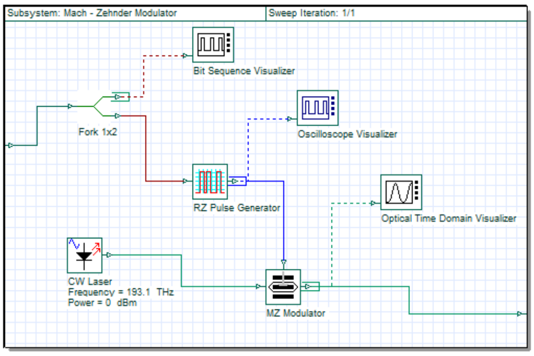

Figure 6 – Mach–Zehnder Modulation

The input Binary Signal fed to Mach–Zehnder is shown in figure 7 and the output Optical waveform of Mach–Zehnder modulation is shown in figure 8

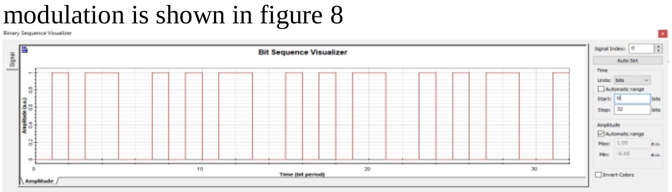

Figure 7. – Input Electrical Waveform

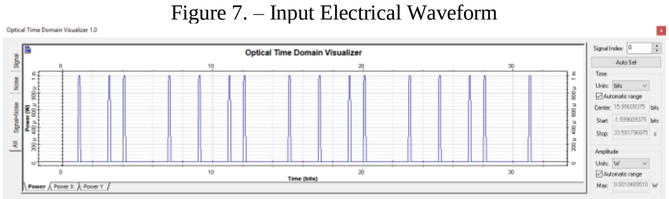

Figure 8. – Output Optical Waveform

4) *OPTICAL TIME–DIVISION MULTIPLEXER*

The optical signal from each channel are multiplexed over time domain and so multiplexed signal will be multiplexed optical signal. Optical Time–Division multiplexer combines basic data stream from four channels as a high–speed data stream. Optical Time–Division multiplexer consists of time delayer and power combiner. Finally, the multiplexed data stream propagates in fiber link.

The Optical Time–Division Multiplexing is made up of power combiner and delayer. Each channel has a calculated

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delay. If there are N channels to be multiplexed, then the delay of nth channel (δ) is given by below formula.

$$\delta = 1/\ ((\text{Bit rate})) \times (\text{nth channel} - 1)/\ N$$

The Power combiner will sum up the power of the input optical signal. The figure 9. shows the layout diagram of 4 channel Optical Time–Division Multiplexing. Here in this paper we considered only four channels. So Optical signal from each channel is multiplexed using below setup. Each channel is applied with respective delay and the signals are added up in power combiner.

For example, in our project we consider only four channel. Let's consider the bit rate of the system is 1Gbps. So for first channel there will be no time delay, that is 0 seconds. For second channel there will be delay of 0.25ns. For third channel there will be delay of 0.5ns. For fourth channel there will be delay of 0.75ns.

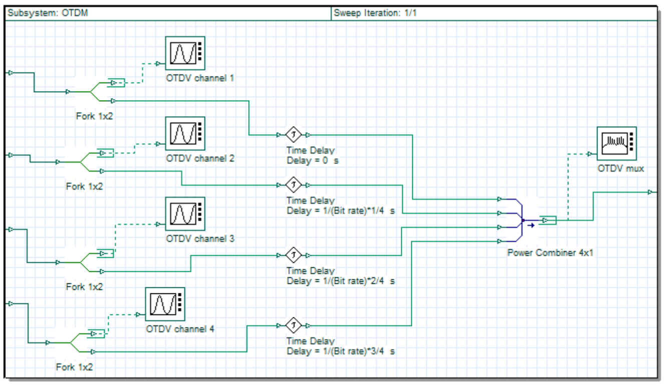

Figure 9 – Optical Time–Division Multiplexer

The four input optical signals from different channels of Mach–Zehnder are fed to Optical Time–Division Multiplexing are shown in figure 10 to figure 13. And the output Optical waveform of Optical Time–Division Multiplexing is shown in figure 14.

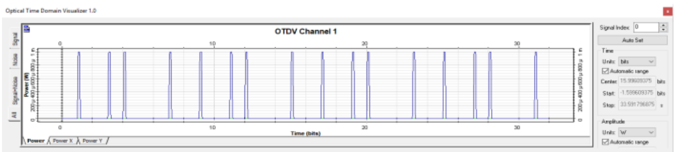

Figure 10 – Optical Signal of channel 1

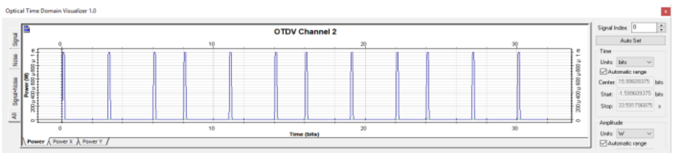

Figure 11 – Optical Signal of channel 2

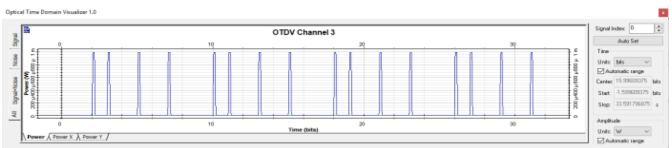

Figure 12 – Optical Signal of channel 3

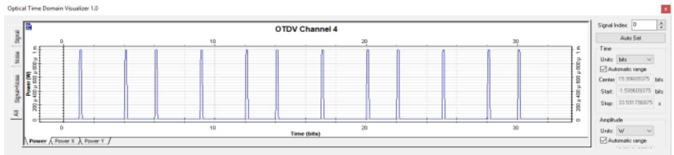

Figure 13 – Optical Signal of channel 4

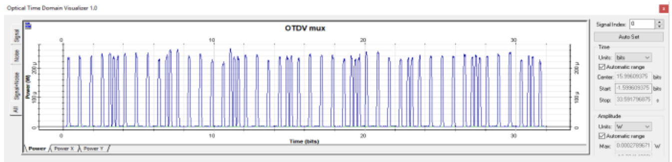

Figure 14 – Optical Signal of of Multiplexed channel

B. RECEIVER BLOCK

Receiver block contains four sub–blocks. Namely 1. Optical Time–Division De–multiplexing, 2. DPSK De–modulator, 3. Photo Diode, 4. Filters and BER Analyzer. These five blocks are described as follows.

1) OPTICAL TIME–DIVISION DE–MULTIPLEXER

The Optical Time–Division De–Multiplexer consists of Power Splitter cascaded with Mach–Zehnder Modulator. The Optical Time–Division De–Multiplexer takes single optical signal and routes it to several data streams. In this paper we have considered four channel Optical Time–Division Multiplexer, so in the receiver part Optical Time–Division De–Multiplexer splits into four channels.

Power Splitter cascaded with Optical Time Delayer and Mach–Zehnder Modulator forms Optical Time–Division Multiplexer. Power splitter splits data stream into identical data stream. These data streams are added with respective optical delay. Delay(δ) for each arm is calculated by the below formula.

$$\delta = 1/\ ((\text{Bit rate})) \times (N - \text{nth channel} - 1)\ /\ N$$

Power Splitter splits the signal to four identical arms. This arms are added with calculated delay from the above formula for different channels. These optical signals are fed to input optical branch of Mach–Zehnder Modulator. The electrodes are fed with high logic (1 or +Vcc). In the modulation process we have used RZ format and high logic LASER, so in the receiver part we use high logic Return to Zero format signal and the same is fed to electrodes of Mach–Zehnder Modulator. The below Figure 15 and 16 shows the Optical Time–Division De–Multiplexer used to recover the optical signal sent by transmitter.

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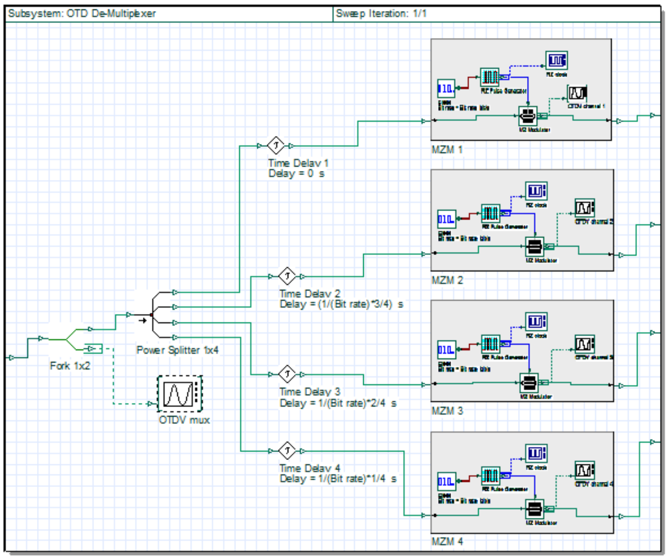

Figure 15 – Optical Time–Division De–Multiplexer

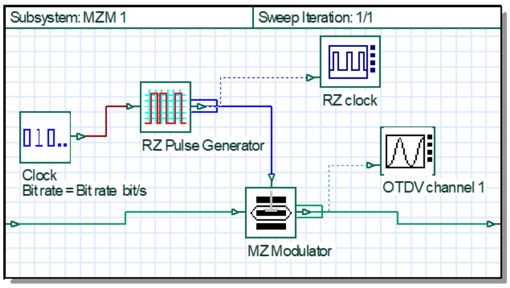

Figure 16 – MZM sub block

The input multiplexed optical signal is shown in the figure 17. and the De–multiplexed and recovered optical signals of four channels from the Mach–Zehnder Modulators are shown in the figure 18 to 21.

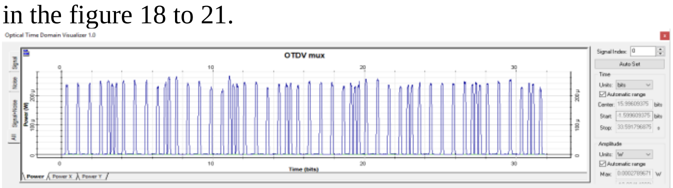

Figure 17 – Multiplexed Optical Input Signal

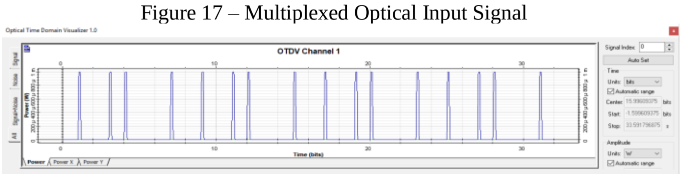

Figure 18 – Optical Signal of channel 1

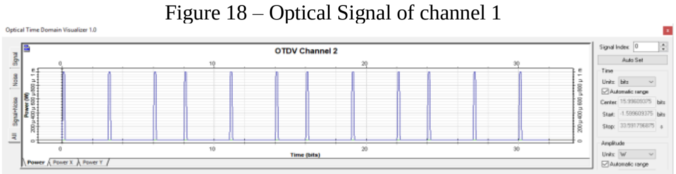

Figure 19 – Optical Signal of channel 2

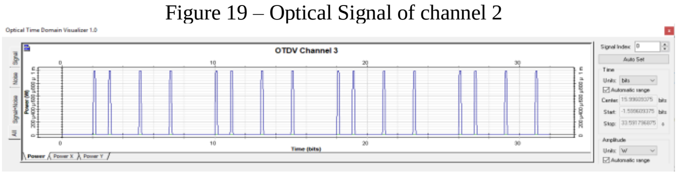

Figure 20 – Optical Signal of channel 3

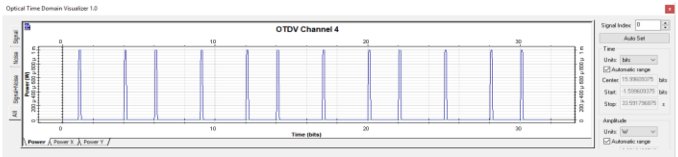

Figure 21 – Optical Signal of channel 4

2) PHOTODETECTOR

The PIN Photodiode component is used to convert an optical signal into an electrical current based on the device's Responsivity. When an optical signal strikes the diode, it generates electrical current corresponds to optical intensity by the electron–hole pair formation. This current is called photocurrent. By the means of this device we convert optical signal into corresponding electrical signal. The layout diagram of Photodetector is show in the Figure 22.

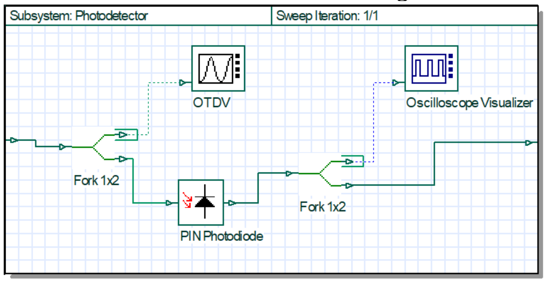

Figure 22 – Photodetector

3) DPSK DE–MODULATOR

Received electrical signals are demodulated to get the binary data sent by the transmitter. The carrier signal which is used in transmitter block is multiplied with input electrical signal in quadrature phase modulator. The carrier is shifted by 90^0. The input electrical signal is split into two and this are multiplied with carrier and phase shifted carrier. These signals are compressed and change to M–ary format. These signals are compared and coded using DPSK Decoder. The output signal is a demodulated Binary Data. The layout diagram of DPSK demodulator is shown in figure 23.

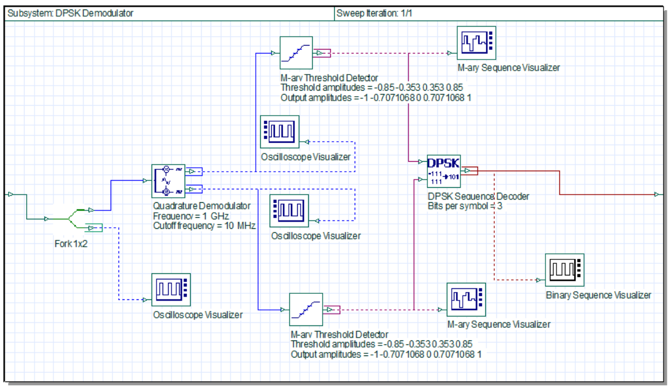

Figure 23 – DPSK De–Modulation

The figure 24 shows the waveform of input DPSK signal to the DPSK Demodulator. And figure 25 shows the Binary output of the DPSK Demodulated signal.

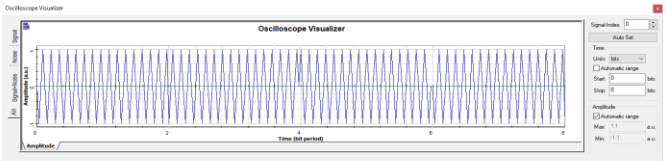

Figure 24 – Input DPSK Signal

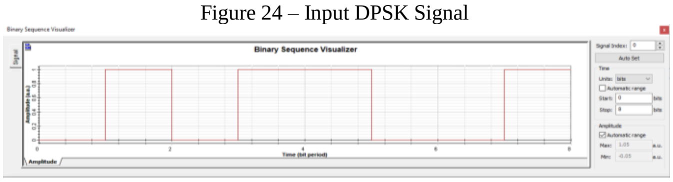

Figure 25 – Output Binary Signal

4) FILTERS AND BER ANALYSER

Filter is used for signal processing functions such as to attenuate or to reduce noise or for selectively filtering some frequencies. To get so we use low power filters, amplifiers and Bessel filters of order 4.

BER visualizer allows us to calculate and display the bit error rate (BER) of an electrical signal automatically. It can estimate the BER using different algorithms. It can also plot BER patterns and estimate this system penalties and margins. Using this we estimate the output correctness of received signal.

III. SOFTWARE USED

We simulate this project using OptiSystem 15.0.0. The OptiSystem is software designed by Optiwave.

OptiSystem is a software from Optiwave Systems Inc. OptiSystem is a comprehensive design tool that enables us to plan, test, and simulate optical links in the layers of Optical System. Optiwave built a complete solution with an extensive component library that is fully capable of designing the complete transmission layer for the creation of next generation networks. OptiSystem 15.0.0 supports External Software like MatLab, Scilab, EDA and so on. It allows to create user defined subsystems and scripting [6]. Optiwave provides a design tool structures leads to high–technology business.

IV. CONCLUSION

In this paper we propose a DPSK Modulation OTDM system and verify that the system is feasible. Accuracy of Optical Time–Division Multiplexing and De–multiplexing is analyzed. As Optical signals from individual channels are multiplexed, the efficiency and Data recovery is high. This system is more useful because it improves bit rate of transmission and bandwidth of the system.

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