Analysis of Intensity Modulation Techniques in DWDM Transmission Systems

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Abstract— DWDM is a fiber optic transmission technique which allows the transmission of voice, email, multimedia, video and data over the optical layer. It increases the capacity of embedded fiber by first assigning incoming optical signals to specific frequencies within a designated frequency band and then multiplexing the resulting signals onto one fiber. The purpose of this paper is to analysis intensity modulation techniques in enhancing signal quality in a DWDM transmission system. Simulation is done by using Optsim ver.5.3.

Key words: DWDM, Using Oprsim, Fiber

I. INTRODUCTION

Optical communication is communication at a distance using light to carry information. Optical fiber is the most common type of channel for optical communications. The transmitters in optical fiber links are generally light-emitting diodes (LEDs) or laser diodes. Infrared light, rather than visible light is used more commonly, because optical fibers transmit infrared wavelengths with less attenuation and dispersion. The signal encoding is typically simple intensity modulation.

The increasing demand in telecommunication capacity has led to wavelength division multiplexing (WDM). This technology multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths of laser light. This technique enables bidirectional communication over one strand of fiber as well as multiplication of capacity. WDM systems are divided into different wavelength patterns, conventional/coarse (CWDM) and dense (DWDM).

Conventional WDM systems provide up to 8 channels in the 3rd transmission window (C-Band) of silica fibers around 1,550 nm. Dense wavelength division multiplexing (DWDM) uses the same transmission window but with denser channel spacing. Using DWDM, up to 80 (and theoretically more) separate wavelengths or channels of data can be multiplexed into a light stream transmitted on a single optical fiber.

Since each channel is demultiplexed at the end of the transmission back into the original source, different data formats being transmitted at different data rates can be transmitted together. Specifically, Internet (IP) data, Synchronous Optical Network data (SONET), and asynchronous transfer mode (ATM) data can all be travelling at the same time within the optical fiber. DWDM promises to solve the "fiber exhaust" problem and is expected to be the central technology in the all-optical networks of the future.

From both technical and economic perspectives, potentially unlimited transmission capacity is the most obvious advantage of DWDM technology.

In addition to bandwidth DWDM has several key advantages such as transparency, Scalability, and Dynamic Provisioning. DWDM is physical layer architecture and it can transparently support TDM and data formats such as asynchronous transfer mode (ATM), Gigabit Ethernet, Enterprise System Connection (ESCON), and Fiber Channel with open interfaces over a common physical layer. DWDM can leverage the abundance of dark fiber in many metropolitan area and enterprise networks to quickly meet demand for capacity on point-to-point links and on spans of existing SONET/SDH rings. It is fast, simple, and dynamic provisioning of network connections give providers the ability to provide high-bandwidth services in days rather than months.

In optical communications, intensity modulation (IM) is a form of modulation in which the optical power output of a source is varied in accordance with some characteristic of the modulating signal. The envelope of the modulated optical signal is an analog of the modulating signal in the sense that the instantaneous power of the envelope is an analog of the characteristic of interest in the modulating signal. In the direct modulation scheme, the driving current to a directly modulated (DM) semiconductor laser is varied according to the data to be transmitted. In the external modulation scheme, the laser that is subjected to a constant bias current emits a continuous wave (CW) while an external modulator switches the optical power on or off according to the data stream.

II. SIMULATION SETUP

In order to make an analysis of direct intensity modulation technique and external intensity modulation in DWDM transmission system, simulation model was made using Optsim 5.3. Each transmitter section includes a Data Source, NRZ coder, Electrical filter, optoelectronic modulator and a Continuous Wave Laser. The receiver section consists of optical filter, PIN photodiode, and electrical filter. The optical filter is to reduce Amplified Spontaneous Emission (ASE). The PIN photo detector is used to detect an optical information signal and convert into the electrical signal. Electrical Scopes simulates an oscilloscope for electrical signals. It collects data that will be available for the following diagrams such as amplitude of the electrical signal, eye diagram, histogram of optimum sampling instant and power spectrum of the electrical signal.
The continuous optical signal is modulated by NRZ coded electrical pulses. Then the generated optical signal is transmitted through 73 kilometres of Single Mode Fiber (SMF) with 0.2 dB/km attenuation and 16 ps/nm/km chromatic dispersion. This SMF fiber length is determined by the required optical signal power at the input of the optical amplifier, which is important due to amplifier saturation effect, especially when using a SOA. For a discrete Raman amplifier this is not so relevant. This is why small signal power at the amplifier input has been optimized for the SOA. The simulation block using Erbium Doped Fiber Amplifier (EDFA) is shown in fig 1.

In order to find the amplifier giving better effect indirect intensity modulation EDFA is replaced by Semiconductor Optical Amplifier (SOA), Raman Amplifier, RamanEDFA, Raman-SOA, and SOA-EDFA. After processing through an amplifier, the amplified signal is transmitted through an SMF fiber of various lengths, which will be varied in order to obtain the maximum transmission distance, and then it enters a Dispersion Compensation Fiber (DCF). After propagating through the DCF fiber, the optical signal is detected and converted into electrical current using a PIN photodiode. DCF fiber attenuation at 1550 nm for the fiber is 0.55 dB/km, and dispersion at the same wavelength is -80 ps/nm/km.

The investigation on the performance on different amplifiers have been carried out on 16 channel DWDM Transmission system operating at a data rate 10Gbit/s with non-return-to zero encoding technique, intensity on/off keying modulation format, and 50 GHz channel spacing has been introduced. In external modulation method, a 10Gbps NRZ signal is modulated by optoelectronic modulator. The modulated signal is again externally modulated by using MachZender modulator with electrical clock generator and bias wave generator as other inputs. The simulation model is shown in fig 2.

III. RESULTS AND DISCUSSIONS

The transmitter block consists of 16 channel transmitters, each of them operating at its own frequency in range from 193.05 THz to 193.8 THz. The most convenient way of assessing transmission quality is analyzing the Eye-diagrams and obtaining the bit-error rate (BER) values of the received signal at each of the 16 channels. In order to assess optical amplifier performance and to estimate transmitted signal distortions, which occur during the amplification process, Eye-diagrams of a specific transmitted signal channel at the input and output of the optical amplifier are analysed using electrical scope. The power meter measures the power (mean square value) of an electrical signal.

Fig. 1: Simulation Model for Direct Intensity Modulation

Fig. 2: Simulation Model for External Intensity Modulation

Fig. 3: Q Value Obtained Using (A) EDFA (B) SOA (C) Raman Amplifier (D) SOA-EDFA (E) Raman-SOA (F) Raman-EDFA in Direct Modulation.
The performances of the different optical amplifiers are analyzed by replacing optical amplifier block by the earlier mentioned amplifiers one by one in the directly modulated and externally modulated 16 channel DWDM transmission systems and the amplifier giving best performance in direct intensity modulation and external intensity modulation was found using the eye diagram obtained from the electrical scope at the receiving section. Quality factor (Q value) is a dimensionless parameter which indicates efficiency. It is a measure of the relationship between stored energy and rate of energy dissipation in certain electrical components and devices. Fig 3 shows the eye diagram obtained for different amplifiers at 100Km for channel 1 in direct intensity modulation.

![Fig. 3: Eye Diagram](image)

**Fig. 3: Eye Diagram**

The Q value obtained for different amplifiers at 100Km for 3 channels are plotted in the fig 4. Fig 5 shows the eye diagram obtained for different amplifiers at 100Km for channel 1 in external intensity modulation.

![Fig. 4: Q Value at 100Km for 3 Channels](image)

**Fig. 4: Q Value at 100Km for 3 Channels**

The Q value obtained for different amplifiers at 100Km for 3 channels are plotted in the fig 4. Fig 5 shows the eye diagram obtained for different amplifiers at 100Km for channel 1 in external intensity modulation.

**Fig. 5: Q Value Obtained Using (A) EDFA (B) SOA (C) Raman Amplifier (D) SOA-EDFA (E) Raman-SOA (F) Raman-EDF in External Intensity Modulation.**

![Fig. 5](image)

**Fig. 6: Q value at 100Km for 3 channels**

The Q value obtained for different amplifiers in external intensity modulation at 100Km for 3 channels are plotted in the fig 6.

**IV. CONCLUSION**

The main aim of this article is to analyze the intensity modulation technique that enhances signal quality. The performance of direct modulation and external modulation was studied to find the technique that enhances amplifier performance and found that external modulation gives better results than direct modulation and among the different amplifiers used Raman-EDFA showed better performance. The main factor that has limited transmission was amplifier produced noise, the amount of which was more in the case of the SOA.

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