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EDFA and Optical Fiber Repositioning in an Optical Fiber Communication Network

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Abstract: This study shows an easy and effective design of an optical fiber communication system, which demonstrates EDFA's ideal position in the whole system. In recent years, erbium-doped fiber amplifiers (EDFAs) have been more attentive with the development of high-speed and long-distance data transmission systems. In our research, EDFA's forward pump capacity is maintained at 100mW, and our three configurations modify and analyze the location of EDFA. First configuration is meant to place EDFA before optical fiber in the entire system. The second arrangement has been intended such that EDFA will precede optical fiber. EDFA is inserted in the third configuration between the optical fiber length. For the three setups, the BER, Q factor and output power level were observed, with the setup one having minimal BER, setup two with the greatest power, and setup three with the maximum Q factor. This paper discusses the causes behind these results and designers may construct an optical fiber communication system in the most efficient and reliable fashion by taking those results into consideration. The simulation was performed in Opti-System software.
Keywords: EDFA, BER, Q factor, Analyzer, Optical fibre

I. INTRODUCTION

Information is communicated from place to place via one medium. Communication Many media have been used by mankind to transmit data. Coaxial cable systems were one of these media that really had a large influence on data transfer. A 3MHz system, which could convey 300 speech channels, was the first coaxial cable system implemented in 1940. But these coaxial cables, which generally have large cable losses, are also relatively small and expensive for a longer transmission length. These deficiencies led to the invention of the communication system for the microwave. The communication system in the microwave employs GHz electromagnetic carrier waves to convey multiple approaches for the modulation of carrier waves. The communications method of the microwave permitted greater repeater distance but had a restricted bit rate. Then we have to deal with the matter. Optical fibre was invented in the 1970s and revolutionised and played an important part in the information age of the telecommunications sector. Optic fibres have replaced considerable amounts of copper wire communications in core networks in industrialised countries due to their benefits over electric transmission. In the visible or near-infrared area of electromagnetic spectrum the optical communication system employs the high carrier frequency (~100 THz). It is increasingly popular because to its low loss, large capacity and bit rate.

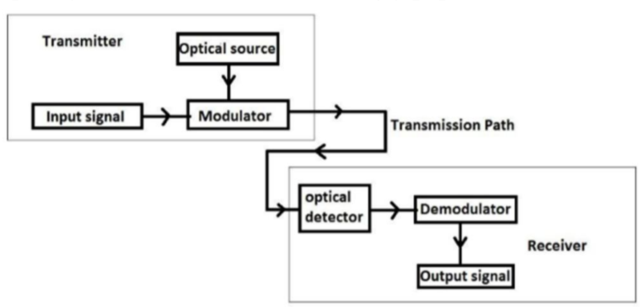

Fig1. Block Diagram of an Optical Communication System

The input signal is created from a data source on the transmitter side. The optical source is a laser source generating a specified wavelength of optical light signal. The data source and the optical signal are sent to the modulator and then the resultant modulated pulse signal is sent over an optical fibre transmission channel. An optical detector detects the optical signal on the receiver side [1]. The signal detected then travels through the demodulator to get the signal sought. The optical fibre is a flexible silica glass filament that takes and transforms electric impulses to optical signal. The optical signal carries the fibre length and the optical signal is re-converted on the receiver side to the electric signal.

Earlier long-haul optical communications systems used electronic regenerators for optical signal amplification. The attenuated optical signal is electronically amplified, the optical signal first converted into an electrical domain and then converted to an optical domain. These regenerators are intended to operate at a certain optical wavelength and data rate. With no electrical domain conversion, the optical amplifier is capable of amplifying optical signals in the optical domain. It needs high-speed circuitry, and it's open to bit rate, and can concurrently amplify several optical signals at various wavelengths. In EDFA development, the capacity of the communication system employing WDM is growing tremendously. In several communication connections, optical amplifiers can be employed. Today, because to its bandwidth and high power and noise characteristics the majority of the fibre optic communication system uses EDFAs.

Erbium Doped Fiber is an optical amplifier that amplifies the weak optical input signals directly without laser diode conversions. EDFA is mostly used to enhance signals in the optical domain.

In the realm of optical communication networks, the EDFA was a crucial enabling technology and has since comprised the great majority of all the optical amplifiers. The most prevalent optical amplifier accessible in the business since the early 1990s is the Erbium doped fibre amplifier. It is a highly stable optical amplifier, having a wavelength range of 1525 – 1565 nm. It works well with an increase of up to 30 dB in this range.

II. OBJECTIVES

The objective of this research is to find the optimum position of EDFA in the optical fiber communication system. EDFA amplifies the optical power comprising both of data and noise. The location of EDFA such that it maximizes the data signal more than noise without losing the information contained in the signals is of primary concern.

III. LITERATURE REVIEW

In the past, much work is done on EDFA and its parameters. Some people have tried to increase its bandwidth of amplification, some have tried to increase its amplification factor and others have tried to vary the erbium concentration in the EDFA for maximum amplification [2]. Our research is based on the overall optical fiber communication design and placing EDFA at the most appropriate position so that maximum benefits from EDFA are observed and enjoyed.

IV. SOFTWARE REQUIREMENTS

A. OptiSystem

1) OptiSystem is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks.
2) It is a system level simulator based on the realistic modelling of fibre-optic communication systems.
3) A comprehensive Graphical User Interface (GUI) controls the optical component layout.
4) OptiSystem allows for the design automation of virtually any type of optical link in the physical layer, and the analysis of a broad spectrum of optical networks, from Long-Haul Networks, Metropolitan Area Networks (MANs) and Local Area Networks (LANs).
5) OptiSystem includes an extensive library of sample optical designs that can be used as templates for optical design projects or for learning and demonstration purposes.
6) OptiSystem capabilities can be extended with the addition of user components, and can be seamlessly interact with a wide range of tools.

V. SIMULATION MODEL

The various components used in my work are:

A. Pseudo Random Bit Sequence Generator

A pseudo random binary sequence is a binary sequence that is difficult to predict and show statistical behaviour similar to a truly random sequence although it is created with a deterministic technique. In communications but also in encryption, modelling, correlation techniques and flight time spectroscopy, PRBS generators are employed.

B. NRZ Pulse Generator

A sequence of non-return to nil pulses programmed for the digital input signal is created by the NRZ pulse generator. The NRZ pulse generator generates an electric signal that relies on bit sequence input that is non-return to zero. Since the output of the pulse generator depends on a little sequence, a user-defined bit sequence generator is connected to their input.

C. CW Laser

Continuous wave (CW) light sources functioning meaning they are not pulsed continually. The phrase is used most often, for example, for lasers but also for gases. Continuous wave operation means that a laser is pumped constantly and produces light continually. In longer time scales the power generation of the continuing laser is more or less constant, but owing to mode beating and other types of Laser noise there may be considerable power changes.

D. Mach Zehnder Modulator

For the regulation of the optical wave amplitude, a Mach-Zehnder modulator is employed. The input guide is divided into two interferometric arms for the waveguide. A phase shift is initiated for the wave flowing through that arm if the tension is placed across one of the arm. The difference in phase between the two waves is turned into amplitude modulation when the two arms are re-combined. The light recombines more or less effectively or does not recombine at all at the interferometer output dependent on the overall phase difference and hence leads to a variation of the output power.

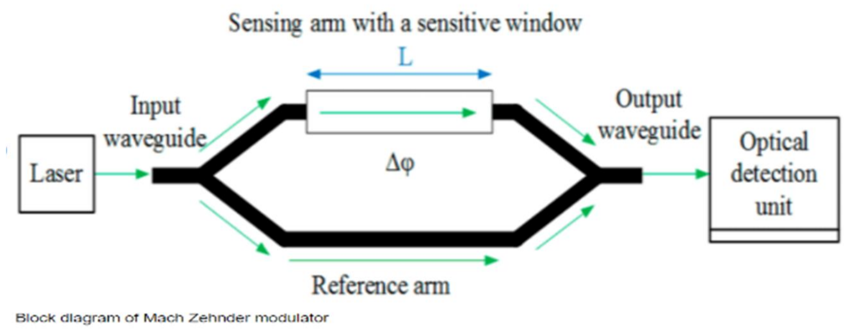

Fig 2 Mach Zehnder Modulator

E. Optical Fibre

Optical fibre refers to the information transmission medium and technology as pulses of light along the glass or plastic strand or fibre. Long distance and high performance data networking is utilised in fibre optics. Also employed for communications services are frequently fibre optics. The utilisation of fibre optic cables is based on several benefits over copper lines, namely greater bandwidth and faster transmission. There are a lot of these glass fibres available on a fibre optic cable. Another glass layer called cladding is around the glass fibre core. The cladding is protected by a layer known as the buffer tube, and the jacket layer serves as the last protection layer for the single strand.

F. EDFA

In terms of long-range optical fibre communications, Erbium-doped fibre amplifiers are the by far most important fibre amplifier; in the 1,5-µm area, where telecoms fibres have a low loss they may effectively amplify light [5]. The basic component of a fibre amplifier is a rare earth-doped fibre that, if it is optically pumped into the fibre with another light, may give laser amplification via stimulated emission. For details on more general topics, see the page on fibre amplifiers.

G. Visualizer

To picture the results, here two types of visualizers are used

1) *Optical Power Meter:* An optical power meter (or laser power meter) is an instrument for the measurement of the optical power. An optical power metre (or laser power metre), for instance a laser beam, is a device to determine the optical power (the energy provided per unit time). Typically, it permits only relatively low bandwidth power measurements and shows the average power on a high pulse repeater. Normally an optical power metre is equipped with a sensor head that is usually fixed on the power sensor with a post to get a horizontal beam input at an altitude above the optical board.
2) *Optical Spectrum Analyzer*: A precise device designed to analyse and show the power distribution of an optical source throughout a certain wavelength is an optical spectrum analyser (OSA). An OSA trace shows the vertical power and the horizontal wavelength.

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VI. RESULTS AND OBSERVATIONS

We have divided the results into two parts.
One without EDFA and other with EDFA.
The setup with EDFA is further divided into three configurations with fibre length and pumping power fixed at 10Km and 100mW respectively.
Configuration A: EDFA followed by Optical fibre. That means just after the transmitter end.
Configuration B**:** Optical fibre followed by EDFA. That means just before the receiver end.
Configuration C**:** EDFA located accurately at the middle of the optical fibre. That means at the length of 5Km from the transmitter end.

A. Before Introducing EDFA:

In this setup, EDFA is not used

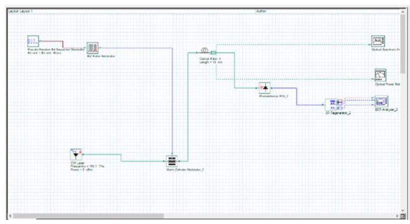

Fig.3 Simulation Setup without using EDFA

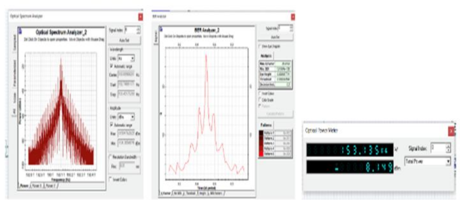

Fig. 4 Output Power, BER and Q factor

B. After Introducing EDFA

Three configurations are used and then their results are compared

1) Configuration A: EDFA followed by Optical fibre

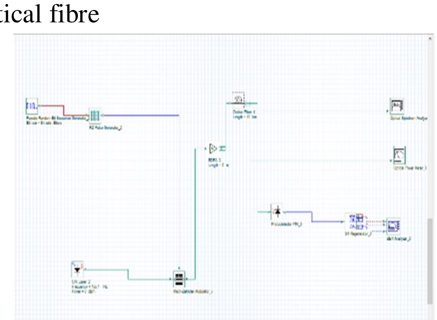

Fig 5 Simulation Setup in Configuration

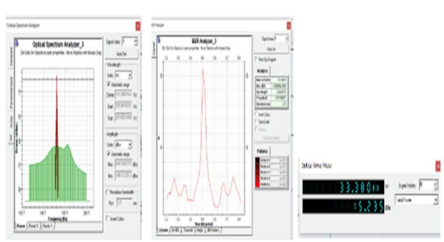

Fig 6 Output Power, BER and Q factor in Configuration A

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2) *Configuration B:* Optical fibre followed by EDFA

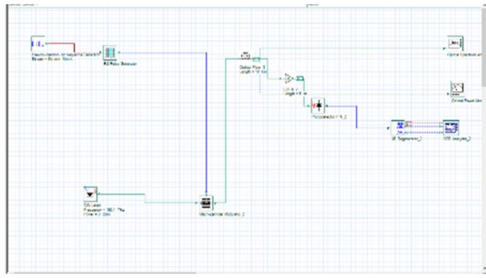

Fig 7 Simulation Setup in Configuration B

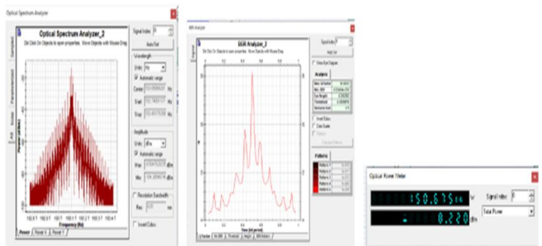

Fig 8 Output Power, BER and Q factor in Configuration

3) *Configuration C:* EDFA located accurately at the middle of the optical fibre

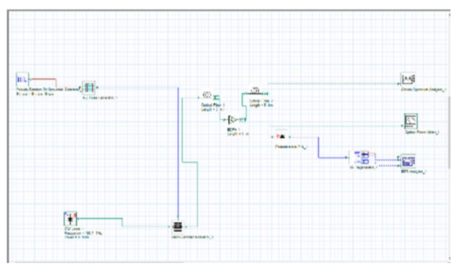

Fig 9 Simulation Setup in Configuration C

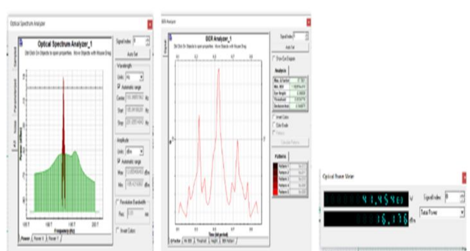

Fig 10 Output Power, BER and Q factor in Configuration C

TABLE 1
Output Power, BER and Q Factor Values

EDFA	Power (dbm)	Q factor	BER
Not Used	-9.584	2.616	$1.92e^{-6}$
Configuration A	8.617	21.02	$1.09e^{-98}$
Configuration B	19.584	30.822	$4.93e^{-209}$
Configuration C	13.855	17.7001	$1.18e^{-70}$

Looking at the values at the output, it is quite clear that without using EDFA, information contained in a signal is lost. It is confirmed by the power level received at the output, that is negative and BER is comparatively very high. So, the receiver won't be able to extract signal from the noise.

Now looking at the three configurations, it may seem to be a random phenomenon. But looking at the practical aspect of it, we can say:

For Configuration A, all the three measured parameters seem good when EDFA is placed just after the transmitter unit and before the optical fibre. It can be understood by the fact that we are at the very beginning making the signal power very strong as compared to the noise and in case the noise adds up in the transmission media, there is no second EDFA to boost the signal. Hence it limits the length of the optical fibre and it has to be within the range such that the noise added does not overcome the signal power.

For configuration B, all the three parameters seem to be perfect but practically, the case is not such. Once the signal passes through the optical fiber of length 10km without having any EDFA in between, it is the similar case as of no EDFA. At the receiving end just before EDFA, the information is already lost and cant be separated from the noise. Now when the same distorted signal is fed to EDFA, it amplifies it and same is shown by the analysers. The information is not retrieved and the power received is simply the amplified version of a signal. For Configuration C, all the parameters seem to have a optimum values. In this case, the EDFA is placed at the centre of the transmission media. With the result, the signal when sent from the transmission end first starts fading but is amplified and regenerated on time, well before it gets totally distorted. Placing EDFA like this is logical as it makes room for the long range transmission of the signal. The output would be much better if the location of EDFA is slightly moved towards the transmission end to avoid any chance of earlier distortion of signal.

Configuration A when combined with configuration C gives the best result. There is no fun of using configuration B in any case.

VII. CONCLUSION

In this paper, we have studied the position of EDFA with respect to the optical fiber in the optical fiber communication system. It was seen that the best configuration for efficient and reliable transmission is possible by placing EDFA in between the optical fiber and the worst configuration is the positioning of EDFA at the end of the optical fiber communication system. Placing EDFA at the end of the communication system makes no sense

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