Compensation of Spectral Loss Variations in Erbium Doped Fiber Amplifier Based Optical Communication

N SINDHU and R. MAHESHKUMAR

Abstract— **The paper aims in developing a novel method for reduction of spectral variations that occurs in Erbium Doped Fiber amplifiers. The paper mainly focuses on Erbium doped optical amplifier and various spectral variation problems affecting the amplifier and the present method for compensating those variations are explained. The modulation formats used for this purpose are also explained and a new method is proposed for the reduction of spectral variations.**

Index Terms*—*Optical amplifiers, EDFA, Jitter, Modulation formats

I. INTRODUCTION

A communication system transmits information from one place to another. The distance between source and destination in a communication system may vary from a few meters to a hundreds of kilometer or to a transoceanic distance. Most often the information is carried through these distances in the form of electromagnetic waves whose frequency varies from a few Megahertz to several hundred Terahertz. Optical communication systems use high carrier frequencies (~100 THz) in the visible or near-infrared region of the electromagnetic spectrum. They are sometimes called lightwave systems to distinguish them from microwave systems, whose carrier frequency is typically smaller by five orders of magnitude (~1 GHz). Fiber-optic communication systems are lightwave systems that employ optical fibers for information transmission.

The optical communication systems are different from microwave communication systems in many aspects. In the case of optical systems, the carrier frequency is about 100 THz and the bit rate is about 1T bit/s. Further the spreading of optical beams is always in the forward direction due to the short wavelengths. Even though it is not suitable for broadcasting applications, it may be suitable for free space communications above the earth's atmosphere like inter satellite communications. To guide light in a waveguide, initially metallic and non-metallic wave guides were fabricated. But they have enormous losses. So they were not suitable for telecommunication. Tyndall discovered that through optical fibers, light could be transmitted by the phenomenon of total internal reflection. Optical fibers can provide a much more reliable and versatile optical channel than the atmosphere.

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The advantages of optical fibre communication over the other communication techniques are mentioned below

a. Higher bandwidth (extremely high data transfer rate).
b. Less signal degradation.
c. Less costly per meter.
d. Lighter and thinner then copper wire.
e. Lower transmitter launching power.
f. Less susceptible to electromagnetic interference.
g. Flexible use in mechanical and medical imaging systems.

The fibre optic communications also have a number of applications in the area of telecommunication. In this paper we are focusing on optical amplifiers which are essential part in fibre optic communications. The optical amplifier of our interest in this paper will be erbium doped fibre amplifier (EDFA) which is widely preferred in the area of fiber optic communication. In this paper an analysis of the performance of optical system consisting of single or a chain of EDFAs (depending upon the system performance) for different data formats are made. This project also aims in developing a hybrid of the data format which combines the advantages of data formats used previously so as to compensate for the spectral losses without affecting the system performance.

Section II gives an introduction to Erbium doped optical fibre amplifiers. Section III focus on the spectral problems such as jitters, associated with the EDFA. Section IV deals with various modulation formats used in suppressing the nonlinearities in EDFA.[1][2][3][4] The paper will be concluded in section V which will explains the project aim to reduce the above mentioned problem associated with EDFA.

II. ERBIUM DOPED FIBER AMPLIFIER (EDFA)

Erbium doped fiber amplifier (EDFA) is a device that boosts the signals in optical amplifier, i.e. it acts as a power amplifier. EDFA is designed for Dense Wavelength Division Multiplexing applications in which multiple optical signals are taken and are multiplexed into a single fiber. In doped fiber amplifiers (DFA), the fiber core is doped with rare earth erbium ions. The ions constitute the active medium through which optical gain is obtained. When optically pumped, these ions are excited to a higher energy state. When simulated by incoming photons the ions emit photons which results in optical gain[8]. The EDFA has generated significant interest because of its high gain ,large bandwidth and low noise.

The active fiber is pumped with light from two lasers diodes. The pump light, having a wavelength of 980nm or 1450nm excites the erbium ions Er^{3+}, from where they can amplify light via. Stimulated emission. The isolators present in the amplifier input stages will prevent spontaneously emitted light from affecting the previous stages and the one in the output suppresses the reflection of output back to amplifier**.**

III. SPECTRAL VARIATIONS IN EDFA

Many researches are going on for the reduction of spectral variations in EDFA. The most important factor for spectral variations are as a result of the timing jitter, which are introduced by various sources along the propagation path in an optical communication system. The controlling of time jitter thus becomes an essential requirement [4] for long distance optical communications.

Jitter is short term timing variations from its ideal position. Frequency variations above 10 Hertz are normally considered as jitters. Jitter causes bit errors and degrades the performance of transmission system. Jitter causes the decision point to get shifted from optimized position. In optical communication point of view there are two types of jitters, they are random jitters, which are as a result of influence of electronic components and systematic jitter as a result of the finite Q of the clock recovery circuits. Under jitter testing categories the maximum tolerable jitter, in which how well the jitter can tolerate the incoming signal is measured and also the jitter transfer function are considered.

IV. MODULATION FORMATS USED

A. RETURN TO ZERO

In return to zero format the width of optical signal is smaller than its bit period.[1][2]. Usually a clock signal with the same data-rate as electrical signal is used to carve RZ shape of optical signals. Initially, NRZ optical signal is generated by an external intensity modulator; then, it is modulated by a synchronized pulse train with the same data-rate as the electrical signal by cascading another intensity modulator. We can also generate RZ waveforms first and then modulate onto an optical carrier. RZ optical signal has been found to be more tolerant to nonlinearity than NRZ optical signal. If the average optical power launched into the fiber is kept constant, an optical RZ pulse with a 50% duty cycle will have twice the peak power of an NRZ pulse. This increase in power occurs because optical amplifiers are run in the saturation mode, resulting in a gain that scales with average input power. The photodiode is a square-law detector, i.e., the photocurrent is proportional to optical power. Hence the received electrical power (proportional to the square of the photocurrent) is proportional to the square of the optical power. Therefore, the electrical power of an RZ pulse with a 50% duty cycle will be twice that of an NRZ pulse.

B. NON RETURN TO ZERO

Non-return-to-zero on-off-keying (NRZ-OOK) has been the dominant modulation format for fiber-optical communication systems [1]. There are several reasons for using NRZ in the early days of fiber-optical communication: First, it requires a low electrical bandwidth for the transmitters and receivers (compared to return-to-zero); second, it is not sensitive to laser phase noise (compared to phase shift keying); and last, it has the simplest configuration for the transmitter and receiver. Considering recent advancements in optical communication field, NRZ modulation format may not be the best choice for future high capacity optical networking systems. However, it has been widely deployed in field and due to its simplicity, and its historic dominance, NRZ would be a good reference for the comparison. NRZ modulated optical signal has the most compact spectrum compared to that with other modulate formats [3]. However, this does imply that NRZ optical signal has superior resistance to residual chromatic dispersion in an amplified fiber system with dispersion compensation. Also this does not reflect that NRZ is more tolerant to XPM and FWM in DWDM systems because of its strong carrier component in the optical spectrum

C. CARRIER SUPPRESSION RETURN TO ZERO (CSRZ)

CSRZ is a pseudo-multilevel modulation format. It is characterized by reversing the sign of the optical field at each bit transition [3]. In contrast to the correlative coding formats like duo binary, the sign reversals occur at every bit transition, and are completely independent of the information-carrying part of the signal. CSRZ (67% RZ) can easily be generated by driving an MZM pulse carrier sinusoid ally at half the data rate between its transmission maxima. Phase inversions between adjacent bits are achieved because optical field transfer function of the MZM changes its sign at the transmission minimum. Thus, on average, the optical field of half the 1-bits has positive sign, while the other half has negative sign, resulting in a zero-mean optical field envelope. As a consequence, the carrier at the optical center frequency is diminished.

V. NEW METHOD PROPOSED

The modulation formats mentioned above posses some advantages as well as disadvantages. The NRZ which is widely used has the problem of gain in the output while the RZ format will result in an additional DC content which result in signal distortion [3].

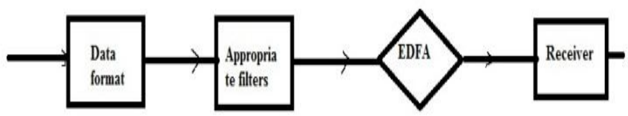

Figure 1: block structure of proposed method

This project aims in developing a hybrid of the data format which combines the advantages of data formats used previously so as to compensate for the spectral losses without affecting the system performance. The aim is to get an optimized result which will not affect the output signal power and the results can be verified by finding the eye diagram corresponding to the new modulation formats used.[3][6] .

VI. CONCLUSION

The paper gives an overview of the optical amplifiers and the working mechanism of the same. Of the many types of optical amplifiers the most widely used Erbium doped optical amplifier and its spectral characteristics are dealt in detail. The spectral problems associated with the EDFA's are mentioned and a new approach for the compensation of spectral variations that occurs in EDFA's are proposed by combining the various types of modulation formats used. The analysis of the spectral characteristics of the EDFA's are done by analyzing the eye diagrams corresponding to the modulation formats .

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