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Enhanced BER Performance in Optical OFDM System

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ABSTRACT

Multiplexing of the signals in any communication media is very important. In past various techniques are proposed and successfully implemented. In the similar context OFDM scheme is very popular. However, in the wireless system, the data propagation distance is very limited and the bit rate is low. As more data centric applications are coming up, the need of higher bandwidth demands the use of wired media. As fiber cable provides enormous bandwidth, thus it is very good candidate for the wired media. In this paper, optical OFDM scheme is presented. A complete detail analysis is presented for the designing of the system. It is discussed in the paper that the transmission of a Gaussian pulse is not a very good idea as it broadens with distance and degrades the system by increasing the BER. Finally a soliton based Optical OFDM based system is proposed which can provide very effective solution for the transmission of the very high bit rate in optical system with very less error rate.

Keywords:— *Bit Error Rate, Gaussian Pulse, Optical OFDM, Soliton pulse.*

I. INTRODUCTION

Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link. Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation technique that divides a channel into a number of equally spaced frequency bands. Subcarrier carrying user information is transmitted in each band. In this each subcarrier is orthogonal with other subcarrier, differentiating OFDM from the frequency division multiplexing.

OFDM has many advantages over other transmission techniques. One such advantage is high spectral efficiency. OFDM is a combination of both modulation and multiplexing. The "Orthogonal" part of the name refers to a precise mathematical relationship between the frequencies of the sub channels that make up the OFDM system. Each of the frequencies is an integer multiple of a fundamental frequency. This ensures that even though the sub channels overlap they do not interfere with each other. The use of IFFT and FFT for modulation and demodulation results in computationally efficient OFDM modems.[2]

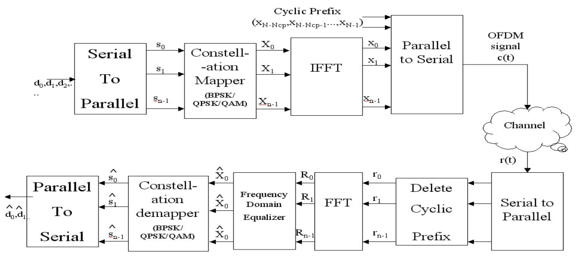

Figure 1: An OFDM communication Architecture with Cyclic Prefix [3]

Orthogonality of OFDM subcarriers is critical since it prevents inter channel interference. The data has to be first converted into parallel stream from serial stream and these parallel streams are individually converted into required digital modulation format like BPSK, QPSK, QAM etc. An OFDM system is defined by Inverse Fast fourier transform (IFFT)/ Fast fourier transform (FFT) of length N. The length of FFT/IFFT, defines the number of total subcarriers present in the OFDM system. With the addition of cyclic prefix to each OFDM symbol, mitigates the problems of Inter Symbol Interference ISI.

The cyclic prefix (CP) is a copy of the last part of the Orthogonal frequency division multiplexing symbol which is added to the beginning of the symbol (hence the term prefix in the name) as shown in figure 2 [4].

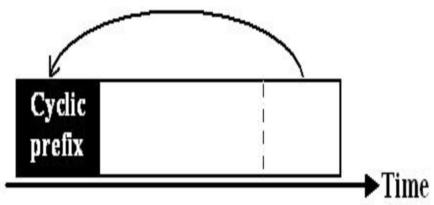

Figure 2: The Cyclic Prefix [4]

An optical fiber communication system is similar in basic concept to any type of communication system. A block schematic of a general communication system is shown in Figure 3(a), the function of which is to convey the signal from the source over the channel to the destination.

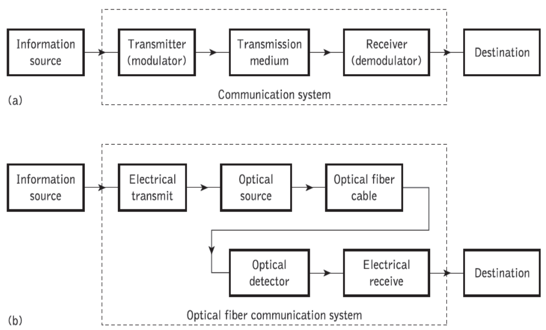

Figure 3 (a): The general communication system. (b) The optical fiber communication system [5]

For optical fiber communications the system shown in Figure 3(a) may be considered in slightly greater detail, as given in Figure 3(b). In this case the source provides an electrical signal to a transmitter comprising an electrical stage which drives an optical source to give modulation of the light wave carrier. The optical source which provides the electrical–optical conversion may be either a semiconductor laser or light emitting diode (LED). The transmission medium consists of an optical fiber cable and the receiver consists of an optical detector which drives a further electrical stage and hence provides demodulation of the optical carrier.

The laser drive circuit directly modulates the intensity of the laser with encoded digital signal and a digital optical signal is launched into the optical fiber cable. The avalanche photodiode detector is followed by an equalizer and front end amplifier to provide gain as well as noise bandwidth reduction and linear signal processing.

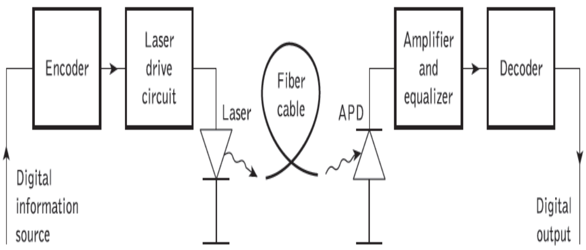

Figure 4: A digital optical fiber link using a semiconductor laser source and an avalanche photodiode (APD) detector [5]

Figure 4 shows a block schematic of a typical digital optical fiber link. In this, the input digital signal from the source is suitably encoded for optical transmission. [5]

Light Propagation in Optical Fiber:

An optical fiber consists of a cylindrical core surrounded by a cladding. Both the core and the cladding are made primarily of silica (SiO_2). The refractive index of a material is the ratio of the speed of light in a vacuum to the speed of light in that material. During the manufacturing of the fiber, certain impurities (or dopants) are introduced in the core and/or the cladding so that the refractive index is slightly higher in the core than in the cladding. Materials such as germanium and phosphorous increase the refractive index of silica and are used as dopants for the core, whereas materials such as boron and fluorine that decrease the refractive index of silica are used as dopants for the cladding. The resulting higher refractive index of the core enables light to be guided by the core, and thus propagate through the fiber. [6]

II. Methodology

In the optical OFDM, soliton pulse is used to propagate in the fiber.

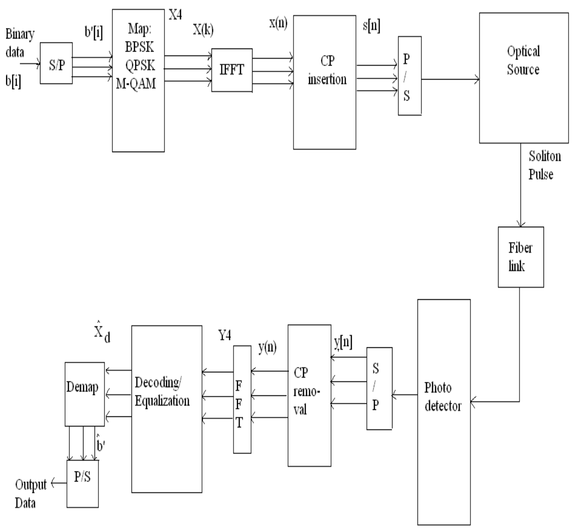

Figure 5: Optical OFDM System Block Diagram

Evolution of Soliton:

The nonlinear Schrodinger equation (NLSE) is an appropriate equation for describing the propagation of light in optical fibers. Using normalization parameters such as: the normalized time T_0, the dispersion length L_D and peak power of the pulse P_0 the nonlinear Schrodinger equation in terms of normalized coordinates can be written as,

$$i\left(\frac{\partial u}{\partial z}\right)-\frac{s}{2}\left(\frac{\partial^2 u}{\partial t^2}\right)+N^2|u|^2u+i\left(\frac{\alpha}{2}\right)u=0 \qquad \text{..........(1)}$$

where u(z, t) is pulse envelope function, z is propagation distance along the fiber, N is an integer designating the order of soliton and α is the coefficient of energy gain per unit length, with negative values it represents energy loss. Here s is −1 for negative β_2 and +1 for positive β_2

$$N^2=\frac{L_D}{L_{NL}}=\frac{\gamma P_0 T_0^2}{|\beta_2|} \qquad \text{...............(2)}$$

with nonlinear parameter γ and nonlinear length LNL.

It is obvious that SPM dominates for N > 1 while for N < 1 dispersion effects dominate. For N ≈ 1 both Self Phase Modulation (SPM) and Group Velocity Dispersion (GVD) cooperate in such a way that the SPM induced chirp to cancel the GVD induced broadening of the pulse. The optical pulse then propagates undistorted in the form of a soliton.

By integrating the NLSE, the solution for fundamental soliton (N = 1) can be written as u (z, t) = sec h(t) exp(iz/2)

where sech (t) is hyperbolic secant function. Since the phase term exp (iz/2) has no influence on the shape of the pulse, the soliton is independent of z and hence is nondispersive in time domain.

It is this property of a fundamental soliton that makes it an ideal candidate for optical communications. Optical solitons are very stable against perturbations, therefore they can be created even when the pulse shape and peak power deviates from ideal conditions (values corresponding to N = 1) [7].

III. Result

In figure 6, The BER analysis for the different number of users for a both Gaussian and

Solitons pulses is presented. As the non-linear effect at the higher power level degrades the system in case of Gaussian pulse, thus very high power is not acceptable. It is obvious from the figure due to the very high BER of the optical system the overall BER of Optical OFDM is very high and not acceptable. However, for the solitons pulse the BER of Optical OFDM well under the acceptable limits or in other words using the solitons pulse same performance of the Optical OFDM can be obtained, which was earlier possible with wireless channel for some kilometres.

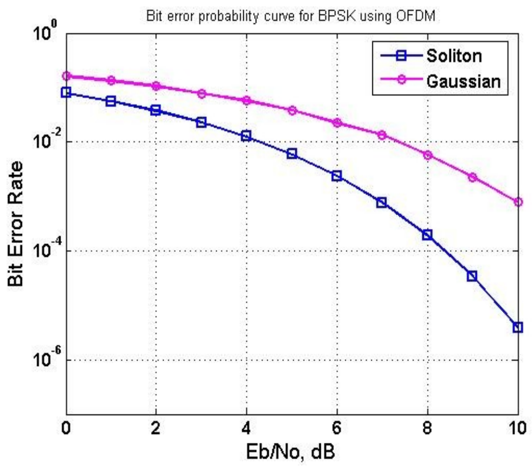

Figure 6: Bit error probability curve BPSK using OFDM for Gaussian and Soliton pulse

IV. CONCLUSION

In this paper, the design and analysis of the optical fiber based OFDM (O-OFDM) system is presented. Over, the advantages of the OFDM and optical fiber communications are added together to develop a robust long distance communication system.

The obtained results are detailed are it has been found that the Gaussian pulse is not a good option in Optical OFDM system. The results are also obtained for the solitons pulse, and it has been found that the solitons based Optical OFDM system provide very effective solution.

V. ACKNOWLEDGMENT

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