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Performance of Gaussian and Soliton pulse in Optical OFDM System

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Abstract**—***In the communication medium, multiplexing of the signals is very important. Multiplexing is the method that allows the simultaneous transmission of multiple signals across a single data link. 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. 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. Finally a Soliton based Optical OFDM system is proposed which can provide very effective solution for the transmission in optical system.*

Keywords:— *Optical OFDM, Gaussian pulse, Soliton Pulse, Cyclic Prefix*

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a combination of both modulation and multiplexing. It is a multicarrier modulation technique, which employs many carriers, within the allocated bandwidth, in order to convey the information from source to the destination. Each carrier may employ one of the digital modulation techniques like BPSK, QPSK, QAM etc.

OFDM has emerged as leading technology for high data rates due to its robustness and flexibility in resource allocation. OFDM transforms a high data rate signals into a group of parallel low data rate signals which are transmitted over subcarriers. OFDM offers robustness against channel dispersion and ease of phase and channel estimation. [1]

OFDM divides a channel into a number of frequency bands. A subcarrier carrying a portion of the user information is transmitted in each band of OFDM. Each subcarrier is orthogonal with other subcarrier, differentiating OFDM from the frequency division multiplexing (FDM). The use of an FFT/IFFT pair for modulation and demodulation make it computationally efficient. The block diagram of OFDM is shown in Figure 1.OFDM has many advantages over other transmission techniques. The "Orthogonal" part of the name refers to a 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, so these results in high spectral efficiency. [2]

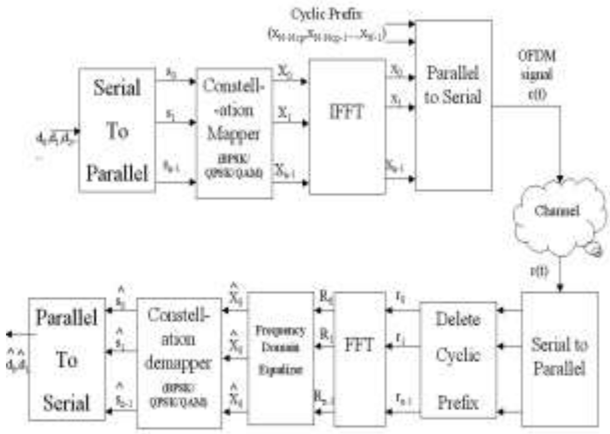

Figure 1 An OFDM communication Architecture with Cyclic Prefix [3]

The cyclic prefix (CP) is a copy of last part of the OFDM symbol which is added to the beginning of the symbol (hence the term prefix in the name) as shown in following figure [4]

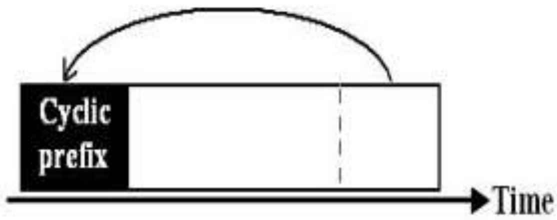

Figure.2.The Cyclic Prefix [4]

2. OPTICAL COMMUNICATION

An optical fiber communication system is similar to any other 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. The communication system consists transmitter or modulator linked to the source, the channel, and a receiver at the destination point. The transmission medium can consist of a coaxial cable or a free space which the signal is transmitted to the receiver. In transmission medium the signal is attenuated, or suffers loss, and is subject to degradations due to contamination by any random signals, noise and possible distortions imposed by mechanisms within the medium. In communication system there is maximum permitted distance between transmitter and receiver beyond which the system effectively ceases to give intelligible communication. For long distance applications these factors necessitate the installation of line amplifiers at intervals, both to remove signal distortion and to increase the signal level before transmission is continued down the link.

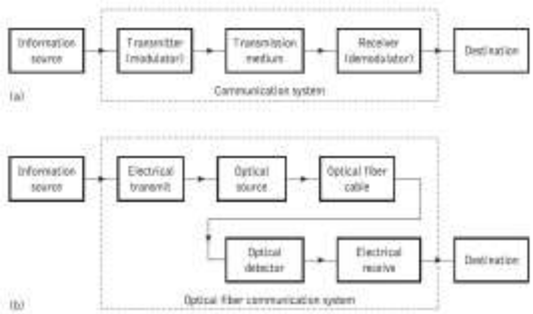

Figure.3. (a) The general communication system. (b) The optical fiber communication system [5]

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 information 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. Photodiodes (p–n, p–i–n or avalanche) and, in some instances, phototransistors and photoconductors are utilized for the detection of the optical signal and the optical–electrical conversion. Thus there is a requirement for electrical interfacing at either end of the optical link and at present the signal processing is usually performed electrically.

The optical carrier may be modulated using either an analog or digital information signal. In the system shown in Figure 3(b) analog modulation involves the variation of the light emitted from the optical source in a continuous manner. With digital modulation, however, discrete changes in the light intensity are obtained (i.e. on–off pulses). Although often simpler to implement, analog modulation with an optical fiber communication system is less efficient, requiring a far higher signal-to-noise ratio at the receiver than digital modulation. Also, the linearity needed for analog modulation is not always provided by semiconductor optical sources, especially at high modulation frequencies. For these reasons, analog optical fiber communication links are generally limited to shorter distances and lower bandwidth operation than digital links Figure 4 shows a block schematic of a typical digital optical fiber link. The input digital signal from the information source is suitably encoded for optical transmission.

The laser drive circuit directly modulates the intensity of the laser with the encoded digital signal. An optical signal is launched into the optical fiber cable. The avalanche photodiode detector is followed by a equalizer and front-end amplifier or filter to provide gain as well as linear signal processing and noise bandwidth reduction. The signal obtained is decoded to give original digital information. [5].

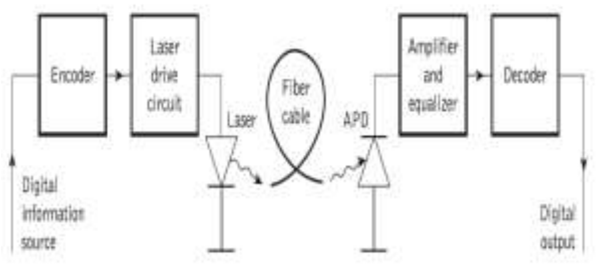

Figure.4. A digital optical fiber link using a semiconductor laser source and an avalanche photodiode (APD) detector [5]

3. 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), which has a refractive index of approximately 1.45. The refractive index of a material is 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]

4. RESULT

The simulation for the evolution of the Gaussian pulse is done in MATLAB, using fast Fourier Transform (fft) technique, the initial pulse width is 20 ps. Here the results are plotted over a large set of distances.

The obtained results for the distance varying from 100KM to 500 KM are shown in the figures below. In figure 5, the FWHM is obtained at a distance of 100 K.M. and it is evident from the figure Gaussian pulse shape is intact but the FWHM has increased from 20 ps to 26 ps and the peak power is reduced to 0.8 mW. In figure 6, the evolution of the pulse at a distance of 200 KM. is shown. Here as distance has increased the FWHM has increased to 39 ps and power level goes down to 0.5. This is the critical value in optical communication as the decision threshold is set as

$$P_{Th} = \frac{P(1)+P(0)}{2}$$

It is further noticeable that in optical system OOK (On-Off keying) is employed. Therefore for a bit '1' a fixed power pulse is launched and for bit '0' no pulse is launched. As we have taken

$P(1)=1$ (mW)

The threshold level will lie at 0.5.

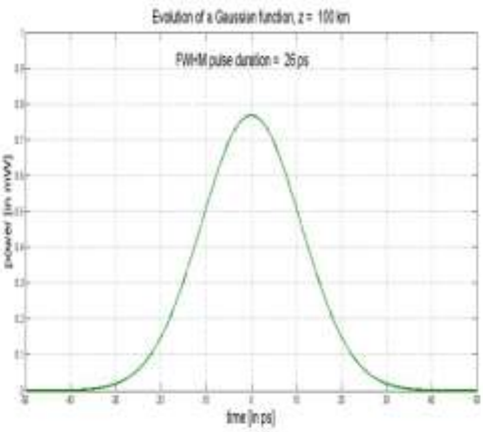

Figure.5. The evolution of the Gaussian pulse for a distance of 100 KM.

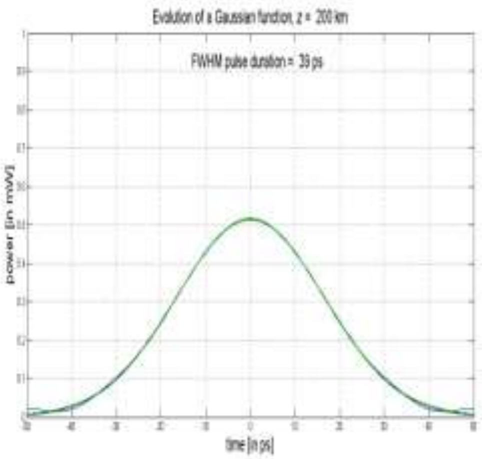

Figure.6. The evolution of the Gaussian pulse for a distance of 200 KM.

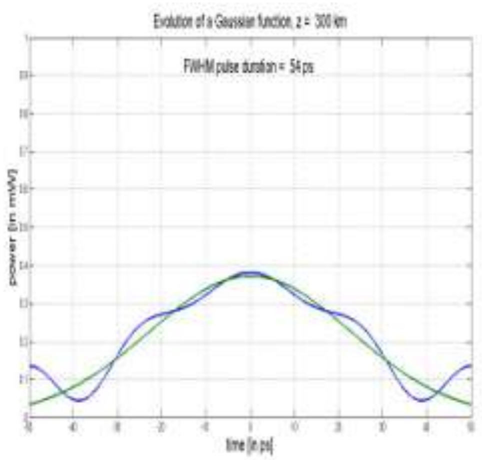

Figure.7. The evolution of the Gaussian pulse for a distance of 300 KM.

In figure 7, the evolution of the Gaussian pulse over a distance of 300 K.M. Here the pulse width has gone up to 54 ps and the pulse peak power goes down to value of 0.4 The other important point is that the pulse shape has now become distorted. In figure 8, the evolution of the Gaussian pulse over a distance of 500 K.M. Here the pulse width has gone up to 86 ps and the pulse peak power goes down to value of 0.3. The other important point is that the pulse shape has now become more distorted and pulse looses its Gaussian shape.

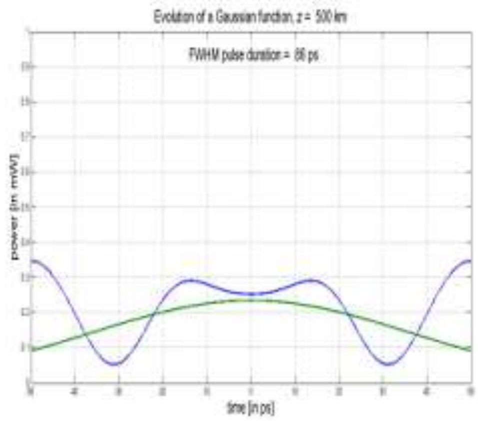

Figure.8. The evolution of the Gaussian pulse for a distance of 500 KM.

4.1 Soliton Pulse Propagation

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,

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

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 (anomalous GVD– Bright Soliton) and +1 for positive β_2 (normal GVD-Dark Soliton)

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

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 SPM and GVD cooperate in such a way that the SPM induced chirp to cancel the GVD induced broadening of the pulse. The optical pulse then propagate 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) …………..(3)

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 non-dispersive 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].

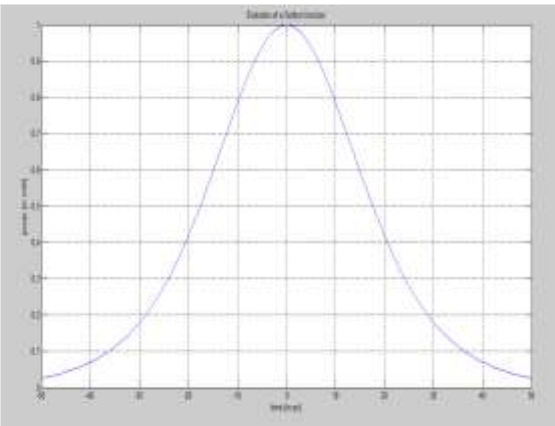

Figure.9. The evolution of the Soliton pulse

5. CONCLUSION

In this paper, the design and analysis of the optical fiber based OFDM (O-OFDM) system is presented. It is also observable from the above figure that after travelling a distance of 300 K. M., the Gaussian pulse looses its shape and becomes distorts and such a pulse can't be easily detected by the receiver. The Gaussian pulses are not very effective in Optical OFDM system. Using the Solitons pulse where self phase modulation is balanced with dispersion a long distance communication is possible.

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