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Comparative Efficacy Estimation of OIDMA System using Gaussian and Soliton Pulses for Long Haul Communication

[1]Ravi Prakash, [2]Ajay Kumar Maurya, [3]PoonamSonkar and [4]B. B. Tiwari
[1,2,3,4]*Department of Electronics Engineering* Uma Nath Singh Institute of Engineering and Technology
Veer Bahadur Singh Purvanchal University Jaumpur

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Abstract:
This article contains the comparative analysis of optical Soliton pulses verses Gaussian pulses, used in convolutionally coded OIDMA system. Earlier a lot of work has been done on OIDMA system using LASER source at input with Gaussian pulses and the output detection is done by APD. An optical Soliton pulse which is intense and narrow in shape has the property to propagate larger distance in non linear optical medium without changing its shape and velocity. Such optical Soliton pulse property is utilized in OIDMA system and BER of system is analyzed. The complete OIDMA system is programmed on MATLAB and at the electrical to optical conversion section the LASER diode with 1mW input power and Gaussian shape pulses, and optical Soliton pulses are connected separately for comparative analysis purpose.

Keywords:*Code Rate, Constraint Length, Gaussian Pulse, OIDMA, Soliton Pulse.*

I. INTRODUCTION

The demanding aspects of modern generation are larger data rate, full accuracy and security with less input power [1-2]. The technologies which fulfill all these demands are used in 4G and 5G upcoming networks [3-4]. The proper utilization of bandwidth of optical Fiber isessential for enhancing the capacity of the system and suitable multiple access technology for serving such larger bandwidth is to be decided [5]. A latest technology which will suits with all these parameters on optical communication is OIDMA technology which is purely based on interleaving mechanism [6-7]. Interleaving is just like scrambling of bits to enhance the security as well as error correction capability.MIT 6.02 DRAFT Lecture Notes Chapter 8 deals a lecture notes which is based on convolutional codes [8-9]. This note deals all aspects of convolutional codes like its significance, designing procedure, basic operating principle, trellis diagram decoding process, code tree decoding process, viterbi decoding process etc. A table is also given in this paper which comprises of maximum free distance with various constraints length and code rates [10-11]. The corresponding sgenerators in octal form are also given which is used for convolutional encoder design.Ahmed Al Amin et. al compared the performance for Soliton pulse and Gaussian pulse in long distance optical communication [12-13]. The obtained results shows supremacy of Solition pulses as compared to Gaussian pulses in terms of BER as well as number of optical amplifiers used in transmission.Vijendrakumar et. al, low density parity check codes are used for error correction in optical transmission [14-15]. The code word generated are converted into optical Gaussian pulse with ASK modulation. Some nonlinearity features of optical transmission are also taken into account and results of FWHM and BER are calculated for different fiber lengths.After having detailed survey, it is found that the performance of OIDMA system is analyzed by various authors by using Gaussian pulse but the performance of OIDMA system is not checked by using Soliton pulses. So here we have checked the comparative performance of OIDMA system by

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using Solitonand Gaussian, both pulses connected in OIDMA system with convolutional encoder.The remaining paper is organized as one by one in following sections. Section 2 defines OIDMA system. Section 3 gives the ideas about Gaussian and Soliton Pulse. Section 4 defines the mechanism of random interleaving. Section 5 describes convolutional encoding. Section 6 shows and describes the simulation result and their discussion. Further, the paper ends by giving conclusion and necessary references.

II. OIDMA SYSTEM

The block diagram of OIDMA system consisting transmitter (Top) and receiver (Bottom) are shown in Fig. 1 [2, 16]. There are q different users depicted as b1, b2……….bq. The input data stream of every user is first coded using low rate (1/3) convolutional code. The encoded stream are spreaded (1/16) using spreading sequences for all users. Spreading improves the security and reduces the interference rejection capability of the system. Subsequently, the data of each user (spreaded – coded) signals is interleaved (π1, π2……. Πq) using specific random interleaver [17-18]. The interleavers work to scatters the power of the given signal surrounded by block of the frame. The q number of users is interleaved with different interleaving pattern by using q specific random interleaver. Here, we have taken interleaver block length is 512 bits which provides minimum processing delay, enhanced error correction and detection capability, and better efficiency [19-20]. After interleaving, the resultant signal are converted from LASER (electrical to optical) source and passes through channel. Here, optical source wavelength is 1550nm (zero dispersion) taken.In the receiver side, firstly signal is converted into optical to electrical by APD detector [17-18]. The noisy (interference) signal goes to APP decoders and ESE for user detection. The ESE is already stored various sets of predictable noise patterns, and their cross correlation and auto-correlation signals are presented in memory and its impact on incoming signal are checked chip by using LLR (long likelihood ratio) calculation with feedback mechanism at various de-interleaving sections the correct user is identified [21-22].

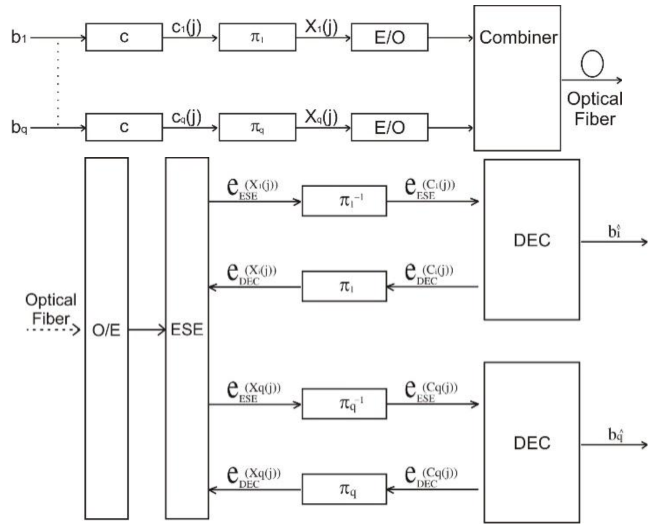

Fig. 1 Block Diagram of OIDMA System

III. SOLITON AND GAUSSIAN PULSE

SOLITION PULSE

Dispersion is a problem which is evident for both high bit rate and as well as for long distance communication system [12-14]. In order to solve this problem we use optical Solitons because it is the system where for very long distances pulses can preserve their shapes. Soliton can also be termed as a solitary travelling wave shown in Fig. 2 which is represented by a nonlinear partial differential equation. Soliton Path has following characteristics.In order to describe long-wave propagation on shallow water they derived the following nonlinear partial differential equation:

$$\frac{\delta v}{\delta t} + v\frac{\delta v}{\delta t} + \frac{\delta^3 v}{\delta x^3} = 0 \qquad (1)$$

This equation is termed as Korteweg-de Vries Equation (KdV Equation). This equation can also be written in the following form:

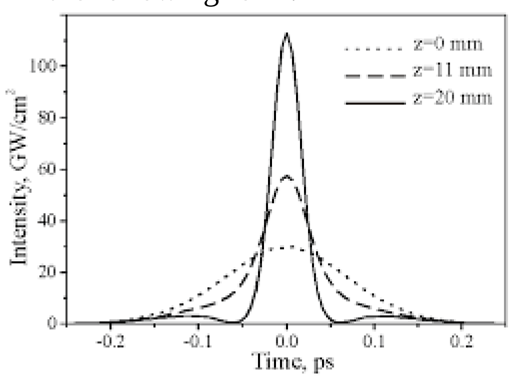

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Fig. 2 PDF of Soliton Pulse

$$\frac{\delta v}{\delta t} = 6v\frac{\delta v}{\delta x} - \frac{\delta^3 v}{\delta x^3} \quad (2)$$

This equation can be termed as a nonlinear one because of $\frac{\delta v}{\delta x}$ term. (Because 2 times then this term will increase term.As a travelling wave a solitary wave has a unique form of v(x, t) = f(x − ct) for some smooth function f. f function decays rapidly at infinity. Solitary wave solutions can be easilt admitted but nonlinear wave equations. However instance,

$$v_{tt} - v_{xx} = v(2v^2 - 1) \quad (3)$$

has solutions that is family of solitary waves

$$v(x,t) = \mathrm{sech}(x cosh\theta + t\, sinh\theta) \quad (4)$$

parameterized by $\theta \varepsilon R$ [12, 13]

For compromising Group Velocity Dispersion (GVD) and Self- Phase Modulation (SPM) the existence of solitons in optical fiber is found. For mathematical descriptions, Nonlinear Schrödinger (NLS) equations are employed by solitons, in presence of GVD and SPM they are satisfied by the pulse envelope.

The equation is expressed by

$$\frac{\delta A}{\delta z} + \frac{i\beta_z}{z}\frac{\delta^2 A}{\delta t^2} - \frac{\beta_3}{6}\frac{\delta^3 A}{\delta t^3} = i\,\Upsilon\,|A|^2 A - \frac{\alpha}{2}A \quad (5)$$

Here α indicates fiber attenuation tells about seconds and third degree dispersion.In order to discuss soliton solutions let α = 0 and $\beta_3 = 0$. In order to write the solution in normalized form we introduce.

$$\tau = \frac{t}{T_0}, \quad \varepsilon = \frac{z}{L_D}, V = \frac{A}{\sqrt{P_0}}$$

Here $T_0 = Measurment\ of\ pulse\ width$

$$P_0 = Peak\ power\ of\ the\ pulse$$

$$L_D = \frac{T_D^2}{|\beta_2|}\ is\ the\ dispersion\ of\ the\ length$$

So equation 5 becomes

$$i\frac{\delta V}{\delta \varepsilon} - \frac{S}{2}\frac{\delta^2 V}{\delta t^2} + N^2|V|^2 V = 0 \quad (6)$$

Where $= sgn(\beta_2) = +1\ or - 1$, it depends on whether β_2 is positive (for normal GVD) or negative (for anomaous GVD). The parameter N can be defined by following equation

$$N^2 = \Upsilon\, P_0 T_0^2/|\beta_2|$$

(7)

A dimensionless combination of the of pulse and fiber parameters are represented by this.

GAUSSIAN PULSE

In mathematics and physics Gaussian path is used quite regularly [12-14, 17]. The exceptional characteristics that it possess is that it can be exactly integrable over [-∞, ∞] which is shown in Fig. 3 but it cannot be evaluated in closed form over finite limits.

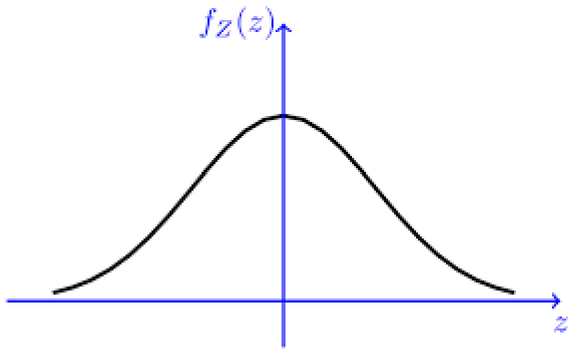

Fig. 3 PDF of Gaussian Pulse

A typical Gaussian path can be described by the following equation

$$y = \exp\left(-\frac{1}{2}ax^2\right) \quad (8)$$

Where a can be termed as constant. Another equation which can be termed as simplest Gaussian integral is

$$I = \int_{-\infty}^{\infty} \exp(-x^2)\, dx \quad (9)$$

Gaussian PDF is represented sometime as

$$p[n_0 T] = \frac{1}{\sigma\sqrt{2\pi}} exp\left\{\frac{-n_{0\ (T)}^2}{2\sigma^2}\right\} (10)$$

Where, n_0(T)istermedasgaussiannoise

and σ is denotes from mean valueThis property of Gaussian pdf is used for calculating probability of bit error for data transmission.Application of Gaussian Pulse

Applications of the Gaussian Pulse are:

[1] In motion planning Probability Roadmap Planners (PRMs) has got very bright potentials. Gaussian sampling strategy has been used for Probability Road Planners which has given a much better coverage of the difficult parts of the free configuration space [12-14].

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[2] For measuring brain diffusivity and its mapping on global scale DTJ (diffusion tensor imaging) is used.

[3] In all semi classical calculations of fluctuating systems Gaussian path integral evaluation is mainly needed. Especially when we face a ratio of functional a ratio of functional determinants of second-order differential operators Gaussian path integral is needed.

[4] Gaussian path integral has different boundary conditions in quantum mechanical fluctuation problems.

LONG HAUL COMMUNICATION

The optical communication channel can be divided into few classes depending upon type of channel, type of source and quality of detector [12-14, 16].Short haul: This type of communication channel is used for very small range of kilometers.Long haul: This is the optical communications which transmits visible light signals over optical fiber cable for the range of few hundreds of kilometers. This type of channel tries to establish communication without or with minimum use of communications.Ultra-long haul: The length of channel is around thousand kilometers (Approximately 3000 km) for this kind of communication channel. “SEA-ME-WE 4 (South East Asia-Middle East-West Europe for submarine optical fiber communication which is expanded in ocean approximately 20,000 km which is backbone of communication between East/Asia with Europe.

IV. RANDOMINTERLEAVER

Random interleavers is the mechanism of interleaving the bits by un-deterministic, un-periodic manner [5-6]. Input bits are arranged in a non-periodic random manner and at the output same arrangement of de-interleaving is maintained [7, 23-24]. It is easy to generate but requires larger memory hardware components required for manufacturing random interleavers are larger in quantity. An simple example which express the ethos of random interleaving process is shown in Fig. 4 below.

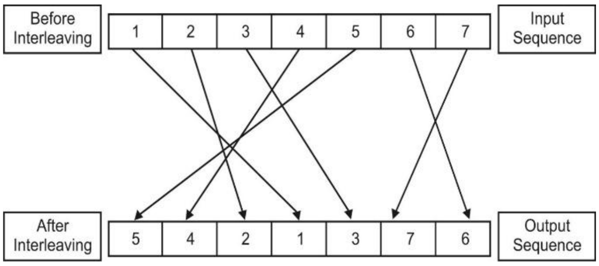

Fig. 4 Process Un-deterministic Interleaving

V. CONVOLUTIONAL CODING

Convolutional coding is the important coding technique applied for reducing errors in communication networks [8-9]. Typically, convolutional encoder is consisting of a combination of logic gates and flip-flop, D- flip-flops as its unusual shifting commonly used in encoder hardware design [10-11]. The number of shift register is decided the constraint length in convolutional encoder. Generally, constraint length is decided by memory elements and code rate is generated by the number of logic gates (Ex-OR, Ex-NOR etc.). Ex-OR gates are used to create uncorrelated code-words in design of the encoder. Convolutional encoders are nominated as [P Q R], where Q stands for number of input bits, P stands for number of output bits, and R denoted number of memory elements succeed to by encoder. The ratio of Q and P is known as code rate [Q/P]. As the number of Ex-OR gates are increases that means the outputs bits P increases makes the code rate as ½, 1/3 & ¼ etc. with fixed number of input bits Q = 1.From the Table 1 mentioned below gives an outline that how convolutional encoder is designed and how the feedback connections of various memory elements and Ex-OR gates are considered. Generators trellis which are written in octal form are converted into binary as connections are taking into account accordingly considering 1 as connection (shot) and 0 as no connection (open) [25]. By this way architecture of Fig. 5 and Fig. 6 are implemented. In designing technology of convolutional encoder flip flops design the constraint lengths of encoder. In present work initially we have taken two memory elements with constraint length (L = 5 and L = 7) and fixing the (3) Ex-OR gates.

Table 1: Maximum Free Distance Codes [Code Rate 1/3], Source – Odenwalder (1970) and Larsen (1973)

Constraint Length	Generators in Octal	d_{free}	Upper Bound of d_{free}
5	25 33 37	12	12
7	133 145 175	15	15

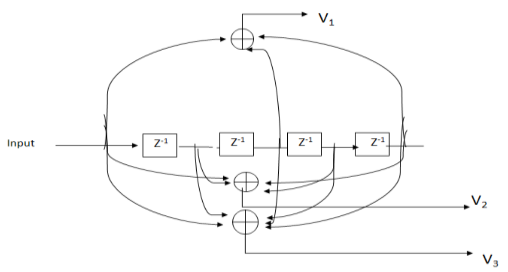

Fig. 5 Convolutional Encoder [1, 3], 3 – Ex-OR Gates Network Topology [5(25, 33, 37)]

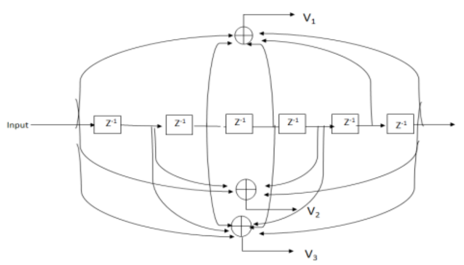

Fig. 6 Convolutional Encoder [1, 3], 3 – Ex-OR Gates Network Topology [7(133, 145, 175)]

VI. SIMULATION RESULT AND DISCUSSION

Here, the bit error rate performance (BER) of the Soliton pulse and Gaussian pulse for convolutional OIDMA system has been implemented on MATLAB software. The input parameter is taken as the input block length is 100, spread length is fixed as 16, E_b/N_O is 3, data length is 512 has been fixed. In the optical parameter the input power is 1Mw, optical source wavelength is 1553nm, input pulse is Gaussian and Soliton pulse, fiber cross section 8×10^{-11} is fixed and fiber loss is 0.15 dB. Optical detector having characteristics such as efficiency 0.85, gain 1000 type APD has been used in receiver section. The bit error rate is calculated by Soliton and Gaussian pulse, varying number of element (L = 5 and L = 7) and fixing the Ex-OR gates by using random interleaver. The observed result for BER verses number of users for constraint length (L = 5 and L =7) and code rate (1/3) using Soliton and Gaussian pulse has been arranged in graphical and tabular form for random interleavers. From Table 2 and Fig. 7 which is described for random interleavers code rate (1, 3) and constraint length L = 5, for using Gaussian pulse, when the number of users 120, BER is 1.9531×10^{-9} and when using Soliton pulse for same number of users (120) as indicated in, , BER is 3.4321×10^{-10}. From the two reading it clearly indicates that BER for soliton pulses is 10 times improves as compared to Gaussian pulse. Same trend is obtained (Table 3 and Fig. 8) for code rate (1, 3) but constraint length L = 7 taking other parameters are same as in previous case. Here again the readings of BER for users 120 (Gaussian) is 1.6276×10^{-9} is longer as compared to Soliton which is 0.2431×10^{-10}. The best reading obtained for code rate (1, 3) L = 7, number of users 120 which is 0.2431×10^{-10}. When it is compared with BER reading of code rate (1, 3) L = 5, number of users (120), which is 3.4321×10^{-10}. From above discussion it clearly shows that the Soliton pulse provides the better performance comparison to Gaussian pulse to constraint length (L = 5 and L =7) for fixed code rate (1, 3). These results emphasis that increasing the constraint length increases the performance of OIDMA system.

Table 2: Comparative Performance of Soliton and Gaussian Pulse in OIDMA System for Constraint Length (L) = 5.

Fix Code Rate = 1/3, Spread Length = 16, Data Length = 512, Block Length = 100			
S. No.	Number of Users	Bit Error Rate (Constraint Length L = 5)	
		Gaussian Pulse	Soliton Pulse
1	100	No Error	No Error
2	120	1.9531×10^{-9}	3.4321×10^{-10}

3	140	4.8828×10^{-9}	1.2465×10^{-9}
4	160	6.9754×10^{-9}	3.4125×10^{-9}
5	180	1.7361×10^{-8}	0.4456×10^{-8}
6	200	3.9063×10^{-8}	1.2456×10^{-8}
7	220	4.8838×10^{-8}	2.3924×10^{-8}
8	240	6.2165×10^{-8}	3.2465×10^{-8}

Table 3: Comparative Performance of Soliton and Gaussian Pulse in OIDMA System for Constraint Length (L) = 7.

Fix Code Rate = 1/3, Spread Length = 16, Data Length = 512, Block Length = 100			
S. No.	Number of Users	Bit Error Rate (Constraint Length L = 7)	
		Gaussian Pulse	Soliton Pulse
1	100	No Error	No Error
2	120	1.6276×10^{-9}	0.2431×10^{-10}
3	140	5.5804×10^{-9}	1.3424×10^{-9}
4	160	1.2207×10^{-8}	5.2462×10^{-9}
5	180	1.6276×10^{-8}	9.3460×10^{-9}
6	200	3.1250×10^{-8}	1.5345×10^{-8}
7	220	4.7940×10^{-8}	2.3124×10^{-8}
8	240	5.8735×10^{-8}	4.3420×10^{-8}

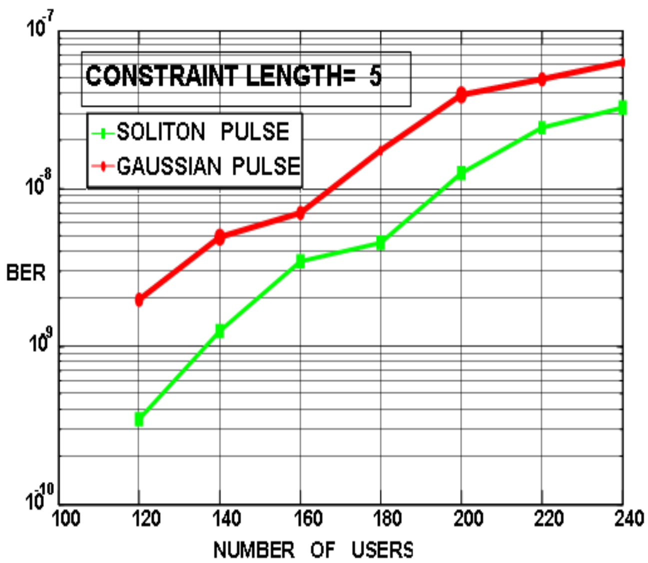

Fig. 7 Comparative Performance of Soliton and Gaussian Pulse in OIDMA System for Constraint Length (L) = 5

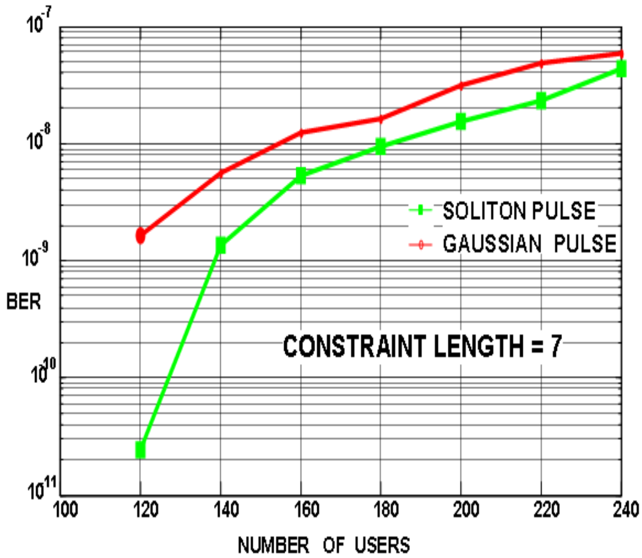

Fig. 8 Comparative Performance of Soliton and Gaussian Pulse in OIDMA System for Constraint Length (L) = 7

CONCLUSION

From the obtained results it may be concluded that Soliton pulse gives better result as compared to Gaussian pulse. Since Soliton pulses are intense and sharp shape having larger energy and low dispersion travels long distance compared to Gaussian shape pulse. Due to this reason the observed BER for Soliton pulses is much smaller as shown in two tables. By using properties of Soliton pulses in OIDMA system improves the response of IDMA system and makes it better alternative for cope up the larger traffic intensity of various users.

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