

Propagation of Fundamental Soliton and Higher order Soliton in O-IDMA Channel

Vimal Prakash Gautam¹, S.K. Sriwas²

P.G. Student, Department of Electronics and Communication Engineering, B.I.E.T Jhansi, U.P, India¹

Assistant Professor, Department of Electronics and Communication Engineering, B.I.E.T Jhansi, U.P, India²

ABSTRACT: The objective of this paper to study the analytical propagation of fundamental Soliton and higher order Soliton pulse propagation in O-IDMA (Optical-interleave Division Multiple Access) channel. The formation of Soliton occurs due to balance between Group Velocity Dispersion (GVD) and Self Phase Modulation. It is analysed the single Soliton and higher Soliton propagation with optical parameter in Optical-interleave Division Multiple Access channel. Matlab is used for simulation. Simulated matlab output result shows the of Soliton propagation in O-IDMA channel with various parameter.

KEYWORDS: GVD, SMP, Soliton pluse, O-IDMA

I. INTRODUCTION

In the present world of wired communication, the optical fiber is generally used for attaining high spectral efficiency. These days, CDMA scheme is generally used in optical fiber based communication system. With the help of CDMA scheme, it can use proper bandwidth.

The CDMA scheme has been the popular for achieving better bandwidth efficiency than Frequency-Division Multiple-Access (FDMA) and Time-Division Multiple-Access (TDMA) schemes. The performance of Optical-CDMA (O-CDMA) scheme also has some drawbacks i.e. multiple access interference (MAI) and inter-symbol interference (ISI). CDMA solution can be explained by another mechanism known as Interleave-Division Multiple-Access (IDMA). In IDMA we used different type of interleavers for user separation as per requirement.

The optical communication has advantage of the higher spectral efficiency but this performance is be limited by the non linear effect when we used Gaussian pulse for communication. The Group Velocity Dispersion (GVD) is another phenomenon which gives effect on the communication when it is used Gaussian pulse for communication. The GVD causes the pulse broadening in the transmitted pulse. It is used a Soliton pulse which gives the advantage using GVD and SMP over Gaussian pulse. Self Phase Modulation (SMP) deducing by the Kerr nonlinearity.

Basically, a Soliton is very narrow pulse. It has high peak power. In O-IDMA channel which is fiber, Soliton pulse is formed by the counter cancellation of the dispersion effect by the self-phase modulation. The Solitons can maintain its shape and velocity during transmitting in O-IDMA channel because it is very stable. In this paper, Solitons put in place of Gaussian pulse in the O-IDMA channel communication. Gaussian pulse transmission is not a very good idea because its broaden with distance and with increasing the bit error rate (BER) the system becomes derogate.

II. MATHEMATICAL MODELING AND PROPAGATION OF THE SOLITARY WAVE IN OPTICAL INTERLEAVE MULTIPLE ACCESS CHANNEL

Soliton wave equation is described by Nonlinear Schrodinger Equation (NLSE) in term of the partial differential equation of hyperbolic equation as given by [1]

$$i \frac{\partial A}{\partial Z} = \frac{\beta_2}{2} \frac{\partial^2 A}{\partial T^2} - \gamma |A|^2 A \quad (1)$$

International Journal of Innovative Research in Science, Engineering and Technology

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By using parameter $\eta = \frac{A}{\sqrt{p_0}}$, $\xi = \frac{z}{L}$, and $\tau = \frac{T}{T_0}$ that will formalize equation (1) to be

$$i \frac{\partial u}{\partial \xi} \frac{1}{L_D} = \frac{\beta_2}{2T_0^2} \frac{\partial^2 u}{\partial \tau^2} - \gamma |u|^2 u p_0 \quad (2)$$

By describing the dispersion length, $L_D = \frac{\tau_0^2}{|\beta_2|}$ and nonlinear length $L_{NL} = \frac{1}{\gamma p_0}$ and putting L_D and L_{NL} into equation (2), it will yield,

$$i \frac{\partial u}{\partial \xi} = \frac{\beta_2}{2} \frac{\partial^2 u}{\partial \tau^2} - N^2 |u|^2 u \quad (3)$$

Where N is the order of the Soliton, So

$$N^2 = \frac{\gamma p_0 \tau_0^2}{|\beta_2|} \quad (4)$$

By solution of profile $(\xi, \tau) = \text{sech}(\tau) e^{\frac{tC\tau^2}{2}}$, where C is the chirp parameter.

This parameter induced by SPM and GVD. Both SPM and GVD balanced each other for maintaining the shape of Soliton pulse in fiber propagate and order of the Soliton determined by $N^2 = \frac{L_D}{L_{NL}}$ [1], this equation explained that the order of Soliton N is proportional the square root of dispersion length and inversely with the nonlinear length. If the Soliton order is increases then the dispersion length of the fiber is also increases when nonlinear length remain constant. The very big change of the dispersion length will caused pulse broaden and pulse will lose its power and it can be described by $P=|A|^2$. By using the Split-step method we can do numerical calculation of Soliton pulse.

III. NONLINEAR EFFECTS ON SOLITON IN O-IDMA CHANNEL

In optical fiber based communication network system, the non-linear distortion is important parameter in the dispersion mechanism for a long distance communication. It causes the optical signal pulse boarding as they move along a fiber. If these pulses propagate for a long distance then they get overlapped with the neighbouring pulses. This causes errors in the receiver output. signal distortion limiting the information carrying capacity of a fiber. In optical network distances are measured in the range of 100 km to 5000 km for better performance of the O-IDMA system. It is essential that optical channel should not gives any reduction in the transmitted signal.

The signal propagates through the optical fiber, the signal peak powers reduce and the pulse goes disperse. For Gaussian pulse, these losses compensated by the Erbium Doped Fiber Amplifiers (EDFA) but for the Soliton pulse the Raman Amplifiers used. These amplifiers are capable of amplifying the loss of the signal power of the propagating signals. Erbium Doped Fiber Amplifiers are responsible for the Amplified Spontaneous Noise (ASN) which increases the overall BER.

For the better performance of the O-IDMA system Solitons are used in place of Gaussian pulse. It is because Soliton does not disperse due to non-linear effects.

In the optical fiber communication, the signal pulse is affected by the Group Velocity Dispersion (GVD) and the Kerr Non-linearity. If the pulse propagates in a medium, the optical Kerr effect produces a refractive index change with intensity [1]

$$n(I) = n_0 + n_2 I \quad (5)$$

Where n_0 is the linear refractive index and n_2 is the second order non-linear refractive index of the medium.

It generates the phase fluctuations in the propagation wave, this introduce the chirping effect shown in the figure (1) At the time of occurrence of the frequency chirping, the advancing edge of pulse gives a red shift in the direction of higher frequencies, while the falling edge of the pulse gives a blue shift in the direction of lower frequencies. So it

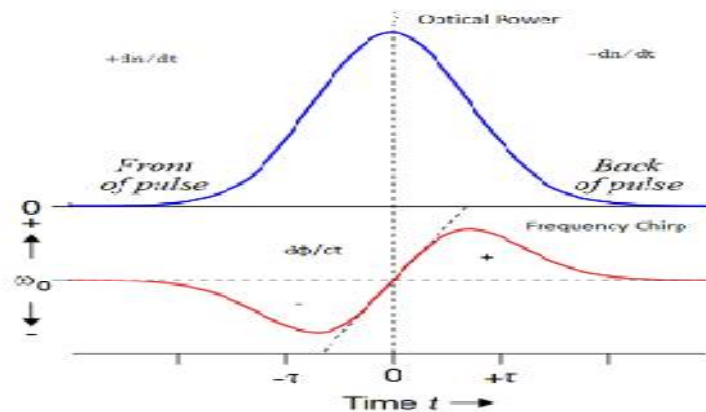
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observed that the degree of chirping which is C, it depends on the transmitted power. Effects of the SPM assert for higher intensity pulse more [1].



Figure(1) Spectral boarding of the pulse due to self-phase modulation

When the high intensity pulse propagate in a medium with a positive Group Velocity Dispersion parameter for the primary frequencies, the advancing part of the pulse is moves towards the lower frequency band. It observed that only in particular region, the data transmission speed increases and for the lagging half, only in particular region, the speed of data transmission decreases which causes an additional delay in the lagging edge. Hence, the energy of the pulse goes dispersed when it moves either side from the centre of the pulse and the pulse undergoes to the shape of a rectangular wave. [2]

During the transmission of the higher narrow Soliton pulse, GVD produces the negative chirp in anomalous region and SPM produces always the positive chirp. So it observed that GVD effect is balanced by the SPM effect for Soliton pulse. In other words because of Group Velocity Dispersion the lower frequencies of the pulse slow down at the front end and at the back end the higher frequencies advancing because of this the shape of the Soliton pulse does not change.

Considering a standardized optical fiber, then around 1320 nm wavelength, there is no dispersion. The chirp of the GVD is positive below 1320 nm and the chirp of the GVD is negative above 1320 nm. So the suitable region for the transmission of the Soliton is above region because the chirp of the GVD is negative.

The Nonlinear Schrodinger (NLS) equation for Soliton transmission is shown as[1]

$$-i \frac{\partial u}{\partial z} = \frac{1}{2} \frac{\partial^2 u}{\partial t^2} + N^2 |u|^2 u - i \left(\frac{\alpha}{2} \right) u \quad (6)$$

Where $u(z,t)$ is the pulse envelope, N order of the Solitons, z is the fiber length and α is loss of the energy in optical fiber.

IV. RESULT AND DISCUSSION

The transmission of the signal in the form of the Gaussian pulse and Soliton pulse for shown in figure (2) and figure(3) Dashed pulse is input of the pulse. With the help of the figure it observed that at $Z= 4\text{km}$ the Gaussian pulse dispersed but Soliton has its original shape and power.

To investigate propagation of Soliton in optical IDMA channel, it numerically solved the Nonlinear Schrodinger Equation using Spilt-Step Fourier method. Let the initial envelop $\xi=0$ the equation become

$$U(0,\tau) = \text{sech}(\tau) \text{ for } N=1,2 \text{ and } 3 \text{ order} \quad (7)$$

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Vol. 6, Issue 5, May 2017

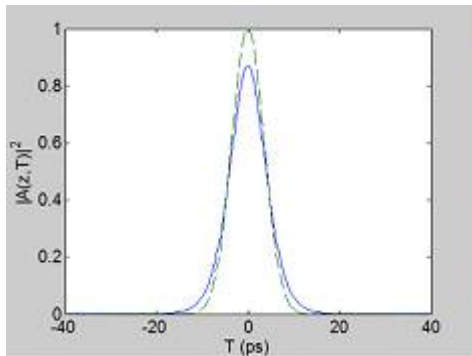
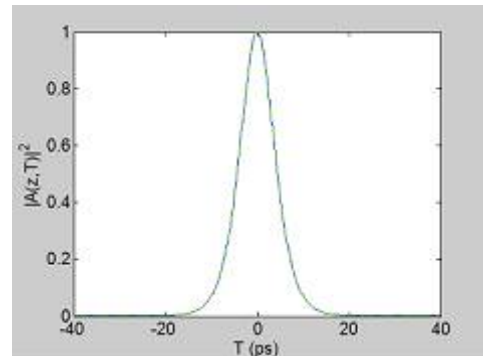


Figure (2) Nonlinearity effect on Gaussian Pulse at z=4km



Figure(3) Nonlinearity effect on Soliton at z=4km

(a) Fundamental Soliton pulse propagation (N=1)

Figure (4) shows the evolution of the fundamental Soliton pulse over one Soliton time period $z_0 = \frac{\pi}{2} L_D$. By varying the parameters and it found the optimum values for pulse broadening ratio close to one which are $g=0.004$, $p=0.00081$, number of steps=20

The Soliton pulse propagation is explained by considering the effects of SPM and GVD. At the time of pulse evolution, the effects of the SPM is produced positive chirp where in the anomalous region, GVD produces the negative chirp. So the positive chirp of the SPM is completely cancelled out by negative chirp of the GVD. Pulse has a zero chirp with over entire width. Under this condition, the pulse propagates without broadening or compression for long distance.

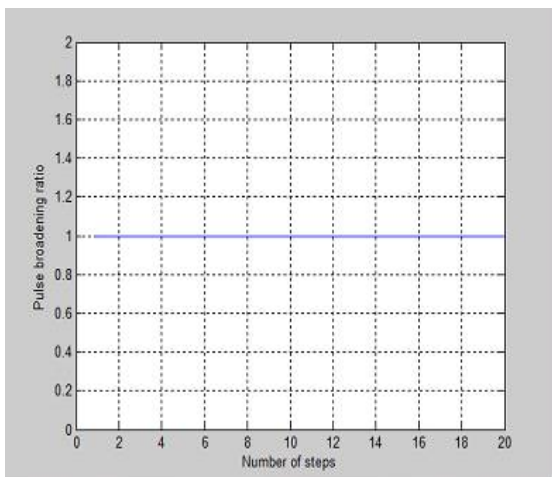
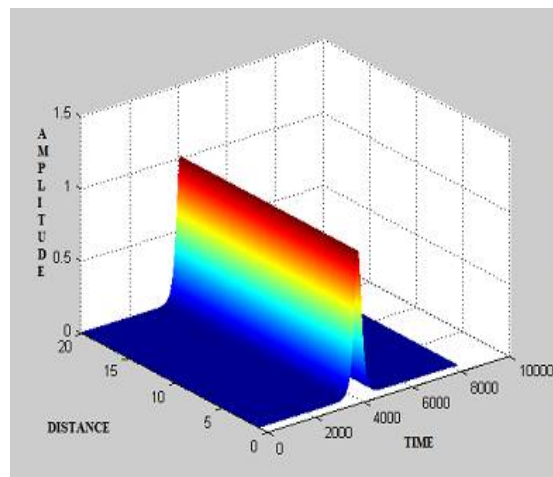


Figure (4) Pulse broadening ratio for N=1



Figure(5) Soliton pulse evolution , N=1

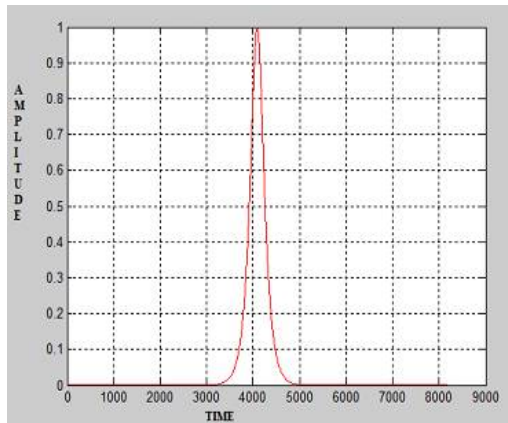
In figure (5) it observed that the amplitude of the output pulse is nearly equal to the input pulse with parameter $g=0.004$, $p=0.00081$, number of steps=20

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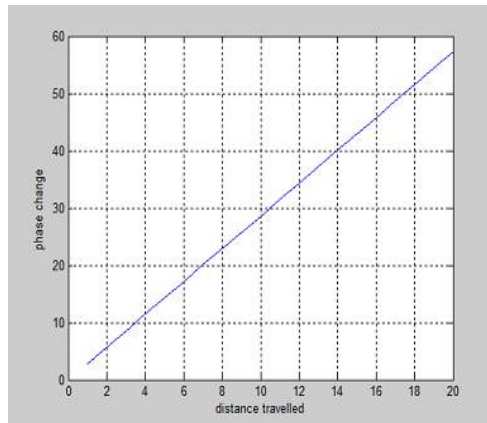
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Figure(6) Input Soliton Pulse, N=1



Figure(7) Phase change of fundamental Soliton

Power of Soliton increases gradually with the order of the Soliton N. It can be described by

$$N^2 = \gamma * p_0 * L_d \quad (8)$$

The input pulse of the NLSE for higher order Soliton is $U(0, \tau) = N \operatorname{sech}(\tau/T_0)$. So increasing the value of N gives affect on the amplitude of the Soliton pulse. Figure (6) shows the pulse amplitude for Soliton order N=1

In Nonlinear process, the phase shift of Soliton is described as[10],

$$d\phi_{nonlin} = |u(t)|^2 dz = \operatorname{sech}^2(t) dz \quad (9)$$

Dispersion effect on phase Shift is described as,

$$d\phi_{disp} = \left(\frac{1}{2} \frac{\partial^2 u}{\partial t^2} \right) dz = \left[\frac{1}{2} - \operatorname{sech}^2(t) \right] dz \quad (10)$$

Phase change of the Soliton is shown in Figure (7) with respect to time. With the help of figure It clearly says that the Soliton phase does not change because of the balance behaviour of the SPM and GVD. For fundamental Soliton, the phase shift due to nonlinear effect maintained by the phase shift due to dispersion effect. With the help of figure it observed that for 20 steps, there is no phase change of the fundamental Soliton.

(b) Second order Soliton Pulse propagation , N=2

If N is an integer is greater than 1 then pulse evolution is totally different from the fundamental Soliton. For higher order, positive chirp of SPM dominates over the negative chirp of the GVD. Because of higher intensity, the positive chirp of the SPM is greater than the negative chirp of the GVD. It does not cancelled out completely. So pulse acquired positive chirp. Compression occurs in the higher order Soliton.

The second order Soliton gives a periodic output. By the figure (8), it observed that after a certain period of distance the initial pulse re-acquired. The length of propagation distance at which pulse re-shaped is called Soliton period.

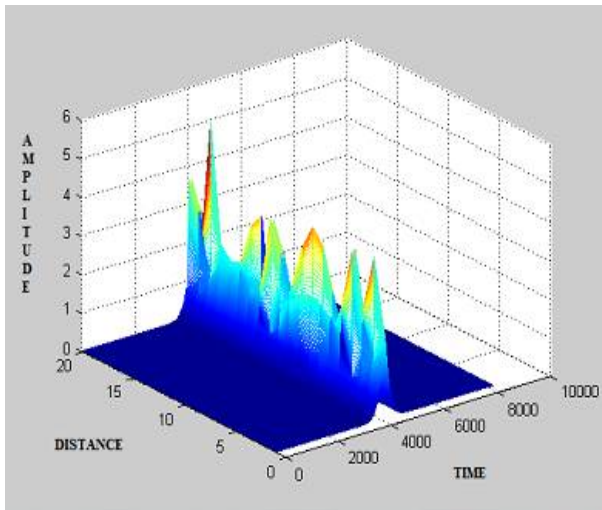
In figure (9) it can determined that pulse of with oscillated at regular time interval which is called Soliton time period z_0 with parameter $g=0.004, p=0.00081$, number of steps=20

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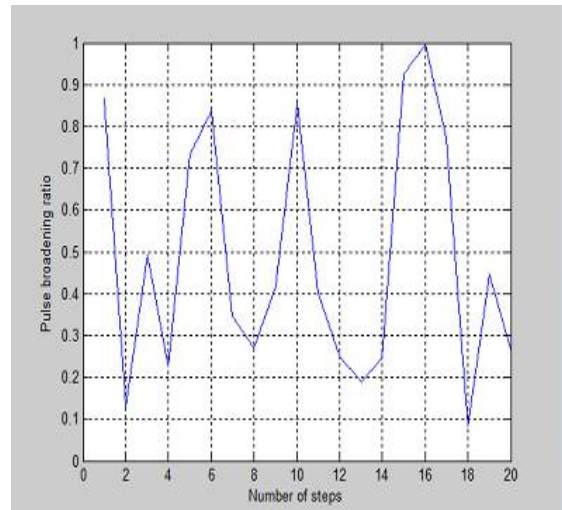
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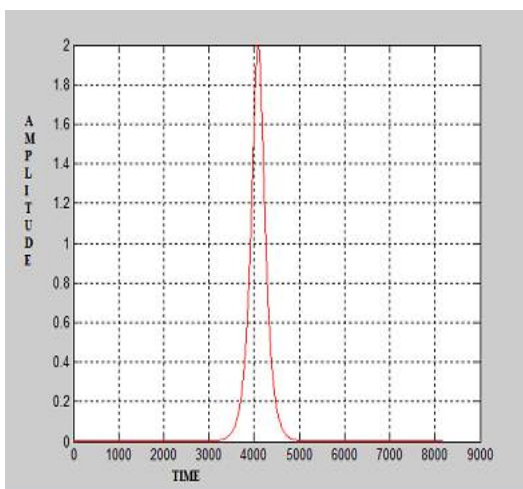


Figure(8) Soliton Pulse Evolution , N=2

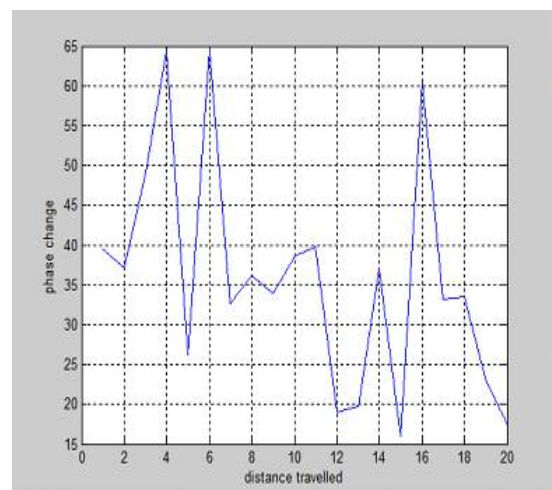


Figure(9) pulse broadening , N=2

As shown in figure (10) with increasing the order of Soliton from 1 to 2, amplitude of the Soliton is also increases. So we can say that with increasing order on Soliton, Energy of the Soliton is also increases. From equation(9) and equation (10), when increases the order of the Soliton N then nonlinear effect gives more affect than dispersion effect, then phase change occurs in the Soliton. Nonlinear effect plays major role than dispersion effect. Due to this the vast change in the phase of the Soliton occurs.



Figure(10) Input Soliton Pulse , N=2



Figure(11) Phase change of Second order of Soliton, N=2

As shown in figure Soliton phase changes several time with respect to distance.

V. CONCLUSION

Based on the matlab simulation of Gaussian pulse and Soliton, it observed that Soliton has advantage over Gaussian pulse because Soliton does not change its shape and power for a long distance fiber communication. The result shown that for lower order of the Soliton is more stable than higher order Soliton, where the power conceded by the pulse keep

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maintains as the pulse travel. The shape of Soliton pulse also preserved as the sensible GVD and SMP effects in anomalous region with the propagation. For higher order Soliton the numerical calculation become more complex. By the pulse Broadening curve and evolution pattern for higher order, it demonstrate that when Soliton order increases $N=2$ the pulse width varies periodically and after the Soliton period z_0 , so by the observation it conclude that the selection of the Soliton order is important to make pulse propagation without loss of power in long distance transmission .

REFERENCES

- [1]. G.P. Agrawal, "Nonlinear Fiber Optics", San Diego, C A, Academic Press, Inc. 3rd Edition, 2001.
- [2]. Keiser G. "Optical fiber Communications", McGraw-Hill Educations, 3rd Edition, Singapore, 2000.
- [3]. E.A. Golovchenko, E. M. Dianov, A.M. Prokhorov and V.N. Serkin, "Decay of optical Soliton", JETP Lett, pp.87-91, 1985.
- [4]. Weideman JAC and Herbst BM, "Split-Step methods for the solution of the nonlinear Schrodinger equation", SIAM Journal on Numerical Analysis, pp.485-507, 1986.
- [5]. Iannone E, Matera F, Mecozzi A, Settlembre H. "Non linear optical communication network". Wiley, 1st edition, New York USA, 1998.
- [6]. K. Ohkuma, Y.H. Ichikawa, and Y.Abe, "Soliton propagation along optical fibers", pp.516-518, 1987.
- [7]. P.K. Wai, C.R. Meyuk, Y. C. Lee, and H.H. chen, "Nonlinear pulse propagation in the neighbourhood of the zero-dispersion wavelength of monomode optical fiber" Opt. Lett., pp.464-466, 1946.
- [8]. S.R. Clarke, R.H.J. Hrimshaw, and B.A Malomed, "Soliton formation from a pulse passing the zero dispersion point in a nonlinear Schodinger equation", Phys. Rev. E. 61,pp.5794-5801, 2000.
- [9]. Muhammad Sufi, Azam Mohammad, Saktioto, and Jalil Ali, "Soliton pulse model in different order for Communication compatibility, International Journal of Applied Physics and Mathematics", Vol. I, No. 3, November 2011.
- [10]. S.K. Sriwas, M. Shukla, R. Asthana and J.P. Saini, "Fix the nonlinear effects and dispersion in Optical- Interleave Division Multiple Access System for long distance", Indian Journal of science and technology, Vol. 9(35), September 2016.
- [11]. K-S. Lee, M.C. Gross, S.E. Ralph, and J.A. Buck, "Wavelenth conversion using $N=2$ soliton decay and recovery in fiber, initiated by dispersion steps", IEEE Photonics Technol. Lett., vol. 16, no.2, 2004.
- [12]. K-S. Lee and J. A. Buck, "Wavelenth conversion through higher-order soliton splitting initiated by localized channel perturbation ", J. Opt. Soc. Am. B, vol. 20, no.3, 2003.
- [13]. W. Hodel, and H.P. Weber, "Decay of femosecond higher-order soliton in an optical fiber induced by Raman self-pumping", Optics Lett., 12 pp. 924-926, 1987.
- [14]. Ping L, Liu L, Wu K, Leung Wk. "Interleve division multiple access". IEEE Transition on Wireless Communication 2006; 5(4): 938-47.
- [15]. Wu H, Ping L, Perotti A. "User-specific chip level interleaver design for IDMA system". IEEE Electronics Letters. 2006; pp42:43-3.