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Analysing and Improving T.O.D Effect on Ultra Long Haul High Bit Rate Optical Communication System

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Abstract: This project presents a comprehensive investigation on pulse distortions due to the third-order dispersion (TOD) on ultra-high speed long-haul single channel optical fiber communication system using Optical fiber System. The optical communication system consists of dispersion-managed line with periodic amplification by Er-doped fiber amplifiers. The presence of the TOD introduces broadening and an additional temporal shift on the propagating pulse. The impact of TOD is observed at the receiving end of transmission line considering the variation of different factors such as transmission reach, bit rate, duty cycle, pulse shape and fiber type. Only self-phase modulation, second and third order dispersion, fiber loss, and amplified spontaneous emission (ASE) noise are considered here. BER performance is also observed considering receiver noise. The numerical result shows that temporal effect on pulse center decreases in the case of NRZ Gaussian pulse while using SSMF-DCF system and when both group velocity dispersion and TOD effects are considered. At first, pulse broadening due to GVD and TOD has been observed by varying bit rates from 40 Gb/s to 160 Gb/s. Then temporal shift of pulse center position is investigated by varying transmission distance, bit rate, duty cycle, input pulse shape and different transmission models for DM systems. Finally, performance of input pulses such as Gaussian and super-Gaussian pulses is evaluated by varying bit rates from 40 Gb/s to 160 Gb/s. Fiber chromatic dispersion, SPM and receiver noises are taken into account for the numerical calculation. DM transmission line is considered for each scheme. A PRBS of length 27−1 is used to propagate through the optical fiber. The presence of the TOD causes pulse broadening, long oscillatory tail as well as introduces a temporal shift to pulse irrespective of shape. With the increase of bit rate, temporal shift of pulse center increases. Pulse center position also changes with the variation of duty cycles and it is found that temporal shift decreases with duty cycle. Time shift of pulse also occurs depending on pulse shape and fiber type.

Keywords: Third-order Dispersion (TOD), Amplified Spontaneous Emission (ASE), SSMF-DCF System.

INTRODUCTION

The increasing transmission rates and link lengths of optical communication systems imply a better knowledge of the impact of dispersion. As the transmission speed is increased, the influence of higher order dispersion is greater and must be understood. In this Project we obtained a solution for a propagating pulse with third order dispersion. We could understand quantitatively the importance of third order dispersion on the pulse shape for high speed transmission systems. Long Haul Optical communication means Transmission of Optical signals over an optical fibre for longer distances,

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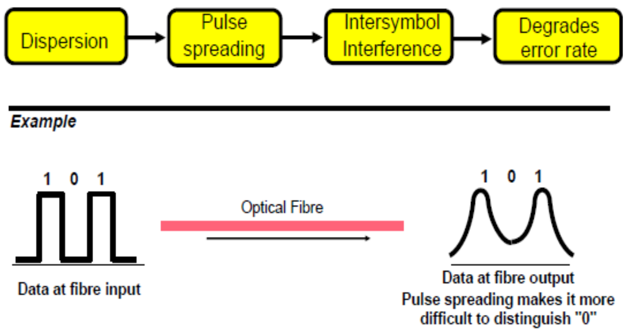
especially without or with minimal use of repeaters. Normally repeaters are necessary at intervals in a length of fibre cable, to keep the signal quality from deteriorating to the point of non-usability. In long haul optical communication system, the goal is to minimise the number of repeaters per unit distance. The main challenge in ultra-long haul optical communication system design is loss. To some extend the loss can be overcome by

i. Increase the brilliance of light, but this brute force approach has limited practically.
ii. Repeaters can be used to boost the signals, at the intervals along the route, but this approach is costly and maintenance of such repeaters are difficult in underground or undersea cable route. One of major issue in optical communication is the Dispersion. In a multimode optical fiber there is an additional dispersion - the modal dispersion which occurs even, when the light introduced into a fiber is an ideal monochromatic source. Indeed, in a single –mode fiber we can assume with a good approximation that the optical path of the rays is directed along the optical axis of the fiber, because the radius of the core is very small (5-10 μm). In a multi-mode fiber the radius of the core is much larger (50-62.5 μm) and the rays can travel along different paths. In a multimode fiber with a step profile of the refraction index all rays travel with the same speed – the rays travelling along the fiber axis have the same speed as the rays travelling close to the core-cladding interface. As they cover the optical paths of different length at the same speed they reach the detector at different times. This leads to the temporal pulse broadening at the end of the fiber. This type of temporal broadening is called the mode dispersion.

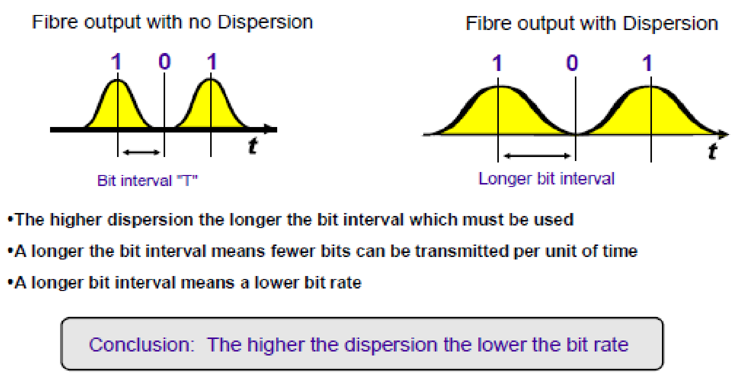
DISPERSION IN OPTICAL FIBRES

An information signal becomes distorted due to attenuation and dispersion as it travels in an optical fibre. Attenuation is the loss of signal power and is governed by different mechanisms, including absorption, scattering, and radiation. Since optical fibres were introduced for communication applications three decades ago, great progress has been accomplished in producing optical fibres that exhibit very low signal attenuation. On the other hand, dispersion is the spreading in the time domain of a signal pulse as it travels through the fibre. Spectral components of a pulse propagating down an optical fibre reach their destination at slightly different times. This translates into a wider pulse at the receiving end of the fibre. Both attenuation and dispersion affect repeater spacing in a long distance fibre-optic communication system. Dispersion affects the bandwidth of the system, hence maintaining low dispersion is of equal importance for ensuring increased system information capacity, versatility and cost effectiveness.

Why Dispersion is a Problem



Dispersion V/s Bit Rate



THIRD ORDER DISPERSION

One attractive aspect of optical fibres is their enormous bandwidth compared to other media, such as radio waves and twisted-pair wires. Still, an optical fibre is not ideal; it possesses some unwanted properties. Dispersion and nonlinearity are the major limiting factors in Optical wave communication. Fibre dispersion causes different spectral components of a signal to travel at different speeds. Hence, for a given transmission distance different spectral components arrive at the destination at different times. This results in a pulse broadening effect when a pulse propagates along an optical fibre. However, the situation is different when the nonlinearity and dispersion are considered together. In some circumstances, the nonlinearity could counteract the dispersion. In addition, when multiple channels are considered, the fibre nonlinearity results in interactions among channels.

FIBRE DISPERSION ANALYSIS

When one considers an optical fibre, the first parameter of interest is the value of dispersion. This is simply because different types of optical fibres have different dispersions. For a single-mode optical fibre, the only source of dispersion is due to group-velocity dispersion (GVD), or intramodal dispersion where the dispersion is the result of the wavelength dependence of the group velocity v_g.

This causes different spectral components to propagate along an optical fibre with different group velocities. For an optical fibre of length ***z***, the spectral component at a frequency ***ω*** would exit the fibre at a time delay of $T = z / v_g$.

The group velocity v_g can be related to the phase$v_g^{-1} = d\beta / d\omega$. Due to the frequency dependence of β, one can show that a pulse having the spectral width of $\Delta\omega$ is broadened

by $\Delta T = 2Z\Delta\omega$, where$\beta_2 = d^2\beta / d\omega^2$,

which is generally called the GVD parameter, with units of ps^2/km. The GVD parameter β2 can be interpreted as the dispersion per unit transmission distance per unit frequency spread of the signal. In optical fibre communication systems, the wavelength unit is more commonly used than the frequency unit, and equation can be rewritten as

$$\Delta T = Dz\Delta\lambda$$

Where **Δλ** is the signal and ***D*** is the dispersion which can be related to β_2 by

$$D = \frac{d}{d\lambda}\left(\frac{1}{v_g}\right) = -\left(2\pi c/\lambda^2\right)\beta_2,$$

Where ***c*** is the velocity of light in vacuum, and ***λ*** is the wavelength.

Single Mode Fibres can be considered as an all pass filter (neglecting fibre loss and non-linearity) and the corresponding transfer function can be expressed as

$$H_o(\omega) = \exp\left\{jz\left[\beta_0 + \beta_1(\Delta\omega) + \frac{1}{2}\beta_2(\Delta\omega)^2 + \frac{1}{6}\beta_3(\Delta\omega)^2 + \dots\right]\right\},$$

Where $\beta_m = (d^m\beta / d\omega^m)_{\omega=\omega 0}$, and $\omega_0$is the operating frequency.

It should be noted that equation is derived under the assumption that $\Delta\omega << \omega_0$, so $\beta(\omega)$ can be expanded about ω_0 by using a Taylor series. In terms of communication theory, the all-pass filter whose transfer function is given by the equation would cause waveform distortion due to the nonlinear phase response. This is commonly called dispersion in the fibre optic communication areas.

When that equation is considered, the first term in the exponent causes only a constant phase shift while the second term results in a time delay. The third and following terms (the second-order and higher-order terms when β_2 is considered) in that equation are the sources of dispersion.

The second-order term is related to the dispersion parameter D by the equation whereas the third and higher-order terms are a result of the phase constant not being a quadratic function of frequency. For the third-order term, it can be related to the dispersion slope S by

$$S = \frac{dD}{d\lambda} = \left(2\pi c/\lambda^2\right)^2\beta_3 + \left(4\pi c/\lambda^3\right)\beta_2$$

In practice, the third and higher-order terms in the equation can be safely neglected as long as the operating wavelength is sufficiently far from the zero-dispersion wavelength so that the contributions of those terms are negligible. Thus, the quadratic dependence of the phase response on the frequency is the major source of dispersion.

PROJECT DESCRIPTION

In an optical fibre communication system, Dispersion is the major limiting factor as bit rate and transmission distance increases. Degradation of the performance of the system occurs due to increased inter-chirp interference and reduced optical power. Dynamic dispersion compensation is becoming a concern of vital importance in high-speed optical fiber communication systems operating at 40 Gb/s and beyond, as such expansion of the transmission bandwidth results in signal waveform distortion.

Even if the transmission bandwidth is limited to a single channel, third-order dispersion (TOD) causes pulses to have trailing ripples which degrades the performance of the ultrahigh speed optical transmission systems. Therefore, in such a high bit rate system, it becomes increasingly important to exactly compensate not only the second-order dispersion, but also the TOD or dispersion slope of the fiber. There have been several dispersion-managed (DM) techniques to compensate for the dispersion effects. Among the different dispersion compensation techniques, there are two methods that are very useful,

i. one using the dispersion compensation fiber (DCF)
ii. and the other, using optical fiber Bragg Grating (FBG).

However, investigations of TOD effect for bit rate of more than 40 Gb/s with actual values of TOD parameters is yet to be addressed. In this project, it is examined the impact of TOD on the pulse shape for ultra-high speed (40 Gb/s and more) system considering group velocity dispersion (GVD) parameter with TOD and evaluated the performance in this ultra-high speed long-haul transmission system. TOD effect has been compared by sending Gaussian and super-Gaussian pulses as input for different bit-rates, duty cycles and different transmission models.

THEORETICAL MODELING

DM system consists of alternating fiber segments with positive or negative dispersion, so chosen that the absolute value of average dispersion remains much smaller than that of local dispersion in either fiber segment. In such a system, effects of TOD can be relatively large, especially when pulse becomes short. Pulse evolution behaviour can be described by TOD perturbed nonlinear Schrödinger equation (NLSE).

The basic equation which governs optical pulse propagation in DM system is given by

$$i\frac{\partial E}{\partial z}+\frac{\beta_2(z)}{2}\frac{\partial^2 E}{\partial t^2}+S(z)|E|^2 E=-i\Gamma(z)E+ig(z)E+i\frac{\beta_3(z)}{6}\frac{\partial^3 E}{\partial t^3},$$

where , E is the slowly varying envelope of the optical pulse, Z is propagation distance; $\beta 2(z)$ is the Fibre GVD , $\beta 3(z)$ is the TOD – Third order Dispersion , $S(Z)$ is the Non linearity ,$\Gamma(z)$ is the Fibre loss and $g(z)$ Amplifier gain.

The DM transmission model consists of a number of fiberspans in between a transmitter and a receiver. The schematic diagram consists of a number of fibre spans in between transmitter and receiver as shown in fig.1.

In the figure, the transmitter section consists of

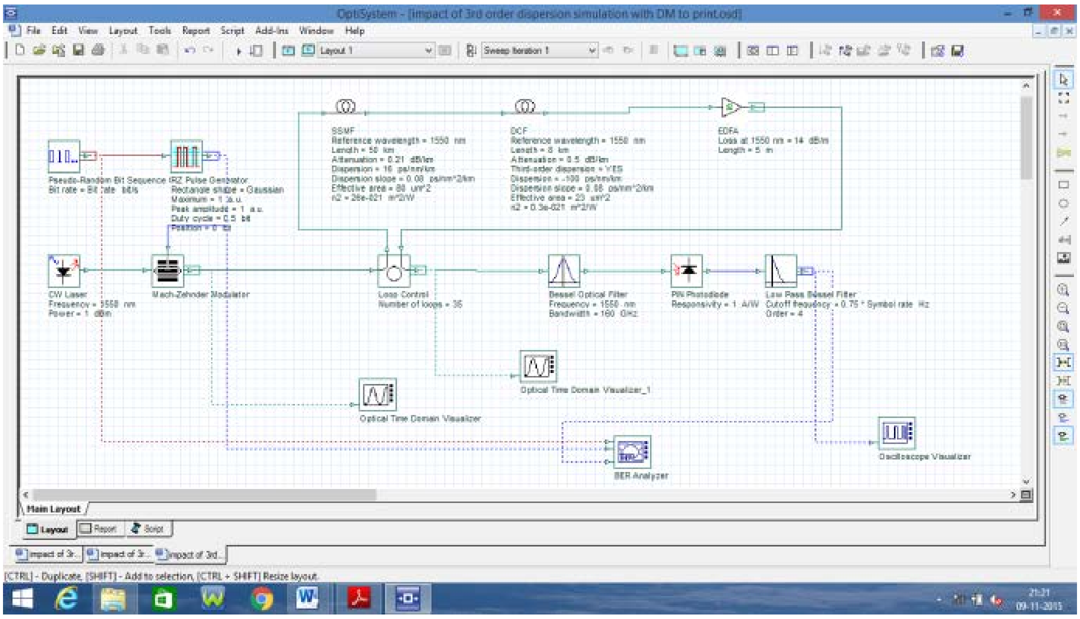
i. Data source,
ii. Electrical driver,
iii. Laser source and
iv. Amplitude modulator.

The data source generates return-to-zero (RZ) Gaussian and super-Gaussian data format at one of the three bit rates (40/100/160Gb/s).

In our simulation, we have used two different DM models. One model consists of SSMF and DCF in each DM map period. In another model, a combination of nonzero dispersion-shifted fiber (NZDSF) and DCF have been used. Each span consists of an optical amplifier at the end terminal of the span. At end of the fibre Receiver is used and consists of p-i-n photodiode, Bessel Optical Filter and Low Bessel Filter.

The numerical simulation has been done by solving the equation using split-step Fourier method for the model shown in Figure. Signal modulation format is a key issue which determines transmission quality and spectral efficiency. In order to maximize optical transmission link capacity, system design and optimization have to take into account all the contributing facts, such as channel data rate, transmission distance, signal optical power, amplifier noise figure, channel wavelength spacing, optical amplifier spacing, fiber dispersion and nonlinear parameters, dispersion management strategy, and receiver bandwidth and so on….

One of the most important factors in the system, which affects the choices of all other system parameters, is the signal optical modulation format. In fact, signal optical spectral bandwidth, tolerance to chromatic dispersion, resistance to non- linear effects, susceptibility to accumulated noise and other system performance measures are directly related to the optical modulation format.



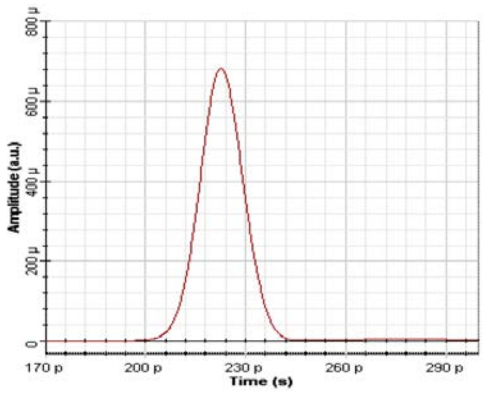
For RZ Gaussian and super-Gaussian pulses we have chosen different types of fiber and system parameters, which are given.

Parameter	SSMF	DCF	NZDSF
α(dB/KM)	0.21	0.5	0.2
D (ps/nm/KM)	16	-100	4.5
S (ps/nm2/KM)	0.08	0.08	0.07
Fibre Length (KM)	50	8 for SSMF 2.5 for NZDSF	55.5

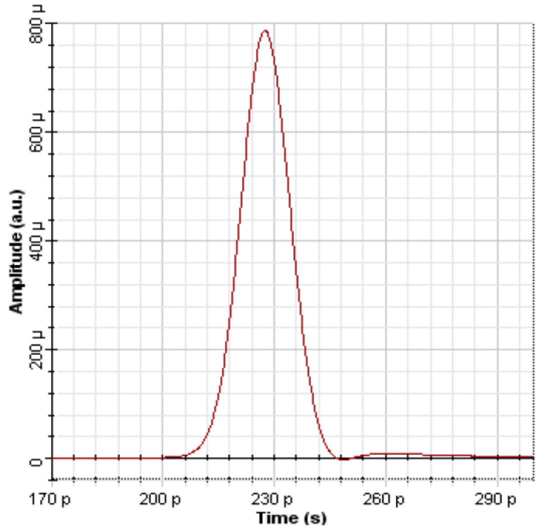
RESULTS AND DISCUSSION

The investigations have been carried out by varying different parameters as mentioned above. Here in the first simulation TOD effect is observed for the Gaussian and super- Gaussian pulses propagating through SSMF-DCF DM system by varying bit rates only. Incident power is 1 mW and duty cycle is 50%. Bit rate is varied from 40 Gb/s to 160 Gb/s. In the simulation, third order super-Gaussian pulse has been assumed to achieve reduced timing jitter in the system. With the increase of bit rates, TOD effect also increases as TOD dispersion length (LD3) becomes smaller than that of GVD which in turn satisfies the condition for TOD effect i.e. LD3 <LD2.

For 40 Gb/s, TOD effect is negligible as evident from Figure.

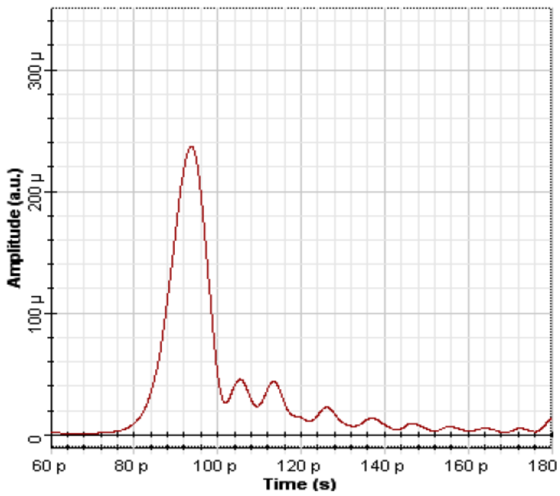


Pulse propagation through SSMF-DCF at transmission distance of 2030 km for 40 Gb/s Gaussian

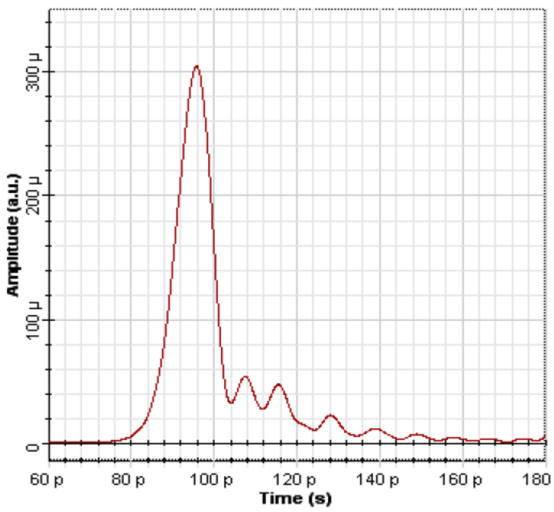


Pulse propagation through SSMF-DCF at transmission distance of 2030 km for 40 Gb/s Super Gaussian

In case of 100 Gb/s, the pulse broadens to almost 10 ps from 5 ps (FWHM) for Gaussian pulse after transmission of 2030 km and exhibits a long oscillatory tail extending around40 ps for both Gaussian and super-Gaussian pulse shapes as shown in Figures.

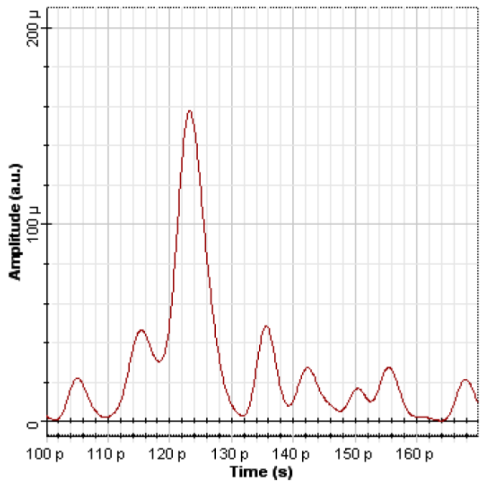


Pulse propagation through SSMF-DCF at transmission distance of 2030 km for 100 Gb/s Gaussian

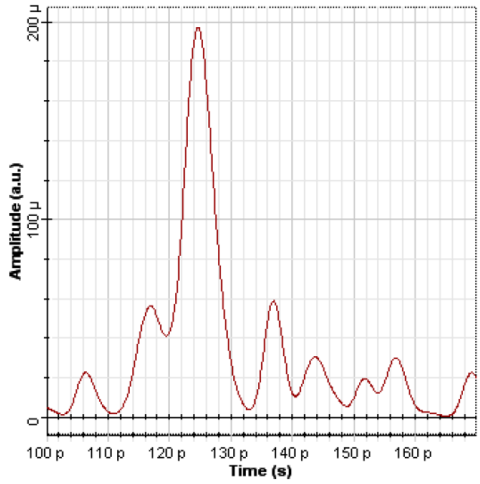


Pulse propagation through SSMF-DCF at transmission distance of 2030 km for 100 Gb/s Super Gaussian

For 160 Gb/s, pulse broadens to almost 6 ps from 3.125 ps (FWHM) for Gaussian pulse and oscillatory tail is found on both edges of pulse which extends around 60 ps as shown in Figures



Pulse propagation through SSMF-DCF at transmission distance of 2030 km 160 Gb/s Gaussian



Pulse propagation through SSMF-DCF at transmission distance of 2030 km for 160 Gb/s Super Gaussian.

CONCLUSION

The performance of a long distance optical fibre communication system is limited by various factors, one of which is dispersion, as mentioned earlier. Pulse distortion reduces maximum spacing between optical transmitters and receivers if the same BER performance for the system is to be maintained When commercial single-mode optical fibre links were first introduced and installed, they were designed to offer zero dispersion 1.3μm, since that was the wavelength of commercially available light sources. Operated nowadays at 1.55μm, these fibres exhibit substantial positive dispersion that may be cancelled out by using dispersion compensating fibres which provide large negative dispersion at that wavelength. The TOD effect has been evaluated by varying bit rate, transmission distance, duty cycle, pulse shape and different transmission models for DM system. The presence of the TOD causes pulse broadening, long oscillatory tail as well as introduces a temporal shift to pulse irrespective of shape. With the increase of bit rate, temporal shift of pulse center increases. Pulse center position also changes with the variation of duty cycles and it is found that temporal shift decreases with duty cycle. Time shift of pulse also occurs depending on pulse shape and fiber type. When bit rate is 40 Gb/s, temporal shift of pulse occurs but pulse ripple at trailing edge is negligible. But when bit rate increases to 100 Gb/s or more, both pulse ripple and time shift dominate. From the in-depth analyses, it has been found obvious that the influence of TOD should not be ignored for ultra-high bit rate systems. As far as real environment is concerned, it has been established that performance of RZ Gaussian pulse using SSMF-DCF system is better in ultra-high speed application when both GVD and TOD effects are considered. The outcome of this project will be useful for designing and implementing ultra-high speed long-haul optical fiber communication system.

REFERENCES

[1] Philomina, S., & Karthik, B. (2014). Wi-Fi energy meter implementation using embedded linux in ARM 9. *Middle-East Journal of Scientific Research*, *20*(12), 2434-2438.

[2] Vijayaragavan, S.P., Karthik, B., & Kiran Kumar, T.V.U. (2014). A DFIG based wind generation system with unbalanced stator and grid condition. *Middle-East Journal of Scientific Research*, *20*(8), 913-917.

[3] Rajakumari, S.B., & Nalini, C. (2014). An efficient data mining dataset preparation using aggregation in relational database. *Indian Journal of Science and Technology*, *7*, 44-46, 2014.

[4] Karthik, B., Kiran Kumar, T.V.U., Vijayaragavan, P., & Bharath Kumaran, E. (1803). Design of a digital PLL using 0.35 Î¼m CMOS technology. *Middle-East Journal of Scientific Research*, *18*(12), 2013.

[5] Sudhakara, P., Jagadeesh, D., Wang, Y., Prasad, C.V., Devi, A.K., Balakrishnan, G., Kim, B.S., & Song, J.I. (2013). Fabrication of Borassus fruit lignocellulose fiber/PP composites and comparison with jute, sisal and coir fibers. *Carbohydrate polymers*, *98*(1), 1002-1010.

[6] Kanniga E., & Sundararajan M. (2011). Modelling and characterization of DCO using pass transistors. *Lecture Notes in Electrical Engineering, 86*(1), 451-457.

[7] Sachithanandam, P., Meikandaan, T.P., & Srividya, T. (2014). Steel framed multi storey residential building analysis and design. *International Journal of Applied Engineering Research*, *9*(22), 5527-5529.

[8] Kaliyamurthie, K.P., Udayakumar, R., Parameswari, D., & Mugunthan, S.N. (2013). Highly secured online voting system over network. *Indian Journal of Science and Technology*, *6*(S6), 4831-4836.

[9] Sathyaseelan, B., Manikandan, E., Lakshmanan, V., Baskaran, I., Sivakumar, K., Ladchumananandasivam, R., Kennedy, J., & Maaza, M. (2016). Structural, optical and morphological properties of post-growth calcined TiO2 nanopowder for opto-electronic device application: Ex-situ studies. *Journal of Alloys and Compounds*, *671*, 486-492.

[10] Saravanan, T., Raj, M.S., & Gopalakrishnan, K. (2014). SMES technology, SMES and facts system, applications, advantages and technical limitations. *Middle - East Journal of Scientific Research, 20*(11), 1353-1358.

[11] Rebecca, L.J., Sharmila S., Das M.P., & Seshiah C. (2014). Extraction and purification of carotenoids from vegetables. *Journal of Chemical and Pharmaceutical Research,* 6(4), 594-598.

[12] Udayakumar, R., Khanaa, V., Saravanan, T., & Saritha, G. (2013). Retinal image analysis using curvelet transform and multistructure elements morphology by reconstruction. *Middle - East Journal of Scientific Research,* 16(12), 1781-1785.

[13] Karthik B., Kiran Kumar, T.V.U. (2013). EMI developed test methodologies for short duration noises. *Indian Journal of Science and Technology, 6*(S5), 4615-4619.

[14] Bomila, R., Srinivasan, S., Gunasekaran, S., & Manikandan, A. (2018). Enhanced photocatalytic degradation of methylene blue dye, opto-magnetic and antibacterial behaviour of pure and La-doped ZnO nanoparticles. *Journal of Superconductivity and Novel Magnetism*, *31*(3), 855-864.

[15] Manikandan, A., Mani, M.P., Jaganathan, S.K., Rajasekar, R., & Jagannath, M. (2017). Formation of functional nanofibrous electrospun polyurethane and murivenna oil with improved haemocompatibility for wound healing. *Polymer Testing*, *61*, 106-113.

[16] Saravanan, T., Raj M.S., & Gopalakrishnan K. (2014). Comparative performance evaluation of some fuzzy and classical edge operators. *Middle - East Journal of Scientific Research, 20*(12), 2633-2633.

[17] Karthik, B., & Kiran Kumar, T.V.U. (2014). Authentication verification and remote digital signing based on embedded arm (LPC2378) platform. *Middle-East Journal of Scientific Research*, *20*(12), 2341-2345.

[18] Gokula Krishnan, C.A., & Dr. Suphalakshmi, A. (2017). An Improved MAC Address Based Intrusion Detection and Prevention System in MANET Sybil Attacks. *Bonfring International Journal of Research in Communication Engineering, 7*(1), 1-5.

[19] Kurian, S., & Franklin, R.G. (2013). Trustworthy Coordination of Web Services Atomic Transaction for Net Banking. *The SIJ Transactions on Advances in Space Research & Earth Exploration, 1*(1), 6-9.

[20] Dr.Gopinath, B., Kalyanasundaram, M., Karthika, V., & Pradeepa, M. (2018). Development of Power Quality Event Using Diode Clamped Multilevel Inverter in Conjunction with AANF. *Bonfring International Journal of Software Engineering and Soft Computing, 8*(1), 17-22.

[21] Dr. Chaturvedi, A., Bhat, T.A., & Kumar, V. (2013).Movement based Asynchronous Recovery System in Mobile Computing System. *The SIJ Transactions on Computer Networks & Communication Engineering (CNCE), 1*(3), 1-5.

[22] Jerin Jose, M., Akmal Jahan, S., Arunachalam, R., Karnan, R., & Kishore, V. (2017). Automobile Accident Sensing Unit and Notifier using Arduino. *The SIJ Transactions on Industrial, Financial & Business Management (IFBM), 5*(1), 5-8.

[23] Hoa, N.T., & Voznak, M. (2019). High Speed and Reliable Double Edge Triggered D- Flip-Flop for Memory Applications. *Journal of VLSI Circuits and Systems*, *1*(1), 13-17.

[24] Shamim, F.M., & Vishwakarma, S. (2016). Exploiting the Motion Learning Paradigm for Recognizing Human Actions. *Bonfring International Journal of Advances in Image Processing, 6*(3), 11-16.

[25] Kumar, K.A., Sadulla, S., & A. Surendar, (2018). Statistical Analysis of Reliable and Secure Transmission Gate based Arbiter Physical Unclonable Functions (PUFs).*Journal of Computational Information Systems,* 14(3), 62 - 69.

[26] Puliyath, S. (2014). Advanced Secure Scan Design against Scan Based Differential Cryptanalysis. *International Journal of Advances in Engineering and Emerging Technology, 5*(6), 274-279.

[27] Rinesh, S., and Jagadeesan, S. (2014). Detection and Localization of Multiple Spoofing Attackers in Wireless Networks. *Excel International Journal of Technology, Engineering and Management, 1*(1), 17-20.

[28] Gopalakrishnan, K., Raj, M.S., & Saravanan, T. (2014). Multilevel inverter topologies for high-power applications. *Middle - East Journal of Scientific Research,* 20(12), 1950-1956.

[29] Sakthipriya, N. (2014). An effective method for crop monitoring using wireless sensor network. *Middle-East Journal of Scientific Research*, *20*(9), 1127-1132.

[30] Vijayaragavan, S.P., Karthik, B., & Kiran Kumar, T.V.U. (2014). Effective routing technique based on decision logic for open faults in fpgas interconnects. *Middle-East Journal of Scientific Research*, *20*(7), 808-811.

[31] Kanniga, E., Selvaramarathnam, K., & Sundararajan, M. (2014). Kandigital bike operating system. *Middle-East Journal of Scientific Research*, *20*(6), 685-688.

[32] Sundararajan, M. (2011). Optical instrument for correlative analysis of human ECG and breathing signal. *International Journal of Biomedical Engineering and Technology*, *6*(4), 350-362.

[33] Khanaa, V., Thooyamani, K.P., & Saravanan, T. (2013). Simulation of an all optical full adder using optical switch. *Indian Journal of Science and Technology*, *6*(6), 4733-4736.

[34] Slimani, Y., Baykal, A., Amir, M., Tashkandi, N., Güngüneş, H., Guner, S., El Sayed, H.S., & Manikandan, A. (2018). Substitution effect of Cr3+ on hyperfine interactions, magnetic and optical properties of Sr-hexaferrites. *Ceramics International*, *44*(13), 15995-16004.

[35] Suguna, S., Shankar, S., Jaganathan, S.K., & Manikandan, A. (2017). Novel synthesis of spinel Mn x Co 1− x Al 2 O 4 (x= 0.0 to 1.0) nanocatalysts: effect of Mn 2+ doping on structural, morphological, and opto-magnetic properties. *Journal of Superconductivity and Novel Magnetism*, *30*(3), 691-699.

[36] Mathubala, G., Manikandan, A., Arul Antony, S., & Ramar, P. (2016). Enhanced Photocatalytic Activity of Spinel Cu x Mn1−x Fe2O4 Nanocatalysts for the Degradation of Methylene Blue Dye and Opto-Magnetic Properties. *Nanoscience and Nanotechnology Letters*, *8*(5), 375-381.

[37] Kumaravel, A., & Dutta, P. (2014). Application of Pca for context selection for collaborative filtering. *Middle-East Journal of Scientific Research*, *20*(1), 88-93.

[38] Krishnamoorthy, P., & Jayalakshmi, T. (2012). Preparation, characterization and synthesis of silver nanoparticles by using phyllanthusniruri for the antimicrobial activity and cytotoxic effects. *Journal of Chemical and Pharmaceutical Research, 4*(11), 4783-4794.

[39] Amir, M., Gungunes, H., Slimani, Y., Tashkandi, N., El Sayed, H.S., Aldakheel, F., Ercan, I., & Baykal, A. (2019). Mössbauer studies and magnetic properties of cubic CuFe 2 O 4 nanoparticles. *Journal of Superconductivity and Novel Magnetism*, *32*(3), 557-564.

[40] Raj, M.S., Saravanan, T., & Srinivasan V. (2014). A modified direct torque control of induction motor using space vector modulation technique. *Middle - East Journal of Scientific Research, 20*(11), 1572-1574.

[41] Khanaa, V., & Thooyamani, K.P. (2013). Using triangular shaped stepped impedance resonators design of compact microstrip quad-band. *Middle-East Journal of Scientific Research*, *18*(12), 1842-1844.

[42] Asiri S., Sertkol M., Güngüneş H., Amir M., Manikandan A., Ercan I. & Baykal A. (2018). The Temperature Effect on Magnetic Properties of NiFe 2 O 4 Nanoparticles. *Journal of Inorganic and Organometallic Polymers and Materials, 28*(4), 1587-1597.

[43] Thaya, R., Malaikozhundan, B., Vijayakumar, S., Sivakamavalli, J., Jeyasekar, R., Shanthi, S., Ramasamy, P., & Sonawane, A. (2016). Chitosan coated Ag/ZnO nanocomposite and their antibiofilm, antifungal and cytotoxic effects on murine macrophages. *Microbial pathogenesis*, *100*, 124-132.

[44] Kolanthai, E., Ganesan, K., Epple, M., & Kalkura, S.N. (2016). Synthesis of nanosized hydroxyapatite/agarose powders for bone filler and drug delivery application. *Materials Today Communications*, *8*, 31-40.

[45] Thilagavathi, P., Manikandan, A., Sujatha, S., Jaganathan, S.K., & Arul Antony, S. (2016). Sol–Gel Synthesis and Characterization Studies of NiMoO4 Nanostructures for Photocatalytic Degradation of Methylene Blue Dye. *Nanoscience and Nanotechnology Letters*, *8*(5), 438-443.

[46] Thamotharan, C., Prabhakar, S., Vanangamudi, S. & Anbazhagan R. (2014). Anti-lock braking system in two wheelers. *Middle - East Journal of Scientific Research, 20*(12), 2274-2278.

[47] Thamotharan, C., Prabhakar, S., Vanangamudi, S., Anbazhagan, R., & Coomarasamy C. (2014). Hydraulic rear drum brake system in two wheeler. *Middle - East Journal of Scientific Research,* 20(12), 1826-1833.

[48] Vanangamudi, S., Prabhakar, S., Thamotharan, C., & Anbazhagan, R. (2014). Collision control system in cars. *Middle - East Journal of Scientific Research,* 20(12), 1799-1809.

[49] Vanangamudi, S., Prabhakar, S., Thamotharan C., & Anbazhagan, R. (2014). Drive shaft mechanism in motor cycle. *Middle - East Journal of Scientific Research, 20*(12), 1810-1815.

[50] Anbazhagan, R., Prabhakar, S., Vanangamudi, S., & Thamotharan C. (2014). Electromagnetic engine. *Middle - East Journal of Scientific Research,* 20(3), 385-387.