Cross Phase Modulation in multiband Radio-Over-Fiber Systems

Ch. Venkata Dharani[1], Dr. Brintha Terese A[2]

Post Graduate student[1], Associate Professor[2]
Department of Communication Engineering, School of Electronics Engineering
VIT University, Chennai, India

Abstract**—***A novel approach for the detection of cross phase modulation (XPM) in Radio over fiber (RoF) systems has been proposed. The cross phase modulation is the nonlinear effect observed in the optical fiber and is analyzed for the distance of 50kms. The Bit-error-rate (BER) degradation due to the effect of XPM is analyzed at dispersion value of 20ps/nm/km for different power level. The comparison of XPM effect with and without Radio Frequency (RF) signal has been analyzed.*

Keywords**—***Cross Phase Modulation; RF signal; BER; dispersion;*

I. Introduction

The raising demand by the users in increase of video calls and vast data transmission had led to the emergence of wireless data transmission [1][2]. The advantages of larger bandwidth, low attenuation loss, ease of maintenance and installation made Radio over fiber the flexible medium for the optical and wireless systems [3][4]. The effect of XPM on Wave-length Division Multiplexed systems (WDM), in two different lengths with non-zero dispersion value without RF signal is analyzed and observed that the lesser distance have better BER than longer distance [5]. The research had been done by varying the dispersion value from -4 to 4ps/nm/km in order to reduce the effect of cross phase modulation which resulted in the nonlinear curve of the Q-factor [6]. The intermodulation3 (IM3) nonlinear effect for producing the optical dual-side bands (ODSB) by introducing fiber dispersion for the RoF systems is analyzed [7].

In our present work, the effect of cross phase modulation has been studied. The BER varies for various power levels, with a fixed dispersion value of 20ps/nm/km. Analysis has been done with and without RF signal with modulation techniques.

II. Cross Phase Modulation

The intensity dependent characteristics give the non-linearity in the optics. The non-linearities arise in the fiber due to the change in the refractive index of the medium. The main non-linear effects due to this reason are self-phase modulation (SPM), cross phase modulation (CPM) and four way mixing (FWM). The other reason for the non-linearity is due to scattering characteristics which causes stimulated effects like stimulated brillouin-scattering (SBS) and stimulated raman-scattering (SRS). In WDM channel, intensity of one beam change the phase of the other beam due to Kerr effect.

The cross phase modulation is caused due to the interaction of the two signals passing through the same medium which results in the occurrence of the error or distortion in the output signal. The cross phase modulation is bit similar to the self-phase modulation. Which means the refractive index of pulse not only depend on its own refractive index but also on the pulse travelling simultaneously. Cross phase modulation introduces cross talk in the system, produces amplitude and time jittering and causes pulse broadening. The effect of the cross phase modulation in WDM system is analyzed.

III. Methodology

Fig. 1 shows the block diagram to analyze the cross phase modulation without RF signal and Fig. 2 shows the block diagram of analyze the XPM with RF signal.

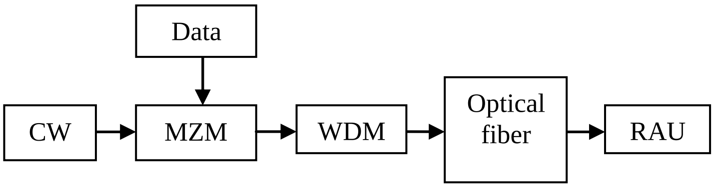

Fig. 1 Multiband WDM system.

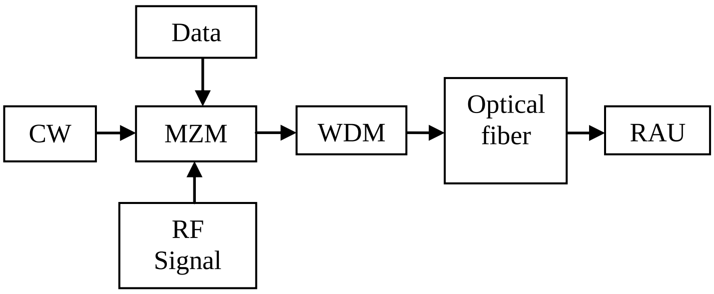

Fig. 2 Multiband Radio-over-Fiber system.

The Mach-Zender Modulator (MZM) is used to modulate the signals given to it. Continuous Wave (CW) at 1552.52nm with line width of 10MHz is given to the MZM as the light source and the pseudo random generator gives the data source in the form of NRZ pulses to the MZM as shown in Fig.1. For the normal WDM systems the change in refractive index occurs due to the Kerr effect for which the RF signal is not given. Whereas to the RoF systems the RF signal acts as carrier wave and it is responsible for the change in the refractive index in the system which causes the cross phase modulation. The sinusoidal RF signal with 28GHz along with bias circuit is given to the MZM as shown in Fig.2. The modulated and multiplexed data is transmitted through the optical fiber of a length 50kms to the Remote Access Unit (RAU). Near the RAU the obtained optical signal will be converted to the electrical signal with the help of photo-detector and filtered with help of a Bessel filter and then transmitted to the end users.

Pulse Shift Keying (PSK) and Offset Quadrature Pulse Shift Keying (OQPSK) are the two modulation techniques used in-order to have better performance of the system. Here the pseudo random generated data will be given as the PSK and OQPSK modulated data to the MZM.

IV. PERFORMANCE EVALUATION

Let us now see the performance of the system with different power levels.

A. NRZ pulse train:

The data source from the pseudo random generator is given to the NRZ generator in order to get the NRZ pulse train to give as input data source to the MZM. The effect of cross phase modulation observed is more as the power level increases. The power range is varied between 0dBm to 30dBm. The eye-diagram shows the obtained output without RF signal in Fig.3 and with RF signal in Fig.4 as given below.

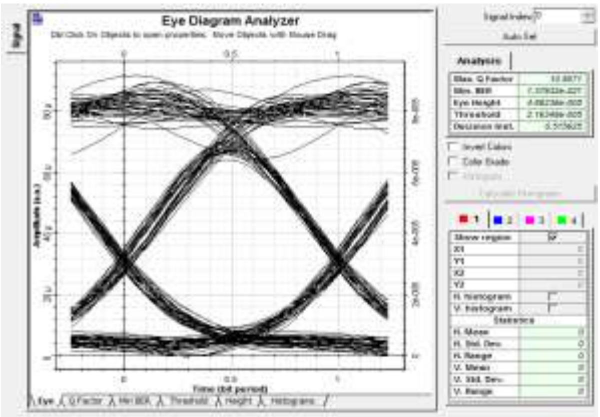

Fig.3 BER for power level 0dBm for a dispersion of 20ps/nm/km without RF signal

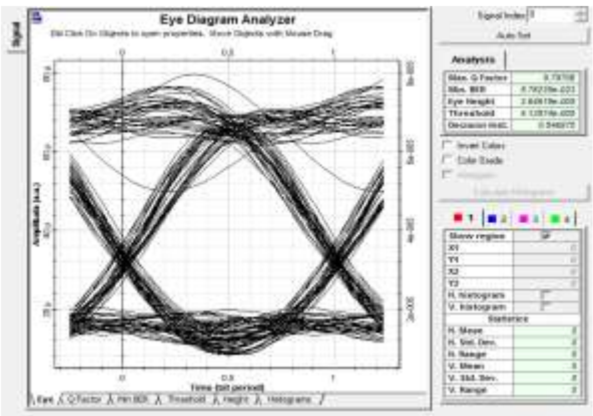

Fig.4 BER for power level 0dBm for a dispersion of 20ps/nm/km with RF signal

The performance analysis for different power levels is tabulated as shown below.

Table1. System performance without RF signal at 20ps/nm/km

Power in dBm	BER (1km)	BER (50km)
0	9.32542e-031	5.88694e-027
10	5.79514e-031	4.51911e-026
20	5.66968e-031	2.13878e-015
30	5.67416e-031	0.0193283

Table2. System performance with RF signal at 20ps/nm/km

Power in dBm	BER (1km)	BER (50km)
0	2.47298e-027	1.47736e-026
10	2.9248e-028	1.03057e-016
20	2.50715e-028	1.12825e-016
30	2.4857e-028	0.000227906

The observation from the Tables 1& 2 says that as the power increases the effect of cross phase modulation which results in the increase in number of error bits.

B. PSK pulse train

The data source from the pseudo random generator is given to the PSK modulator in order to get the PSK pulse train to give as input data source to the MZM. The effect of cross phase modulation observed is more as the power level increases. The power range is varied between 0dBm to 30dBm. The eye-diagram shows the obtained output without RF signal in Fig.5 and with RF signal in Fig.6 as given below.

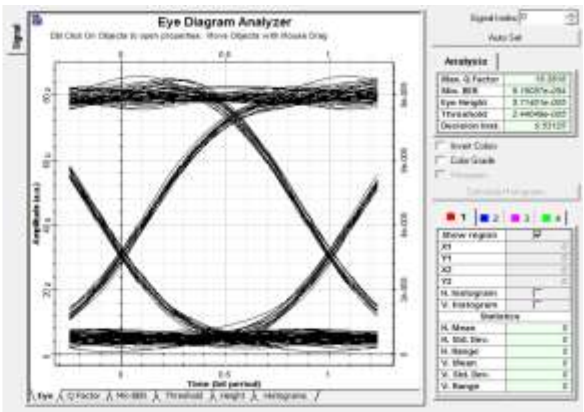

Fig.5 BER for power level 0dBm for a dispersion of 20ps/nm/km without RF signal

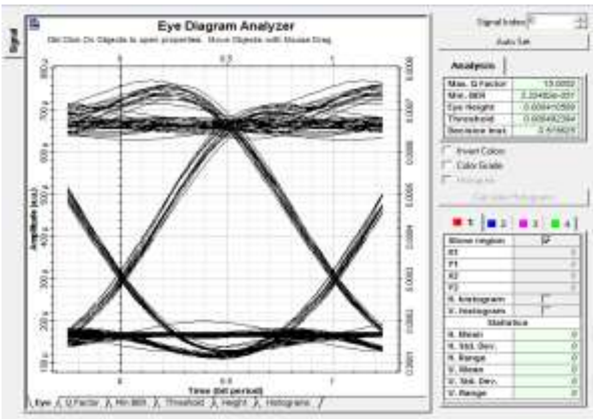

Fig.6 BER for power level 0dBm for a dispersion of 20ps/nm/km with RF signal

The performance analysis for different power levels is tabulated as shown below.

Table3. System performance without RF signal at 20ps/nm/km

Power in dBm	BER (1km)	BER (50km)
0	1.28424e-65	9.15057e-54
10	1.01804e-65	3.66651e-42
20	1.46822e-65	8.40922e-27
30	1.66932e-65	Infinite

Table4. System performance with RF signal at 20ps/nm/km

Power in dBm	BER (1km)	BER (50km)
0	1.1128e-63	3.06897e-51
10	3.2778e-64	3.32482e-33
20	4.6636e-64	1.50793e-12
30	5.26794e-64	infinite

The observation from the Tables 3&4 says that as the power increases the effect of cross phase modulation which results in the increase in number of error bits. When compared to the normal NRZ pulse train the number error bits were less in the input side in PSK modulation but as the power increases the number of error bits in the output became infinite.

C. *OQPSK pulse train*

The data source from the pseudo random generator is given to the OQPSK modulator in order to get the OQPSK pulse train to give as input data source to the MZM. The effect of cross phase modulation observed is more as the power level increases. The power range is varied between 0dBm to 30dBm. The eye-diagram shows the obtained output without RF signal in Fig.7 and with RF signal in Fig.8 as given below.

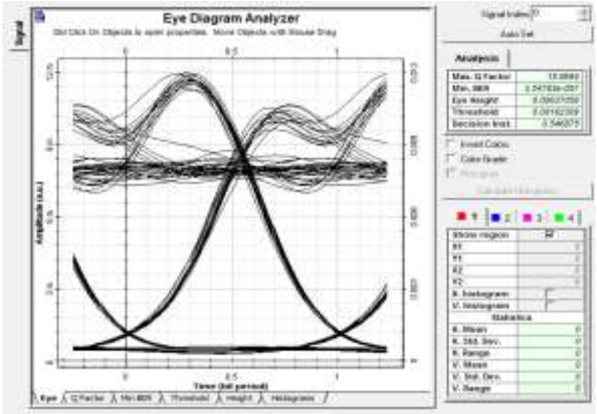

Fig.7 BER for power level 0dBm for a dispersion of 20ps/nm/km without RF signal

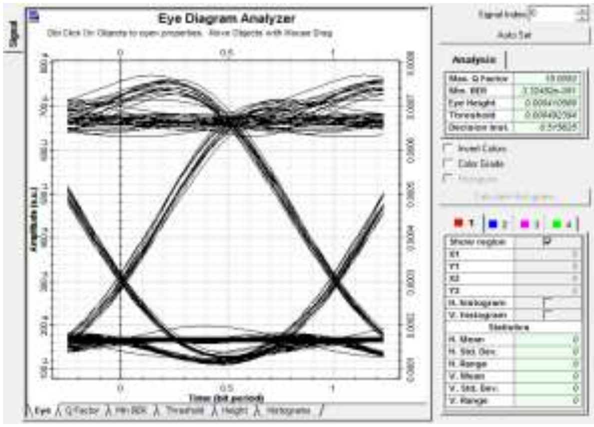

Fig.8 BER for power level 0dBm for a dispersion of 20ps/nm/km with RF signal

The performance analysis for different power levels is tabulated as shown below.

Table5. System performance without RF signal at 20ps/nm/km

Power in dBm	BER (1km)	BER (50km)
0	6.53253e-67	2.19104e-57
10	9.32554e-67	8.67873e-40
20	1.25701e-66	3.54783e-18
30	1.37164e-66	0.00539969

Table6. System performance with RF signal at 20ps/nm/km

Power in dBm	BER (1km)	BER(50km)
0	1.1128e-63	3.06897e-51
10	3.2778e-64	3.32482e-33
20	4.6636e-64	1.50793e-12
30	5.26794e-64	infinite

The observation from the Tables 5&6 says that as the power increases the effect of cross phase modulation which results in the increase in number of error bits. When compared to the normal NRZ pulse train the number error bits were less in the input side in OQPSK modulation but as the power increases the number of error bits in the output became infinite for the system containing RF signal. When compared to the PSK modulation OQPSK modulation have every little difference in the input BER and output remains the same.

CONCLUSION

Thus the study of effect of cross phase modulation has been done and performance difference between the normal NRZ pulse train and the PSK, OQPSK pulse train has also been observed. The Offset QPSK gives better performance than the other two pulse trains even though it has infinite error at the maximum power level. The application for the microwave signal range is taken for the RoF systems for which it gives the better performance than the normal system.

REFERENCES

[1] P. Smulders, "Exploiting the 60 GHz band for local wireless multimediaaccess: Prospects and future directions," *IEEE Commun. Mag.*, vol. 40, no. 1, pp. 140–147, Jan. 2002.

[2] C. Park and T. S. Rappaport, "Short-range wireless communications for next-generation networks: UWB, 60 GHz millimeter-wave WPAN, and ZigBee," *IEEE Wireless Commun.*, vol. 14, no. 4, pp. 70–78, Aug. 2007.

[3] Z. Jia, J. Yu, G. Ellinas, and G.-K. Chang, "Key enabling technologies for optical-wireless networks: Optical millimeter-wave generation, wavelength reuse, and architecture," *J. Lightw. Technol.*, vol. 25, no. 11, pp. 3452–3471, Nov. 2007.

[4] G.-K. Chang, A. Chowdhury, Z. Jia, H.-C. Chien, M.-F. Huang, J. Yu, and G. Ellinas, "Key Technologies of WDM-PON for Future Converged Optical Broadband Access Networks," *IEEE/OSA J. Opt. Commun. Netw.*,vol. 1, no. 4, pp. C35–C50, Sep. 2009.

[5] Geeta Saini , Darpan Gupta , Neeraj Maurya, "Effect on WDM due to Cross Phase Modulation," International Journal of Electronics and Computer Science Engineering, ISSN-2277-1956

[6] Kapil Kashyap, Dr. Hardeep Singh, Preeti Singh, Chetan Gupta, "Effect of Cross Phase Modulation (XPM) on Optical Fiber Using Two Wavelength Division Multiplexed (WDM) Channels," International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS)

[7] Tae-Sik Cho and Kiseon Kim, "Optimization of Radio-On-Fiber Systems Employing ODSB Signals by Utilizing a Dual-Electrode Mach–Zehnder Modulator Against IM3," IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 18, NO. 9, MAY 1, 2006

[8] A. Chowdhury, H.-C. Chien, S.-H. Fan, J. Yu, and G.-K. Chang, "MultiBand transport technologies for in-building host-neutral wireless over fiber access systems," *J. Lightw. Technol.*, vol. 28, no. 16, pp. 2406–2415,Aug.2010.

[9] O. Omomukuyo, M. P. Thakur, and J. E. Mitchell, "Experimental performance analysis of MB-OFDM Ultra-Wideband Radio-Over-Fiber signals in the 60-GHz band using a commercially-available DFB laser," presented at the 14 Int. Conf. Transp. Opt. Netw., Coventry, U.K., Jul. 2012.

[10] Y.-T. Hsueh, C. Liu, S.-H. Fan, J. Yu, and G.-K. Chang, "A novel fullduplex testbed demonstration of converged all-band 60-GHz radio-overfiber access architecture," presented at the Opt. Fiber Commun. Conf. Expo./Nat. Fiber Opt. Eng. Conf., Los Angeles, CA, USA, Mar. 2012.

[11] M. Zhu, A. Yi, Y.-T. Hsueh, C. Liu, J. Wang, S.-C. Shin, J. Yu, and G.-K. Chang, "Demonstration of 4-band millimeter-wave radio-over-fiber system for multi-service wireless access networks," presented at the Opt. Fiber Commun. Conf. Expo./Nat. Fiber Opt. Eng. Conf., Anaheim, CA, USA, Mar. 2013.

[12] H. Yang, J. Zeng, Y. Zheng, H. D. Jung, B. Huiszoon, J. H. C. Van Zantvoort, E. Tangdiongga, and A. M. J. Koonen, "Evaluation of effects of MZM nonlinearity on QAM and OFDM signals in RoF transmitter," in *Proc. Int. Top. Meeting Microw. Photon.*, Gold Coast, Australia, Sep. 30–Oct. 03, 2008, pp. 90–93.