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Effect of FWM (Non-Linearity) on ROF DWDM Optical Fiber Link

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Abstract: Fiber nonlinearities are limiting factors for optical communications systems, specially for wavelength division multiplexing (WDM). Among the nonlinearities effect is four wave mixing (FWM), which is a nonlinear process that produce new frequency components from existing frequency components. FWM is the main factor which eventually limits the channel density and capacity of WDM systems. Many studies have been carried out on the fiber nonlinear effects in WDM baseband-optical modulated systems but very few have been published on radio-over-fiber (ROF)-WDM system. Thus, this research has put a core situation in studying the FWM effect in ROF-WDM systems which carry the modulated microwave carrier and baseband signal. In the ROF-WDM system, the optical modulation method plays an essential role in amount of fiber nonlinearity effect. Therefore, in this regards, different types of ROF-WDM system in terms of optical modulation techniques are investigated and the shortcomings and advantages of these techniques are compared. Among these modulated technique, the most suspected optical modulation method to fiber nonlinearity which is direct intensity modulation is chosen to be modeled for the ROF-WDM system.

Keywords- WDM (Wavelength Division Multiplexing), FWM (Four Wave Mixing), ROF (Radio Over Fiber)

I. INTRODUCTION

As the capacity of fiber transmission systems increases, the spacing between wavelength division multiplexing (WDM) channels needs to drop off to make optimal use of limited optical low loss spectrum window. Besides, high data rates of 10 or 20 Gb/s and long spans between amplifiers in a chain require high optical powers to inject into the fiber to meet signal-to-noise ratio (SNR) requirements. These high-power values as well as the close spacing between channels increase nonlinear crosstalk between the channels due to the nonlinear properties of the transmission fiber. The most significant nonlinear property of fiber which can limit the data rate of the system are Self phase modulation (SPM) Cross phase modulation (XPM) Four wave mixing (FWM), Stimulated Raman Scattering (SRS) and Stimulated Brillion scattering (SBS) [1]. Therefore, to amplify the data rate of any WDM optical communication system this nonlinear effect of fiber need to be moderated. As a matter of the fact, the fiber nonlinearity is present in any communication system which uses the fiber optics as a media. Therefore, Radio-Over-Fiber (ROF) system also is affected by this undesirable phenomenon.

Fiber nonlinearity is the main disparaging observable fact in high data rate optical communication systems. Because of limited low loss optical spectrum, DWDM is an efficient technique to increase spectral efficiency. To have more channels in the low loss optical spectrum, the channel spacing must decline. As channel spacing decline the fiber nonlinearity effects amplify and cause to performance degradation of optical system. This degradation even is more critical for the long haul transmission where we need to supply high level of power to the fiber. Feeding the high power to the fiber not only increase the XPM and FWM effect but also cause to activate the effect of other fiber nonlinearity phenomena like SRS and SBS. Many techniques have been proposed to resolve and mitigate the fiber nonlinearity issues. Among these method we can refer to unequal channel spacing and dispersion compensation shifted (DCS) fiber as well as applying high bandwidth optical amplifier. However, the problem of fiber nonlinearity in the ROF system is a quite new issues and it needs to be investigated more.

Another technical challenge which limits the number of channel in WDM is Fiber nonlinearity. The fiber nonlinearity cause high interference and channel cross-talk between WDM channels. Thus, Extra channel spacing is important. In addition, the simplest approach to defer fiber nonlinearity effects is keeping the light intensity low. This action nonetheless, is unfavorable due to declining the system SNR.

II. PROPOSED METHOD

A simple ROF-WDM simulation model that uses 30 GHz millimeter wave signal to carry the baseband data rate of 2.5 Gb/s. In this paper, a simulation model using Optisystem software has been used to analyze the fiber FWM nonlinearity effect on ROF system. The results are compared with the effect of FWM on the conventional optical system.

A. *SYSTEM MODEL*

Block diagram of the system is shown in the Figure-1. The major components of the system are remote access unit (RAU), optical modulators, WDM multiplexer, fiber optic link, WDM demultiplexer and ROF receiver.

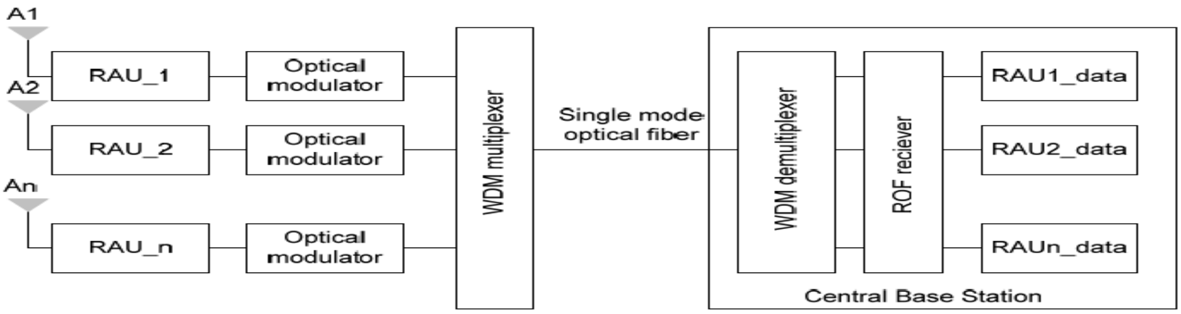

Fig 1 Block diagram of ROF system

B. ROF TRANSMITTER

It can be considered as a device including N number of RAU, optical modulator and WDM multiplexer. Therefore, for this discussion the transmission happen from RAU to central base station (CBS). In this research no wireless standard is considered. The data receiving from RAU can be in the form of CDMA, OFDM, TDMA or any combination of these schemes. From ROF point of view, all of these analog signals receiving by RAU are modulated RF or millimeter wave frequency. Therefore, base station can be modeled as a source of information in the form of zeros and ones which are modulated using RF carrier signal as it's shown in Figure 2.

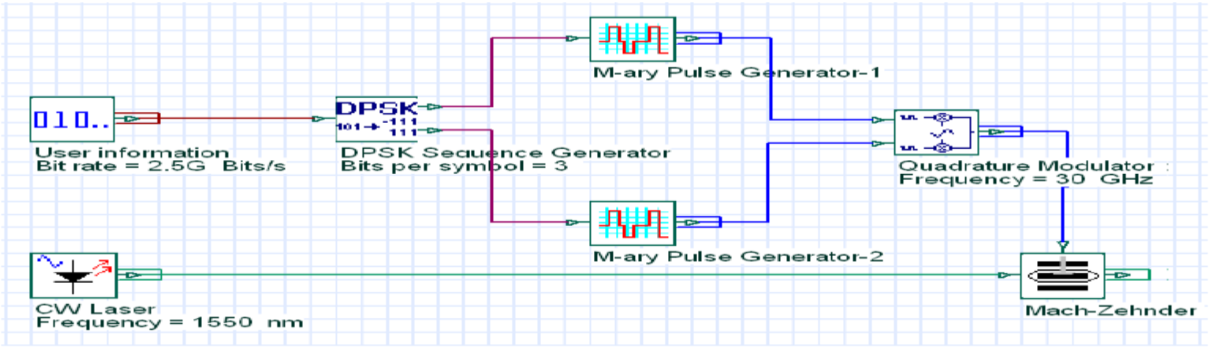

Figure 2 ROF transmitter

Suppose that, the outgoing data rate of each RAU station is about 2.5 Gb/s which possibly can be a good estimation of a RAU capacity. To increase the spectral efficiency of the system the DPSK modulation scheme is added into the system, I and Q signal coming from the DPSK modulator are convert to M-ray pulse using M-ray pulse generator. The resulting pulses from M-ray generator then are modulated using 30GHz RF carrier. By doing the aforementioned steps a RAU is simply modeled. Now it is a turn for modeling ROF transmitter. The transmitter can be constructed using collection of external optical modulation scheme which could be consisting of a laser diode with 10MHz line-width in the arrangement with a Match Zehnder. The laser diode is radiating in the range of 1550 nm. This range is chosen since it is low loss window of optical frequency band [23]. In the next step to make a complete use of optical link, WDM multiplexing scheme is added to the model. Now, the ROF transmitter is almost modeled. It means that for ROF transmitter, each RAU can be just considered as a single wavelength in the system. It should be mentioned that we assume all RAU are working at the same frequency band which is the worst case.

C. ROF RECEIVER

The collections of N RAU modeled are multiplexed using WDM multiplexer as shown in Figure 3 and then are transmitted through a single mode fiber (SMF) into central base station. The fiber length assumed to be 50 kilometers which is good estimation of macro cell radius [23].

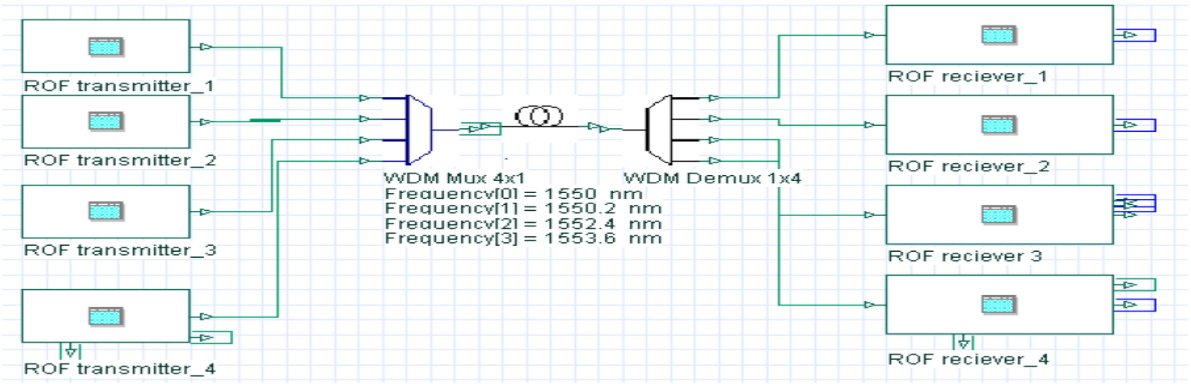

Figure 3 ROF-WDM system model

In the CBS then each base station signal are de-multiplexed through WDM de-multiplexer and are then detected using a ROF receiver as it is given in Figure 4. As it is displayed in Figure 4, the ROF receiver consists of a 30 GHz local I and Q oscillator, M-ray detector, DPSK decoder and a NRZ pulse generator.

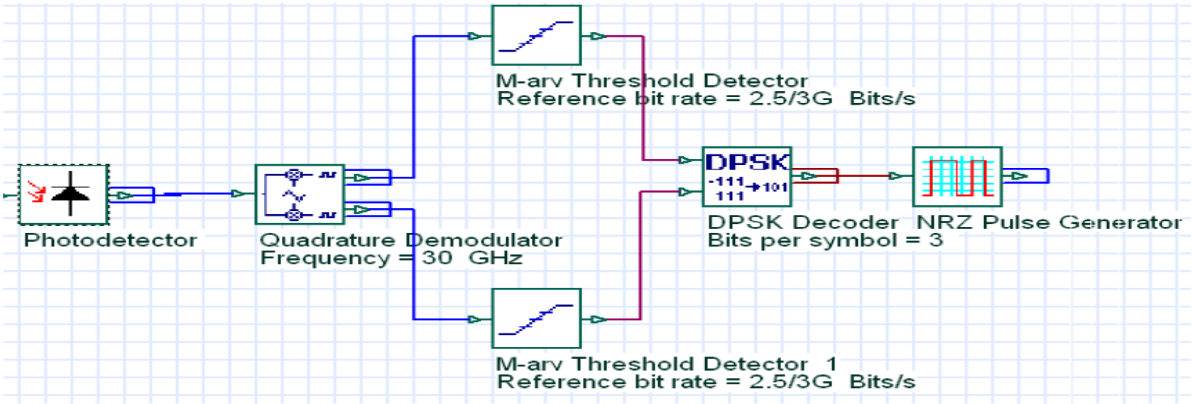

Figure 4 ROF receiver

The complete ROF-WDM system is completely modeled in the next section the results will be given.

D. SIMULATION PARAMETERS

Figure 3 represents the general model of the simulation in this project. The simulation parameters are indicated in Table 1.

Table 1 Simulations parameters

Parameters	**value**
Number of RAU	4
Baseband modulation	DPSK
Data rate	2.5Gb/s
Number of bit in each symbol	3
RF carrier frequency	30GHz
Optical fiber length	50km
Type of optical fiber	Single mode fiber (SMF)
Fiber dispersion	1ps/km/nm
Fiber attenuation	0.2dB/km
Fiber nonlinear coefficient(n2)	2.6×10-20
Optical modulation	External modulation
Photo detector type	PIN
Fiber effective area	64µ2

III. RESULTS

A. BASEBAND MODULATED RESULTS

The results for optical baseband modulation are displayed in Figures 5, 6, 7, 8, 9. The optical spectrum of individual base station with baseband modulation can be seen in Figure 5. The baseband data rate is set to 2.5 Gb/s for this case. The resulting FWM component for baseband modulated optical system is portrayed in Figure 7.

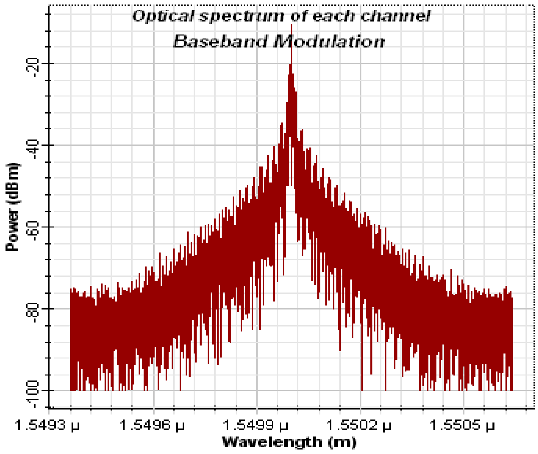

Figure 5 The optical spectrum of individual channel with baseband modulation

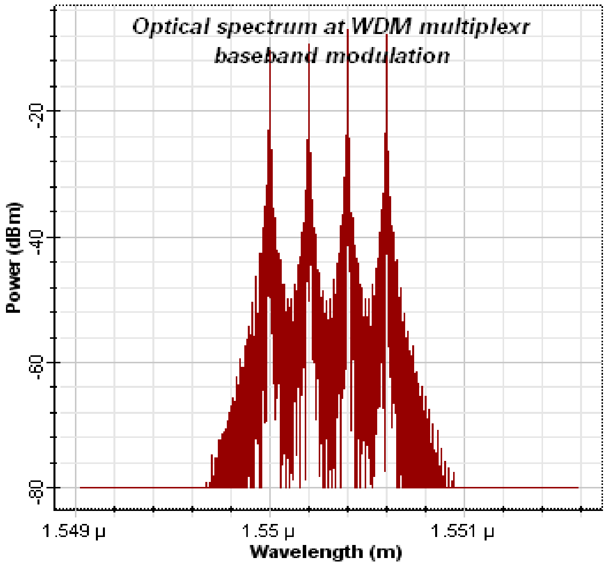

Figure 6 Optical spectrum of 4 channel WDM with baseband modulat ion at transmitter side

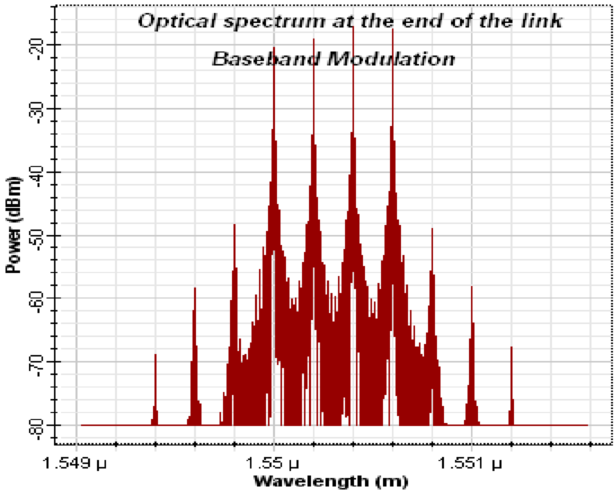

Figure 7 Optical spectrum of 4 channel WDM with baseband modulation at the end of the link

In comparison with Figure 6 which shows the optical spectrum at the first of the optical link, six components can be clearly seen that adds into the original spectrum. However, we expect 24 component as it is indicated in this equation N2× (N-1)/2, where N is number of channels. The fact is that 18 invisible FWM components are probably match or fall into original channels. However, even by this sort of distortion the error free signal can be detected in the receiver for each channel. The eye diagram graph for this case is portrayed at Figure 8. The resulting eye height is 7.34×10-5.

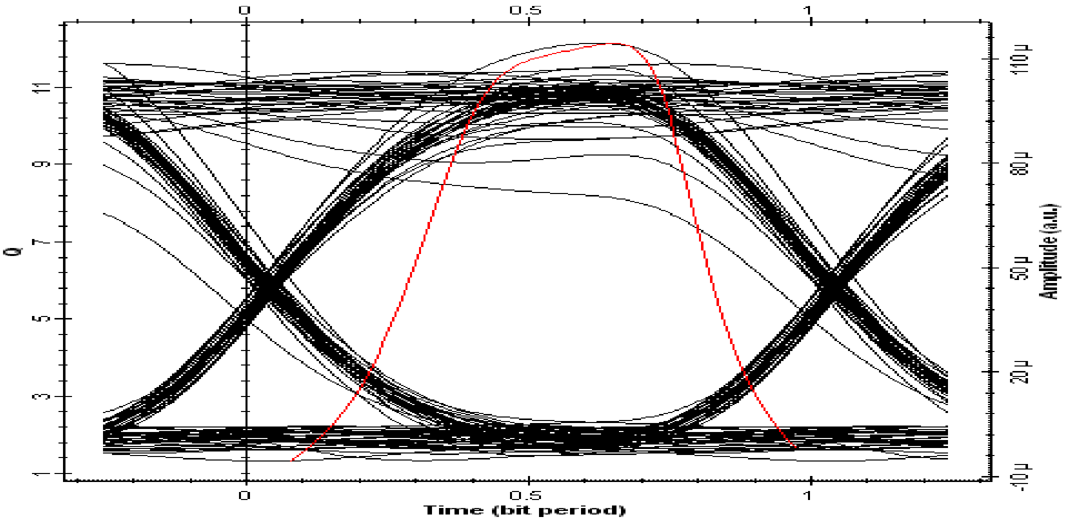

Figure 8 Eye diagram for 4 channel baseband modulate WDM signal

The above simulations have been repeated for optical baseband modulation but this time for data rate 10 Gb/s. For this case, also, the error free signal is found in the receiver. The resulting eye height for this case was 5.32x10-5. However, for higher bit rate the system will not perform well, since the channel spacing has to be more than 2 time, as higher frequencies in electrical signal is 20 GB for this case equivalent to 0.2nm. Means for higher bit rate greater than 10 Gb/s , the channel spacing must be more than 0.2 nm or 20 GHz. In the next section the results for RF modulated signal are given.

B. RF AND MILLIMETER-WAVE MODULATED RESULTS

As in previous section the results for RF modulation are presented at Figures 8, 9, 10, 11, 12. The optical spectrum of individual channel with RF modulation is shown in Figure 8. Two sidebands resulting from RF electrical carrier is present in the optical spectrum of individual channel. The baseband data rate is set to 2.5 Gb/s for this case. The resulting FWM component for baseband modulated optical system is portrayed in Figure 10. For the case channel spacing is 0.2 nm. The resulting eye diagram is given in Figure 11. Thus in this case the information in not detected.

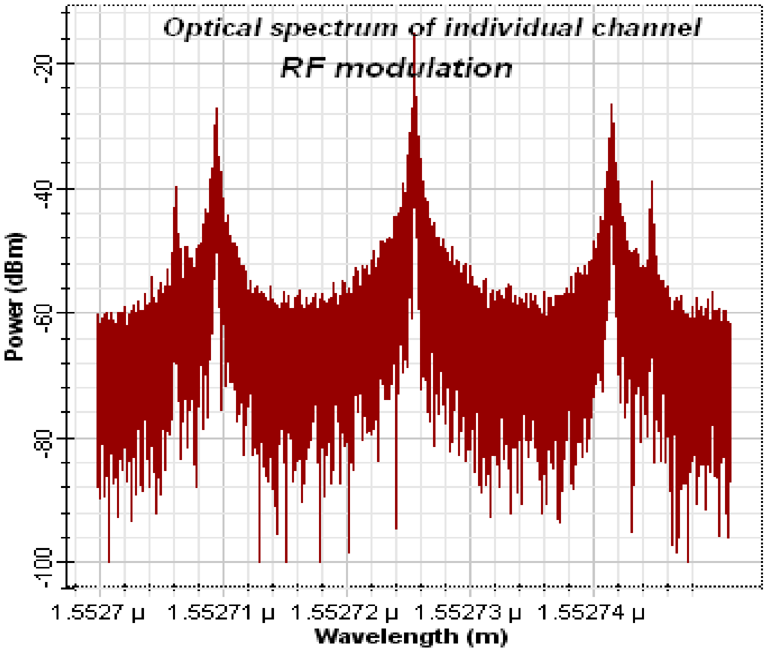

Figure 8 the optical spectrum of individual channel with RF modulation

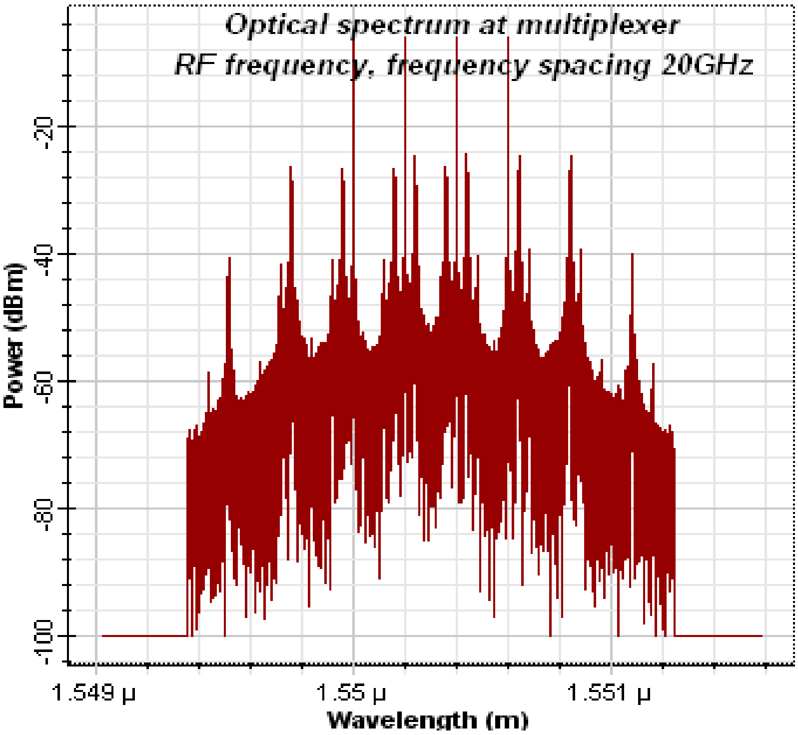

Figure 9 optical spectrum of 4 channel WDM with RF modulation at transmitter side

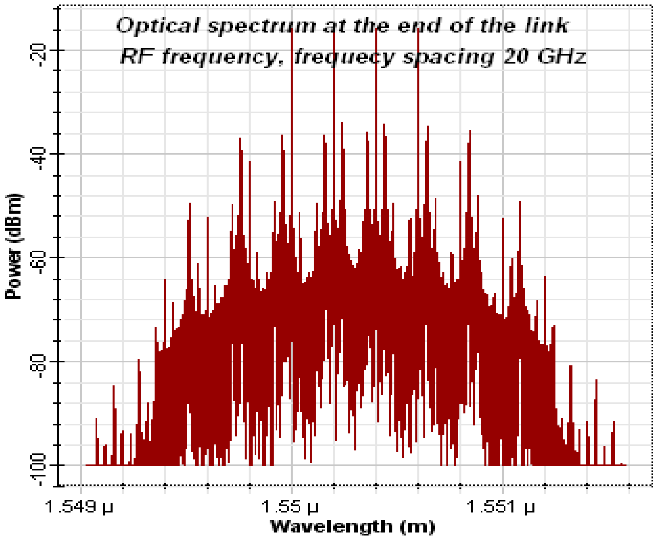

Figure 10 optical spectrum of 4 channel WDM with RF modulation at the end of the link

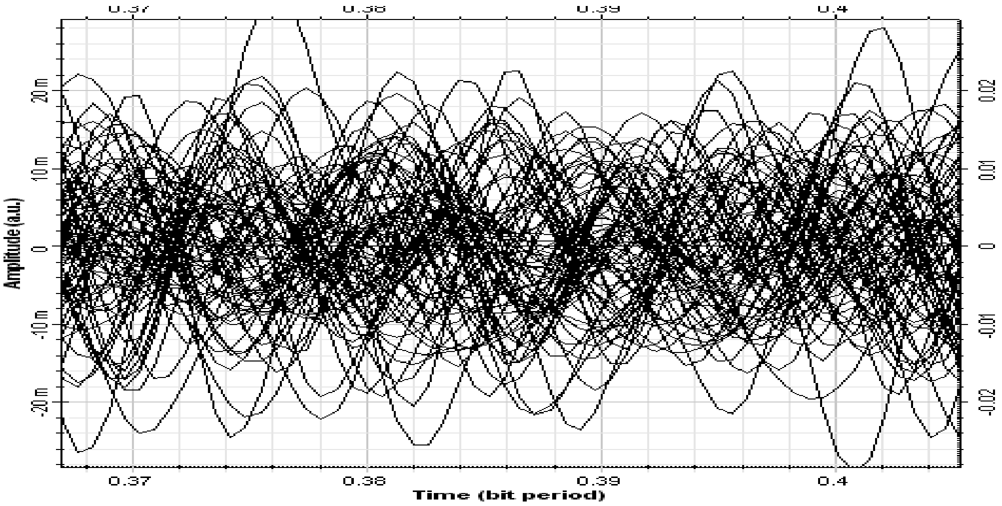

Figure 11 Eye diagram for 4 channel RF modulated WDM signal

Technically, to successfully recover the data we need to increase the channel spacing to 0.6 nm as a rule of thumb in addition we must use single sideband transmission. Therefore, the channel spacing must be chosen as much as 60 GHz, by doing this alteration the information of individual channel can be recovered free of error. The eye diagram resulting from the latest arrangement is given below.

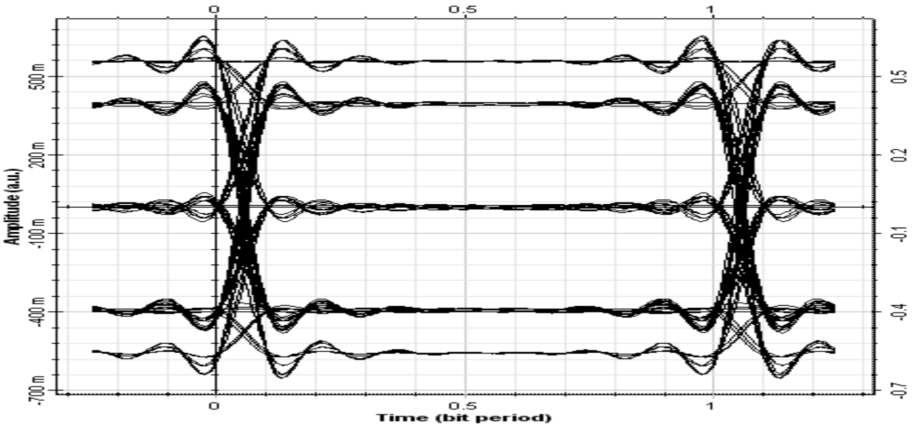

Figure 12 Eye diagram for 4 channel RF modulated WDM signal, with single sideband transmission and channel spacing of 60 GHz

C. Discussion

The optical modulation of RF or millimeter-wave carrier produces double sideband signals. For the case when the data rate was about 2.5Gb/s with the RF carrier frequency of 30Ghz and optical channel spacing of more than 3 nm with double sided transmission the information could not be recovered. The reasons can be found from Figure 13 and 14.

Figure 13 shows the optical spectrum at the end of the link for 4 channels WDM supply by four lasers lasing at 1550 nm with 0.2 nm channel spacing. The case when one the laser is substitute with a ROF transmitter with the 1 GHz RF signal is shown in Figure 14.

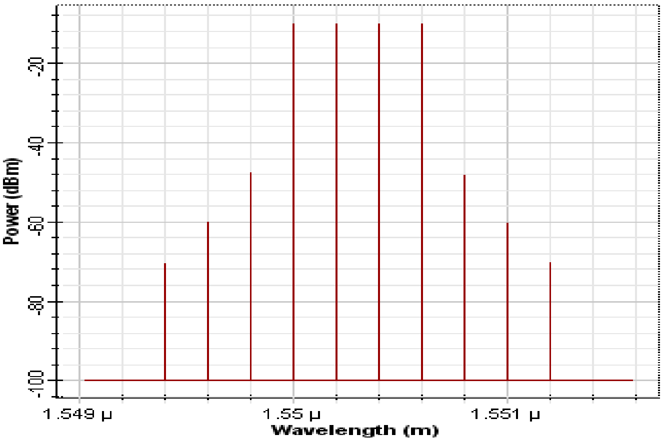

Figure 13 Optical spectrum of 4 channel WDM with 4 CW laser with zero linewidth.

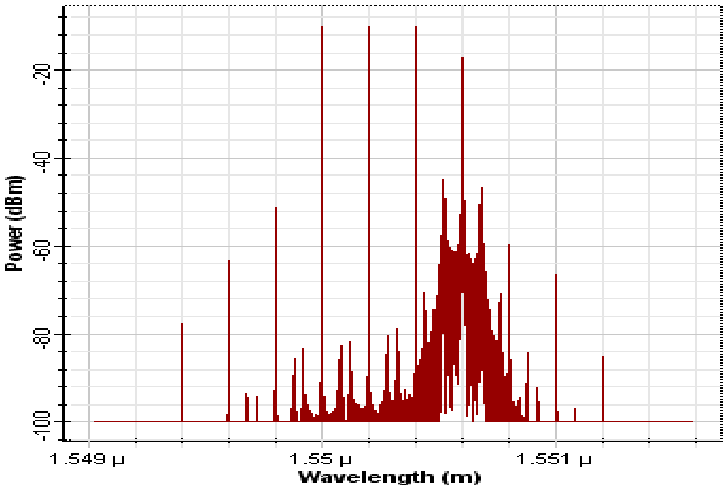

Figure 14 optical spectrum of 4 channels WDM with one RF modulated signal and three CW laser

By the way of comparison, it can be concluded that the side lobes producing from the RF carrier contribute in generating of new FWM component. This phenomenon can be clearly seen in Figure 14. The number of visible FWM component from 6 in Figure 13 increases to 22 visible FWM components. This reason can justify, the case when channel spacing of even 3nm is not sufficient to recover the data in above mentioned scenario. Therefore, in ROF system, in order to reduce the FWM effect on eof the sideband must be filtered out, when the data rate is high and millimeter wave carrier is considered.

IV. CONCLUSION

The result displays the FWM in both baseband and RF modulated optical signal is destructive. The discrepancy between these two systems in terms of FWM impact is due to double sideband nature of optical spectrum generated by RF or millimeter wave carrier. If double sideband optical carrier transmits through the link in addition to optical carrier each individual sideband of optical carrier also add to generate FWM component. Therefore, the number of FWM component amplify noticeably and it causes to transfer energy from the main component to new component. Also most of these components are overlap directly with original channel and causes high level of interferences and performance degradation. In accumulation, the nonlinearity effect of optical fiber causes phase shifting on both sidebands of each channel. Because the frequency of each sideband is different, the phase delay of each sideband may be different, in worst case this dual phase might be in opposite of each other, and in the photodiode they may completely fade each other. Thus, to increase the power and bandwidth efficiency of ROF-WDM system the single sideband transmission is strongly recommended. In the case of single sideband transmission the channel spacing of more than two time of higher RF frequency seems to be efficient to recuperate the data in the receiver.

REFERENCES

[1] L. Rapp, “Experimental investigation of signal distortions induced by cross-phase modulation combined with dispersion,” IEEE Photon. Technol. Lett., vol. 9, pp. 1592–1594, Dec. 1997.

[2] M. Shtaif and M. Eiselt, “Analysis of intensity interference caused by cross-phase-modulation in dispersive optical fibers” IEEE Photon. Technol. Lett., vol. 10, pp. 979–981, July 1998.

[3] [26] Mingchia Wu Way, W.I. “Fiber nonlinearity limitations in ultra-dense WDM systems” Lightwave Technology, Journal of Publication, June 2004 Volume: 22, Issue: 6 On page(s): 1483- 1498 ISSN: 0733-8724

[4] G.E.Kaiser, Optical Fiber Communications, 3rd edition, McGraw Hill, New York.

[5] Govind P. Agrawal, Fiber-optic communication system, Wiley series.

[6] G.P.Agarwal, Nonlinear Fiber optics, 3rd ed, Academic Press, San Diego, CA,

[7] Braun, R.P.; Grosskopf, G.; Rohde, D. ”Optical millimeter-wave generation and transmission technologies for mobile communications, an overview” Microwave Systems Conference, 1995. Conference Proceedings., IEEE NTC '95 17-19 May 1995 Page(s):239 – 242

[8] H. Al Raweshidi, S. Komaki (ed): “Radio over Fiber Technologies for. Mobile Communications Networks” Artech House, London, Boston, 2002

[9] C. R. Lima, P.A. Davies, and D. Wake, “A new optical source for generation of 40-60 GHz signals using a Dual, Mode Multisection DFB Semiconductor Laser”,IEEE IMOC95 Proceeding, pp. 647-652, 1995.

[10] Roberto Paiella, Rainer Martini, Federico Capasso, Claire Gmachl, Harold Y. Hwang, Deborah L. Sivco, James N. Baillargeon, and Alfred Y. Cho, Edward A. Whittaker, and H.c. Liu, “ High Frequency Modulation Without the Relaxation Oscillation Resonance In Quantum Cascade Laser” Applied physics letters, Vol, 79, no. 16, pp 2526-2528.

[11] U. Gliese, S. Norskov, and T. N. Nielsen, “Chromatic dispersion in fiberoptic microwave and millimeter-wave links,” IEEE Trans. Microwave Theory Tech., vol. 45, pp. 1716–1724, Oct. 1997.

[12] Charles H. Cox III, Gary E. Betts, and Leonard M. Johnson, “An analytic and experimental comparison of directand external modulation in analog fiber-optic links,” IEEE Transactions on Microwave Theory and Techniques,Vol. 38, No. 5, pp.501-509, May 1990.

[13] D. G. Moodie, D. Wake, N.G. Walker, and D. Nesset, “Efficient harmonic generation using an electroabsorption modulator,” IEEE Photon. Technol. Lett., vol. 7, pp. 312-314, 1995.

[14] Tadasi sueta and Masayuki Izutzu, “Integrated optic devices for microwave applications”, IEEE Transaction on microwave theory and techniques, Vol.38, No.5, pp. 477-482, May 1990.

[15] A. Stöhr, O. Humbach, S. Zumkley, G. Wingen, G. David, B. Bollig, E.C. Larkins, J.D. Ralston, D. Jäger, InGaAs/GaAs Multiple Quantum Well Modulators and Switches, Optical and Quantum Electronics, vol. 25, pp. 865-883, (invited paper), 1993

[16] Sauer M,Kojucharow K, Kaluzni H, Sommer D.; Nowak W., Finger A. Sauer , “Radio-Optical System Design and Transmission Experiments for a Mobile Broadband Communications System at 60 GHz”, wireless personal communications, vol. 14 147-163, 2000.

[17] C. Lim, A. Nirmalathas, D. Novak, R. Waterhouse, and K. Ghorbani, "Full-duplex broadband fiber-wireless system incorporating baseband data transmission and a novel dispersion tolerant modulation scheme", Proc. IEEE MTT-S International Microwave Symposium, Anaheim, CA, U.S.A., pp. 1201-1204, June 1999.

[18] Hui, R., B. Zhu, K. Demarest, C. Allen, and J. Hong, "Generation of ultrahigh-speed tunable-rate optical pulses using strongly gain-coupled dual wavelength DFB laser diodes," IEEE Photonics Technology Letters, 11(5), pp. 518-520, 1999.

[19] M. Izutsu, S. Shikama, and T. Sueta, "Integrated. optical SSB modulator/frequency shifter", IEEE. J.Quantum. Electron, Vol. QE-17, No. 11, pp2225-2227, November 1981.

[20] R.-P. Braun . R.-P. Braun, G. Grosskopf, D. Rohde, F. Schmidt, “Low Phase Noise Millimeter-Wave Generation at 64 GHz and Data Transmission Using Optical Side Band Injection Locking”, IEEE Photonics Technology Letters,10, 728-730, (1998).

[21] Huntington, E. H.; Ralph, T. C.; Zawischa, I.” Sources of phase noise in an injection-locked solid-state laser” Journal of the Optical Society of America B: Optical Physics, Volume 17, Issue 2, February 2000, pp.280-292, 2000

[22] L. No¨el, D. Wake, D. G. Moodie, Member, IEEE, D. D. Marcenac, L. D. Westbrook, and D. Nesset “Novel techniques for high-capacity 60-GHz fiber-radio transmission systems” Microwave Theory and Techniques, IEEE Transactions , Aug 1997.

[23] G. P. Agrawal, Nonlinear Fiber Optics, 3rd ed. San Diego, CA: Academic,2001, ch. 10.