Quest Journals
Journal of Electronics and Communication Engineering Research
Volume 2 ~ Issue 4 (2014) pp: 01-06
ISSN(Online) : 2321-5941
www.questjournals.org

Research Paper

Nonlinear Effect of Four Wave Mixing for WDM in Radio-over-Fiber Systems

A.Panda[1], D.P.Mishra[2]

Received 21 March, 2014; **A**ccepted 12 May, 2014 © The author(s) 2014. Published with open access at **www.questjournals.org**

ABSTRACT: *Unlike the linear effects which can be compensated, the nonlinear effects accumulate and degrade the system -performance. The information capacity of a light wave is ultimately limited by the nonlinear interactions between the information signals and the fiber medium. Four wave mixing (FWM) is a type of nonlinear effect which occurs in wavelength division multiplexing (WDM) when light of two or more different wavelengths are launched into a fiber. FWM [1] is a major source of non-linear cross talk since they interfere with the desired signals. The magnitude of FWM depends on channel power, channel spacing and fiber dispersion but is independent of the bit rate. The effect of four wave mixing (FWM) as one of the influential factors in the WDM for RoF has been studied here using Optisystem. The investigation of FWM effect for different parameters has also been done*.

KEYWORDS - *WDM, Four Wave Mixing, Optisystem, RoF, cross talk*

I. INTRODUCTION

Fiber optic communication is a method of transmitting information from one place to another by sending light through an optical fiber. The main benefits of fiber are its exceptionally low loss, allowing long distances between amplifiers, high data carrying capacity, high speed, large capacity and high reliability. Radio over fiber (RoF) is flexible and reliable technology for the integration of wireless and optical networks. RoF technology can support multiple radio services and standards. Normally light waves transmitted through fiber have little interaction with each other but when they interact with the materials transmitting them, this can affect optical signals. These processes generally are called nonlinear effects because their strength typically depends on the square (or some higher power) of intensity rather than simply on the amount of light present [4]. This can lead to distortion, interference and attenuation of the signals, resulting in system degradation. The most important types of nonlinear effects are stimulated Brillouin scattering, stimulated Raman scattering, self phase modulation and Four-wave mixing. Four-wave mixing is a parametric process in which different frequencies interact and by frequency mixing generate new spectral components.[2]

Nonlinear effects are comparatively small in optical fibers transmitting a single optical channel. They become much larger when wavelength division multiplexing (WDM) packs many channels into a single fiber. The main objective of this project is to evaluate the FWM in WDM in order to calculate the impairments associated with long-distance high bit rate optical fiber communication systems and reduce the effect by changing some parameters. In order to achieve the objective, Optisystem software is used in the numerical simulation.

II. WAVELENGTH DIVISION MULTIPLEXING

In Fiber-optic communication Wavelength division multiplexing (WDM) is a technology of transmitting data from different sources over the same link at the same time whereby each data channel is carried on its own unique wavelength. This technique enables bidirectional communications over one strand of fiber, as well as multiplication of capacity.[3]

*Corresponding Author: A.Panda, D.P.Mishra

[1] *Department of Electronics and Communication, GIET, Bhubaneswar, Odisha*
[2] *Department of Electrical and Electronics, IIIT, Bhubaneswar, Odisha*

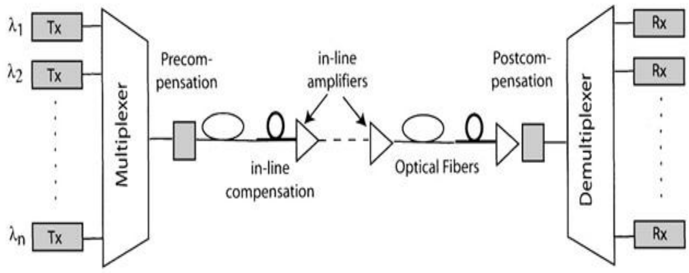

Fig.1: Wavelength Division Multiplexing

One of the major problems related to WDM optical communication systems is FWM (Four wave mixing). [4]

III. FOUR WAVE MIXING

The most common nonlinear optical effect of importance in optical fiber communication systems results from the fiber nonlinear refractive index. The nonlinearity in the refractive index is known as Kerr nonlinearities. FWM is a type of optical Kerr effect which occurs when light of two or more different wavelengths is launched into a fiber.

FWM is a phenomenon that occurs in the case of WDM systems in which the wavelength channel spacing are very close to each other. This effect is generated by the third order distortion that creates third order harmonics. These cross products interfere with the original wavelength and cause the mixing. In fact, these spurious signals fall right on the original wavelength which results in difficulty in filtering them out. In case of 3 channel system, there will be 9 cross products, where 3 of them will be on the original wavelength. This is caused by the channel spacing and fiber dispersion. If the channel spacing is too close, then FWM occurs. [5]

If the dispersion is lesser, then FWM is higher since dispersion is inversely proportional to mixing efficiency. In general, for N wavelengths input channel there will be M cross mixing products and are given by(1):

$$\boldsymbol{M = \frac{N^2}{2}(N-1)} \qquad \textbf{(1)}$$

The number of the interfering products rapidly becomes very large. Since there is no way to eliminate the products that falling on top of the original signals, the priority is to prevent them from forming in the first place.

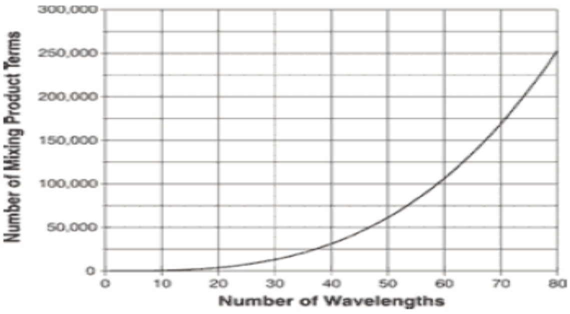

Fig.2: FWM products versus channel count

Therefore the factor that strongly influences the magnitude of the FWM products is channel spacing; where the mixing efficiency increases dramatically as the channel spacing becomes closer. Thus, it is possible to minimize the effects of FWM by increasing the channel spacing.[3]

IV. SIMULATION USING OPTISYSTEM SOFTWARE

Optisystem software is a numerical simulation that enables users to plan, test and simulate almost every type of optical link in the physical layer across the broad spectrum of optical networks. Using Optisystem software, two types of simulation models have been developed to study FWM effects. The two models are with external modulated signal and without external modulated signal.

Direct Modulation:- Here RF signal directly varies the bias of a semiconductor laser diode.

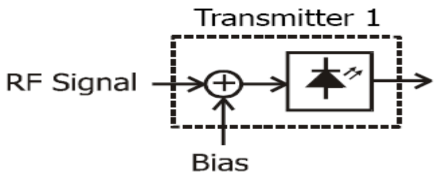

Fig.3: Direct Modulation

External Modulation: Here light is modulated by an external lithium-niobate electro-optic modulator. External modulation is currently preferred over any other form of modulation because it has best performance, in spite of high cost.

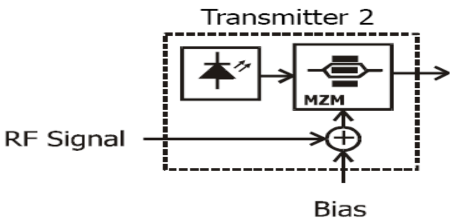

Fig.4: External Modulation

The efficiency of FWM and noise performance is analyzed, taking into account the effects of difference channel spacing. The below equation is presented to evaluate the efficiency of the FWM (2):

$$\eta = \left[\frac{n_2}{A_{eff} D(\Delta\lambda)^2} \right]^2 \tag{2}$$

Equation (3)and (4) given below are used to investigate the relationship between the efficiency and the power of the FWM:

$$P_{ijk} = \left(\frac{\gamma^2}{9}\right)\left(d_{ijk}\right)^2 \left(p_i p_j p_k\right)\exp\left(-\alpha L\right) L^2_{eff}\,\eta \tag{3}$$

$$L_{eff} = \frac{1-e^{-\alpha l}}{\alpha} \tag{4}$$

V. SIMULATION RESULTS FOR TWO SIGNAL SOURCES

In this simulation two CW lasers were used as signals sources. The frequencies were set at 1550 and 1550.1 nm. The channel spacing was set at 0.1. The power level of the input sources was varied from 20 dBm to -10 dBm with step -10 dBm while other parameters were kept unchanged.

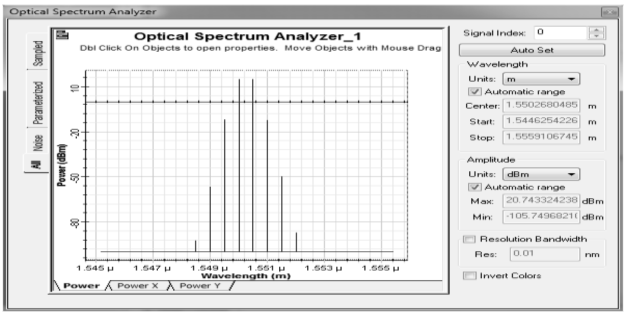

Fig.5: Output of the fiber at input power of 20 dBm

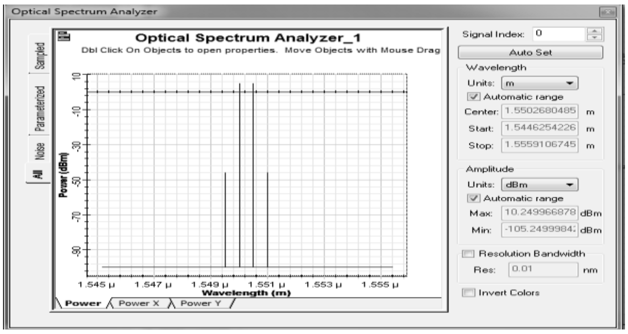

Fig.6: Output of the fiber at input power of 10 dBm

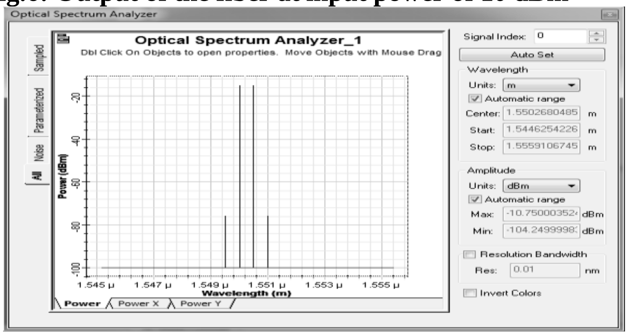

Fig.7: Output of the fiber at input power of -10 dBm

From the above results it is evident that FWM becomes significantly effective at high optical power levels.

Similarly the dispersion parameter of fiber optic was changed from 1.0 ps/nm/km to16.75 ps/nm/km, at input power of 0 dBm. The results were taken at the end of the fiber optic.

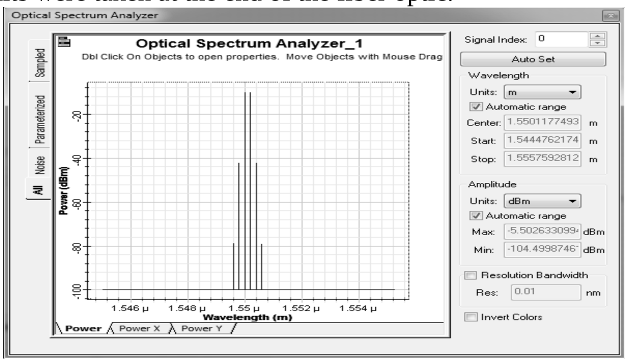

Fig.8: Output of the fiber at dispersion 1 ps/nm/km

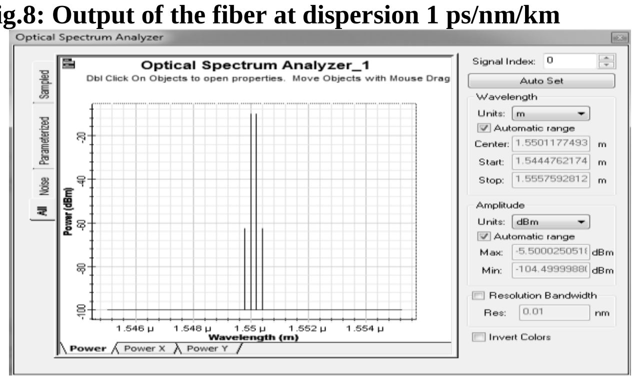

Fig.9: Output of the fiber at dispersion 16.75 ps/nm/km

This result shows that the FWM products were reduced when the dispersion parameter was increased. But the dispersion parameter cannot be set at too high value because it limits bandwidth in the WDM system.[6]

VI. SIMULATION RESULTS FOR EIGHT SIGNAL SOURCES

In this simulation eight CW lasers were used as signals sources. The channel spacing was set at 0.1 nm. The power level of the input sources was varied from 20 dBm to -10 dBm with step -10 dBm while other parameters were kept unchanged.

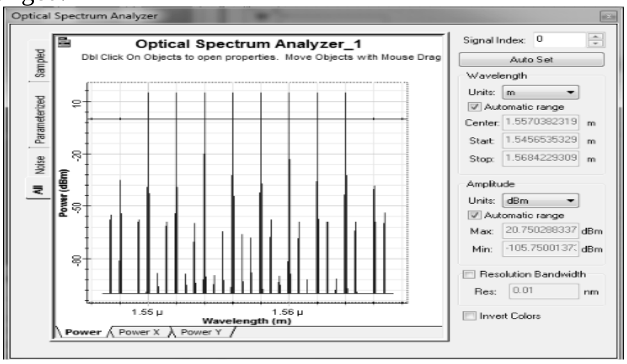

Fig.10: Output of the fiber at input power of 20 dBm

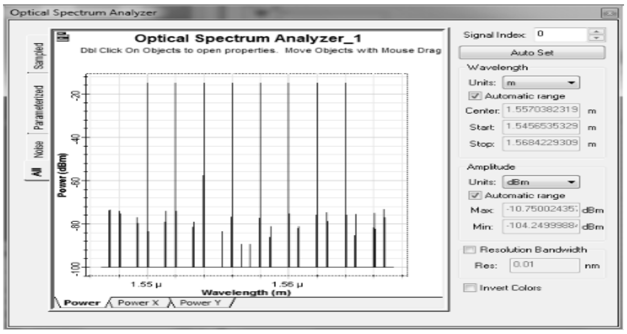

Fig.11: Output of the fiber at input power of 10 dBm

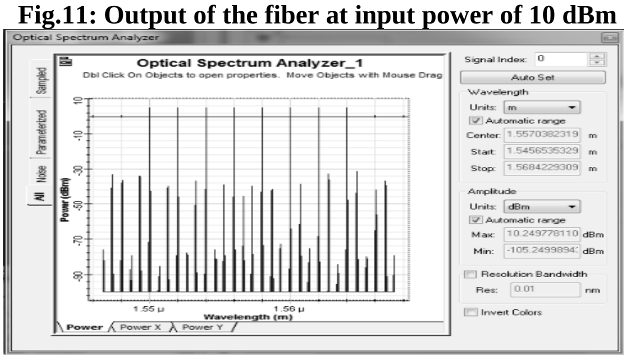

Fig.12: Output of the fiber at input power of -10 dBm

It can be seen that effect of FWM is decreasing for decreased input power.

VII. CONCLUSION

The performance of WDM networks is strongly influenced by nonlinearity characteristic inside the fiber. Therefore the nonlinearity effects of fiber optics pose additional limitation in WDM systems.

The FWM effect has been investigated analytically and numerically simulated. Simple equations to determine the spectral line width, the FWM power due to channel spacing and the power of the FWM components due to the input power have been deduced.

The numerical simulation results obtained have shown the spectral characteristics of the FWM in WDM for RoF where the effects of FWM are pronounced with decreased channel spacing of wavelengths or at high signal power levels.

FWM can be minimized by ensuring that the phase matching does not occur. This has been achieved by increasing the channel separation and supplying low signal power level. The high effective area is also found to decrease FWM effect. It is noticed that the FWM also causes inter-channel cross talk for equally spaced WDM channels. Thus, FWM can be mitigated using unequal channel spacing.

REFERENCES

[1]. D. Marcuse, “Effect of Fiber Nonlinearity on Long- Distance Transmission”, Journal of lightwave technology, 9 (1) (1991)121-128..

[2]. Antti Lamminpää, “Measurement of nonlinearity of optical fiber.” Master thesis, Helsinki University of Technology,

[3]. 2003M. L. F. Abbade, and E. A. M. Fagotto, R. S, “Optical Amplitude Multiplexing Through Four-Wave Mixing in Optical Fibers” Photonics Technology Letters, 17 (1) (2005) 151-153.

[4]. Vrizlynn L. L. Thing, P. Shum, and M. K. Rao, “Bandwidth-Efficient WDM Channel Allocation for Four-Wave Mixing-Effect Minimization”, Transactions On Communications, 52 (12) (2004) 2184-2089.

[5]. S. Betti, M. Giaconi, and M. Nardini, “Effect of Four-Wave Mixing on WDM Optical Systems: A Statistical Analysis”, Photonics Technology Letters, 15(8) (2003) 1079-1081..

[6]. A. V. Yulin, D. V., and P. St. J. Russell “Four-wave mixing of linear waves and solitons in fibers with higher-order dispersion” Journal of light wave technology, 29 (3) (2004) 950-955.