October 2012

Effect of Four Wave Mixing in WDM Systems for Higher number of Channels

A. Panda

GIET Bhubaneswar, India, apanda@gmail.com

D. P. Mishra

IIIT Bhubaneswar Bhubaneswar, India, dpmishra@gmail.com

Follow this and additional works at: <https://www.interscience.in/ijssan>

Part of the [Digital Communications and Networking Commons](#), and the [Electrical and Computer Engineering Commons](#)

Recommended Citation

Panda, A. and Mishra, D. P. (2012) "Effect of Four Wave Mixing in WDM Systems for Higher number of Channels," *International Journal of Smart Sensor and Adhoc Network*: Vol. 3 : Iss. 1 , Article 13.

DOI: 10.47893/IJSSAN.2013.1197

Available at: <https://www.interscience.in/ijssan/vol3/iss1/13>

This Article is brought to you for free and open access by the Interscience Journals at Interscience Research Network. It has been accepted for inclusion in International Journal of Smart Sensor and Adhoc Network by an authorized editor of Interscience Research Network. For more information, please contact sritampatnaik@gmail.com.

Effect of Four Wave Mixing in WDM Systems for Higher number of Channels

A.Panda
ECE, GIET
Bhubaneswar, India

D. P Mishra
EEE, IIT Bhubaneswar
Bhubaneswar, India

ABSTRACT

The integration of wireless and optical networks increases the capacity and mobility as well as decreases costs in the access networks. However, there are nonlinearity and obstacles preventing them from being perfect media. A serious issue for WDM systems is the presence of resonant four wave mixing (FWM) terms, as a result of interactions between different channels. FWM presents a major source of non-linear cross talk since they often fall near or on top of the desired signals. So the best solution is to avoid the FWM generation from early design stages. 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 with different number of channels at various channel spacing has also been done. The simulation results reveal that the less number of users at input cause less FWM but in today's technology, it is important for the circuit to handle WDM.

Keywords: WDM, Four Wave Mixing, Optisystem

1. 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. Normally light waves transmitted through fiber have little interaction with each other, and are not changed by their passage through the fiber. However, there are exceptions arising from the interactions between light waves and the material transmitting them, which 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]. The nonlinear effects degrade the system performance. 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. The magnitude of FWM depends on channel power, channel spacing and fiber dispersion but is independent of the bit rate. 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. In order to achieve the objective, Optisystem software is used in the numerical simulation.

2. WAVELENGTH DIVISION MULTIPLEXING

Wavelength division multiplexing (WDM) is a method of transmitting data from different sources over the same fiber optic link at the same time whereby each data channel is carried on its own unique wavelength. WDM technology can maximize the use of the fiber optic infrastructure that is available what would normally require two or more fiber links instead requires only one.

Fig.1: Wavelength Division Multiplexing

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

2.1 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. 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

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.

2.2 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. Equation is presented to evaluate the efficiency of the FWM.

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

2.3 Simulation Results for Four Signal Source without External Modulated Signal

In this simulation four CW lasers were used as signals sources, the frequencies were set at 1550, 1550.1 1550.2 and 1550.3 nm, where as the power was set at 0 dBm. The channel spacing was set at 0.1 nm.

Fig.5: input of the fiber when channel spacing is 0.1 nm

Fig.6: output of the fiber when channel spacing is 0.1 nm

In this simulation four CW lasers were used as signals sources, where as the power was set at 0 dBm. The channel spacing was set at 0.5 nm.

Fig.7: input of the fiber when channel spacing is 0.5 nm

Fig.8: output of the fiber when channel spacing is 0.5 nm

Therefore, as the spacing between channels is increased the effect of the FWM is decreased.

2.4 Simulation Results for Four Signal Source with External Modulated Signal

In this simulation four CW lasers were used as signals sources, the frequencies were set at 1550, 1550.1 1550.2 and 1550.3 nm, where as the power was set at 0 dBm. The channel spacing was set at 0.1 nm.

Fig.9: input of the fiber when channel spacing is 0.1 nm

Fig.10: output of the fiber when channel spacing is 0.1nm

Here four CW lasers were used as signals sources, where as the power was set at 0 dBm. The channel spacing was set at 0.5 nm.

Fig.11: input of the fiber when channel spacing is 0.5 nm

Fig.12: output of the fiber when channel spacing is 0.5 nm

2.5 Simulation Results for Eight Signal Source without External Modulated Signal

In this simulation eight CW lasers were used as signals sources. The channel spacing was set at 0.1 nm.

Fig.13: input of the fiber when channel spacing is 0.1 nm

Fig.14: output of fiber when channel spacing is 0.1 nm

Fig.15: input of the fiber when channel spacing is 0.5 nm

Fig.16: output of fiber when channel spacing is 0.5 nm

Therefore, as the spacing between channels is increased the effect of the FWM is decreased.

3. CONCLUSION

Based on the results presented, it can be seen that the FWM effects increase as the number of channels is increased. The number of spurious signals due to FWM increases geometrically and is given by

$$M = (N^3 - N^2)/2$$

Where N is the number of channels and M is the number of the newly generated sidebands. The newly generated mixing products have high possibilities to fall directly on the original signal which could produce crosstalk. Therefore, as the spacing between channels is reduced or remained equal the effect of the crosstalk is found to become greater. When the spacing between the channels is unequal, it shows that the mixing products have low power level and they will not fall on the original signal, which makes them easy to be filtered, and in turn improve the system performance.

4. REFERENCES

- [1] D. Marcuse, "Effect of Fiber Nonlinearity on Long-Distance Transmission", *Journal of lightwave technology*, 9 (1) (1991)121-128..
- [2] M. 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.
- [3] 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.
- [4] 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..