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# Suppression of Four Wave Mixing Based on the Pairing Combinations of Differently Linear-Polarized Optical Signals in WDM System

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**Abstract:** Data transmission in optical systems and increased transmission distance capacity benefit by using optical amplification wavelength division multiplexing (WDM) technology. The combination of four waves (FWM) is a non-linear effect in the wavelength division multiplex (WDM), when more than two wavelengths of light in a fiber launch will occur. FWM amount depends on the channel, the channel spacing and dispersion fiber, but is independent of the bit rate. A simple equation for the spectral line width is shown. Dispersion causes distortion of the transmitted signals and needs to be compensated to achieve a long-haul system. The four-wave mixing effect have been studied as one of the factors influencing by using OPTISYSTEM Software. In this paper, a new approach for suppressing the four-wave mixing (FWM) crosstalk by using the pairing combinations of differently linear-polarized optical signals is investigated. The simulation is conducted using an eight-channel system. The proposed technique is to suppress the FWM interaction using different input powers. It has been evaluated for single-mode fiber (SMF). FWM can be strongly reduced, when the polarization technique is conducted for SMF. We also compare our new method with a conventional method to demonstrate the effect of FWM as well. The comparison was conducted at an input power range of 2 dBm. Decreasing the input power can decrease the FWM effects. In the absence of the polarization technique the FWM power was –64 dBm at an input power of 2 dBm. The FWM power decreased to less than -82 dBm at a 2 dBm input power. The system performance greatly has been improved.

**Keywords:** four wave mixing, linear polarization, wavelength-division-multiplexing, dispersion.

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## 1. Introduction

Data transmission in optical systems and increased transmission distance capacity benefit by using optical amplification wavelength division multiplexing (WDM) technology. Four wave mixing is one of the most important non-linear signals effects in channels with different wavelengths. Indeed, the third harmonic generation is known as a four wave mixingphenomenon. During this process three waves with $\omega_1$ , $\omega_2$and$\omega_3$ are mixed together and the waves generate their sum and difference frequency. Generally, transmitting multiple frequencies together in fiber and interacting these frequencies with each other will produce new components. These undesirable components are often destructive on different bands, including, principal components will appear and on the other hand interfere channels. The most important factors in increasing FWM include:

- Increase channel power.
- Low chromatic dispersion.
- Low frequency channels.

Dispersion effect in reducing the FWM is remarkable. Hence, in optical fiber transmission systems there is never zero dispersion. However, dispersion causes distortion of the transmitted signals and needs to be compensated to achieve a long-haul system. As the channel count increases, more channels have to be confined to the erbium-doped fiber amplifier. This condition increases the FWM effects and has a negative effect on the FWM suppression methods. Increased channel separation would prevent the implementation of a dense WDM. Similarly, reducing the levels of FWM crosstalk by choosing unequal channel frequency spacing may not be a practical option because this technique also needs additional optical bandwidth [1,2].

By contrast, orthogonal polarization has recently been found to reduce the FWM crosstalk. The FWM time average power strongly depends on the relative polarization states of the mixing channels. The researcher has reduced the FWM by randomly adjusting the polarization state of the adjacent channels to be orthogonal to one another [3-5].

In this work, we combined pairs of channels with different polarizations. The first channel was polarized by a linear polarization of $45^0$, while the second channel was polarized at $90^0$ away by a linear polarization of ($45^0$+$90^0$). Both of the polarized channels were combined using a polarizer combiner. The proposed technique was investigated in both single-mode fiber (SMF) with a 70 km fiber length and eight channels. The results confirm the robustness of the polarization technique in comparison with the FWM crosstalk and show that the FWM crosstalk has no negative influence on the system performance, even at a high value of input power.

## 2. Four Wave Mixing

Four-wave mixing (FWM) also known as four photon mixing (FPM) is a parametric process in which different frequencies interact and by frequency mixing generate new spectral components FWM efficiency dependson channel power, channel spacing and fiber dispersion but is independent of the bit rate[6].

Four-Wave Mixing (FWM) is one of the nonlinear effects, also known as Kerr effects. It originates from nonlinear refraction which is a phenomenon that refers to the intensity dependence of the refractive index. FWM is the third-order nonlinearpolarization process in which three waves of frequencies $f_i$, $f_j$, and$f_k (k \neq i, j)$interact through the third order electric susceptibility of the opticalfiber to generate a wave of frequency[7].

$$f_{ijk} = f_i + f_j - f_k \quad (1)$$

Thus, three co propagating waves give rise, by FWM, to nine new optical waves. The output power $P_{pqr}$of the FWM product is given by:

$$P_{pqr} = \frac{\gamma^2}{9} d_{pqr}^2 P_p P_q P_r e^{-\alpha l} L_{eff}^2 \quad (2)$$

Where:

$P_{pqr}$is the output power of the FWM product.

$\boldsymbol{\gamma}$is the non-linear co-efficient of the fiber.

$d_{pqr}$is the degeneracy factor.

$\alpha$is the fiber loss co-efficient.

$L_{eff}$is the effective length of the fiber.

ɳ is the mixing efficiency.

In a WDM system, this is because of every possible choice of the three channel waves (Figure 1).

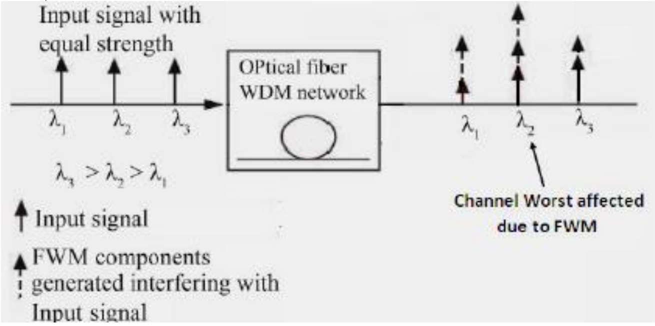
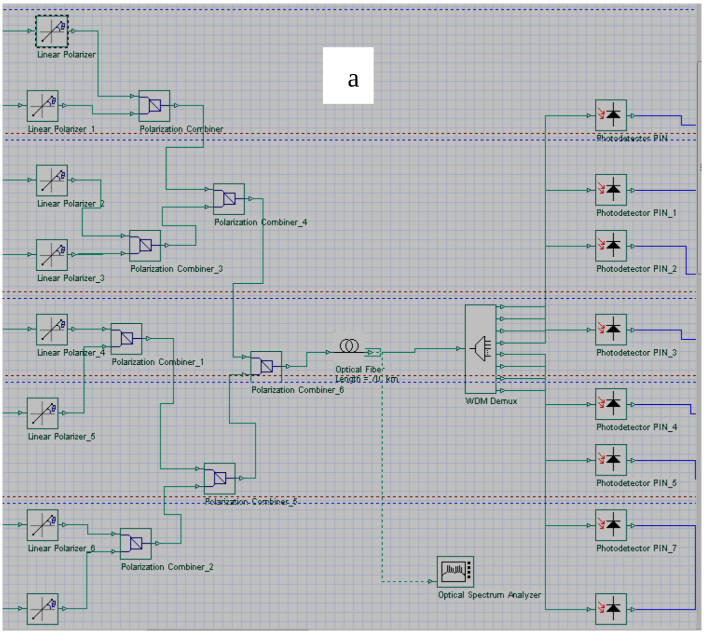



Fig. 1. FWM effect in an optical WDM network

It is experimentally observed that four wave mixing reaches to its maximum value when the chromatic dispersion of the fiber is zero.

## 3. Simulation Setup

Figure 2(a-b) describes the proposed and conventional system configuration of the transmitter and receiver. At the transmitter part,the array of continuous wave lasers ($L_1 - L_8$) is used to generate the carrier signal.The frequency of the first user is set to 193 THz, and the spacing between each user is 100GHz. The array laser sources are connected to an external modulator. The external modulator comprised a Pseudo–Random Bit Sequence (PRBS), which is connected to a pulse generator to modulate the optical signals using an NRZ modulation format. It is then connected to the Mach-Zehndermodulator (MZM), which acts as an intensity modulator. In the proposed system simulation, each two channels are linearly polarized $90^0$ apart and then combined together. As shown in Figure (2-a), the first channel is polarized using a linear polarization of $\theta = 45^0$ , while the second channel is polarized using a linear polarization of $(\theta + 90^0)$. Each two channels are combined using a polarizer combiner that combines the two input signals to one output port. Then the eight signals are collected using a polarizer combiner with a $0^0$ polarization angle.The combined signals pass through optical fiber with a 70 km length. At the receiver, the signal isdemultiplex andit is detected by a PIN photodiode for direct detection. It is then passed through the low-pass Bessel used to generate the graph.



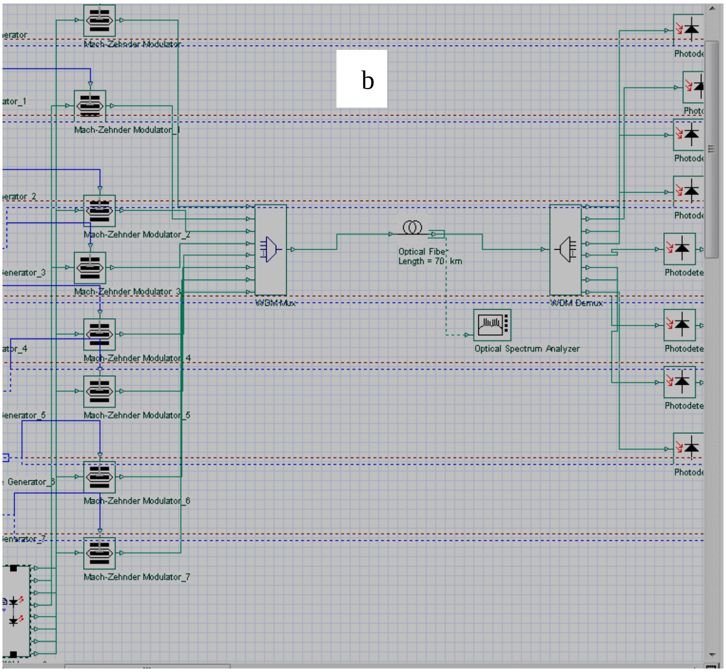


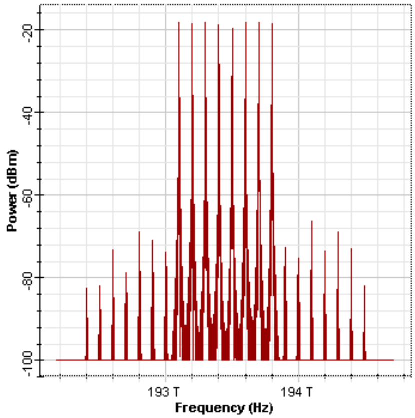

Fig.2. (a) Optical system simulation configuration, (b) conventional system.

***Results and Discussions***

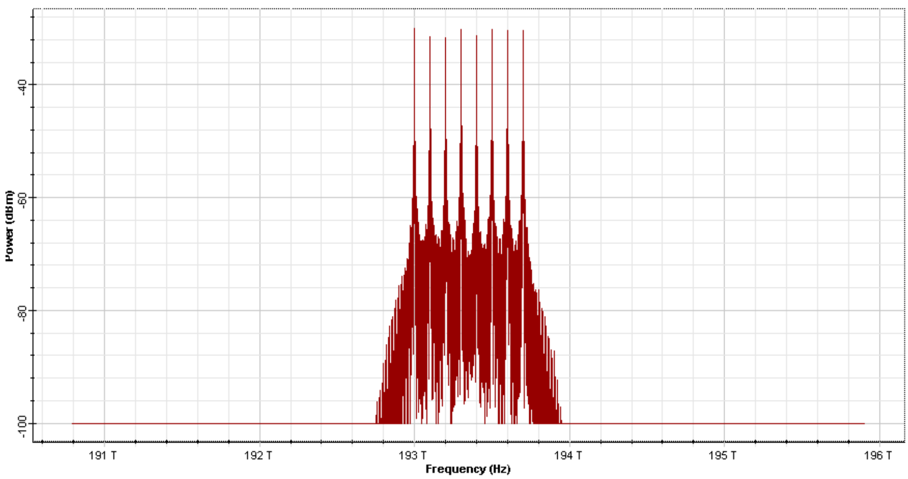
The proposed polarization technique is compare with the conventional method (without using the polarization) and examined with SMF. The comparison was conducted at an input power range of 2 dBm. Decreasing the input power can decrease the FWM effects. In the absence of the polarization technique, the FWM power was -64 dBm at a 2 dBm input power. With the proposed technique, the FWM numbers and power dramatically reduced. The FWM power decreased to less than -82 dBm at a 2 dBm input power.

## 4. Conclusion

This paper demonstrates the effective results of the polarization approach schemes for the suppression of FWM power. We propose an efficient approach for reducing the transmission limitation caused by the FWM in a WDM system by using the pairing combinations of differently linear–polarized optical signals. The FWM behavior and system performance were evaluated with the proposed technique. The FWM powers are suppressed with this technique.Using polarization approach significantly reduced the FWM crosstalk through fiber transmission. The obtained results also show that in the existence of the polarization approach, the FWM crosstalk has no dangerous effect, even with a high input optical power.




(a)




(b)

Fig. 3. Optical spectrum comparison after 70km SMF, (a) without polarization technique at input power of 2dBm, (b) with polarization technique at input power of 2dBm.

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