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Comparative Performance Analysis of FWM Effect in DWDM System

[I]Priyanka Rani, [II]Hardeep Singh
[I,II]Dept. of Electronics and Communication Engineering, Thapar University, Patiala, India

Abstract

The developments made in DWDM system on one side increases speed, transmission distance, channel traffic and on other side produces non lineareffects which degrades the system performance. The four wave mixing effect is most dominating factor in dense wavelength division multiplexing system. This paper proposes a strategy to determine the single and combined effect of input power, effective area, length of fiber and channel spacing on FWM in Dense Wave Length Division Multiplexing (DWDM) optical communication system. The simulation is carried with eight channels in Optisystem software. Results show that increasing fiber length, effective area, channel spacing and decreasing input power reduces four wave mixing power to -70dBm. BER and Q factor are estimated using BER analyser at the receiver side

Keywords

Dense Wavelength Division Multiplexing System, Four Wave Mixing, Non Linearities, Fiber Optic Communication System, Bit Error Rate, Channel Spacing

I. Introduction

Fiber-optic communication is a method of transmitting information from one position to another by transferring pulses of light through an optical fiber. Information of multiple channels can carry over a single fiber in Dense Wavelength Division Multiplexing with channel spacing as 1.5nm. The fiber nonlinearities and dispersion are the main factors which degrades the performance of optical fiber communication system. Fiber nonlinearities become a problem when number of wavelengths, data rate, transmission distance without repeater and optical power levels are increased. There are two types of fiber nonlinearities. One type is intensity dependentand generated due to stimulated processthat are stimulatingRaman scattering andstimulating Brillouinscattering. Self Phase Modulation (SPM), Cross Phase Modulation (XPM) and Four Wave Mixing (FWM) fall under the second category of fiber non linearity.FWM is third order non linearity and one of the major limiting factor in DWDM system. In FWM when two or more signal travels in a fiber, interaction between these two signals generates a new signal. Let f_a, f_b and f_c be three frequencies which on combined together produces fourth frequency f_{abc} i.e

$f_{abc}=f_a \pm f_b \pm f_c$

The worst combination from the above four combinations is $f_a f_b - f_c$ which degrade the system performance. The f_{abc} is four wave signal or interfering signal. The number of newly generated side bands in FWM is given by:

$$M = \left(N^3 - \frac{N^2}{2} \right)$$

Where N is the number of channels and M is newly generated side bands. Like we are using eight channels in simulation set up therefore newly generated side bands are 224. The four wave mixing power generated due to interaction of channels at frequencies f_i, f_j and f_k is given by:

$$P_{FWM} = \eta\{1024\,\Pi^6/n^4 \lambda^2 c^2\}\left\{\frac{DX3\,Leff}{Aeff}\right\}^2 P_i P_j\, P_k e^{-\alpha L}$$

Where η is four wave mixing efficiency, n is refractive index of core, L is length of fiber, c is velocity of light in free space, λ is wavelength, X_3 is non linear susceptibility, D is degeneracy factor whose value is 1,3and 6 for $f_i=f_j=f_k$, $f_i=f_j\neq f_k$ and $f_i\neq f_j\neq f_k$ respectively, α is attenuation coefficient, A_{eff} is effective area of fiber and L_{eff} is effective length of fiber. Four wave mixing can limit the bandwidth and the data rate. By increasing the input power and changing the refractive index FWM product increases. When new frequencies overlap the original frequency, it causes sharp crosstalk between channels passing through an optical fiber. When the number of WDM channels increase and have small spacing degradation becomes very severe. FWM can be reduced by using unequal channel spacing, decreasing the input power, decreasing number of channels, increasing the channel spacing, decreasing the input power. This paper, proposed methods for the suppression of FWM and compared the results with existing methods like: equal channel spacing and unequal-channel spacing.

II. Simulation Setup

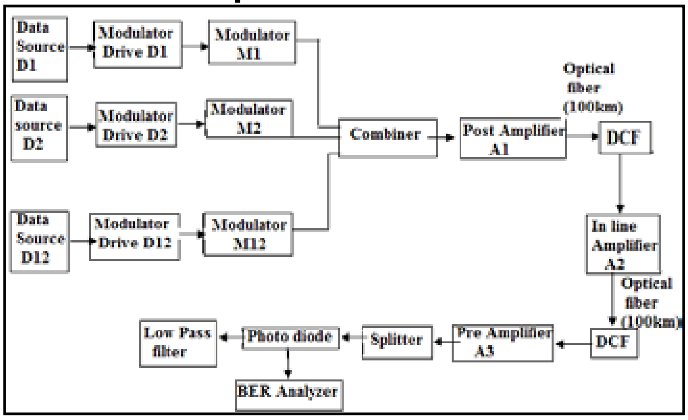

Fig. 1: Simulation Setup

Fig. 1 shows system setup for eight-channel 120 Gbps DWDM transmission link. The optical transmitter consists of 8 continuous wave Semiconductor laser sources to create the carrier signal. The data Sources d1 to d8 is externally modulated by D1 to D8 modulator drivers respectively.PRBS generator generates pseudo random bit sequence at the bit rate of 15Gbps with 2^7 -1 bits. This bit sequence is fed to RZ pulse generator to generate RZ sequence. Modulator driver decides the input data format.The RZ cosine data format is used here. The modulated data from M1 to M8 is combined in multiplexer/combiner. To evade losses from fiber post amplifier is used. After amplification signal goes to optical fiber.

Then non linear effects, dispersion and attenuation are activated. Then Dispersion Compensation Fiber (DCF) is used to neglect the dispersion and to introduce phase mismatching in the signals. Then In line amplifier is used to amplify the signal. Then again signal goes through fiber and dispersion compensating fiber. Then pre amplifier is used before the splitter/demultiplexer. Splitter split the signals into the same number of signals as they were combined. Then optical to electrical conversion is done using photodiode. BER analyzer is used to estimate the BER and Q factor. Then signal is passed through low pass filter and final result is obtained.

III. Methodology

Case-1: Fiber Length

Increasing the fiber length reduces the four wave mixing power. Fig 2 shows the FWM power is reduces to -84 dBm when length of fiber is 150 km while FWM power is -52dBm at 10 km.

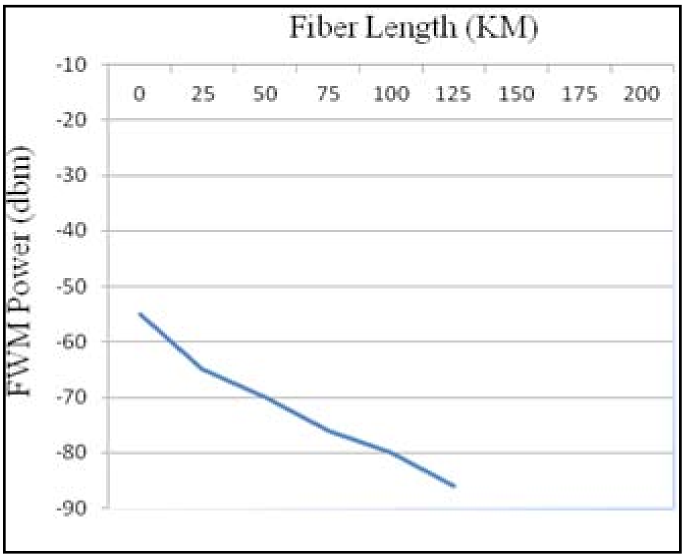

Fig. 2: FWM power against fiber length

Case-2: Input Power

Decreasing the input power reduces the four wave mixing Power. Fig 3 shows FWM power is reduces to -86 dBm when input power is -5 dBm while FWM power is -48 dBm at 10 dBm power.

Case-3: Effective Area

Increasing the effective area decreases the four wave mixing power because effective area is inversely proportional to input power. Fig 4 shows FWM power isreduces to-82 dBm wheneffective area is 80 m^2while FWM power is -70 dBmat 45m^2

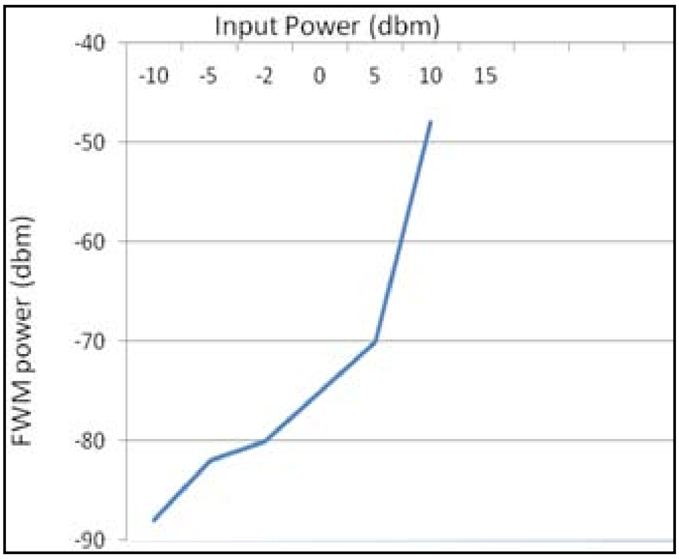

Fig. 3 FWM Power against Input Power

Case-4: Combined effect of Input power and Fiber Length

Decreasing the input power and increasing the fiber length can reduce the four wave mixing power. Fig 5 shows FWM power isreduces to -56 dBmat fiber length of 25km and input power of 0.08 W while FWM power is -22 dBm at fiber length of 10 km and input power of 0.08W

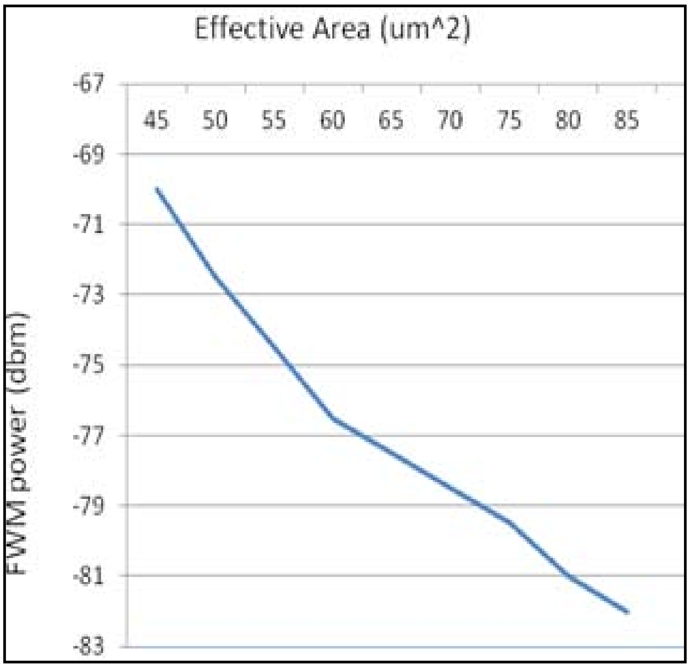

Fig 4: FWM Power against effective area

Case-5:Combined effect of Input Power, Fiber length and Channel Spacing

Fig 6 shows FWM power is reduces to -70 dBm at fiber length of 25 km and input power 0.08 W with increased channel spacing while FWM power is -37 dBm at 10 km.

As compared to case 3 FWM power reduces to -70 dBm from -56 dBm Therefore combined effect of decreasing input power, increasing channel spacing and fiber length reduces FWM power from 4% to 12%.

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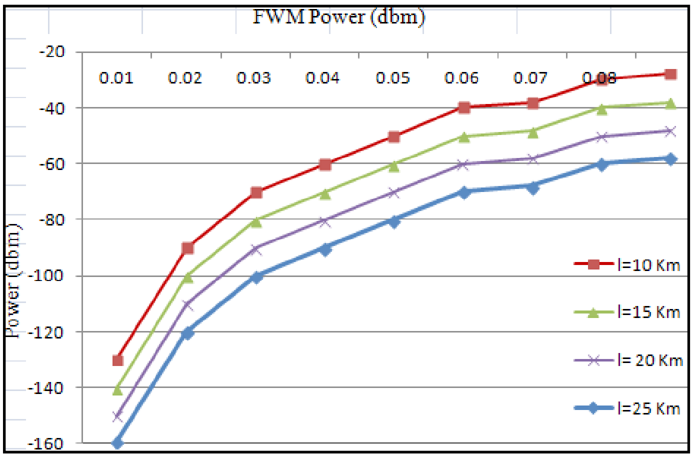

Fig 5: FWM Power against input power for different lengthof fiber

In this paper single and combined effect of various parameter such as fiber length effective area,inpu power and channel spacing have been analyzed to determine the effectiveness of FWM power. DWDM system with 120Gbps is implemented in the presence FWM to calculate and compare the BER, Q-factor and FWM power. Decreasing the BER and increasing the Q factor, decreases the four wave mixing effect and increases the system performance. is interesting to note that increasing the fiber length + effective area + channel spacing + decreasing the input power is the optimum approach to reduce the effect of four wave mixing power to lowest value. FWM power is reduced to 20% as compared to individual parameters.

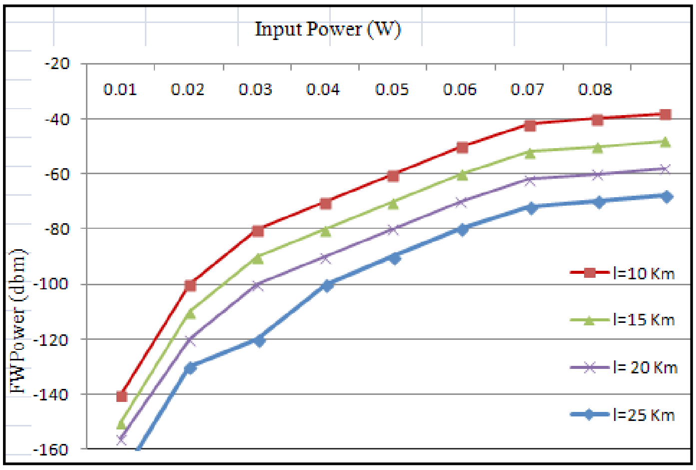

Fig 6: FWM Power against input power for different Length of fibers with increased channel spacing

III. Results And Discussion

Simulation software Optisystem 13.0 is used to evaluate and compare the performance of the proposed DWDM system in the presence of Four Wave Mixing under the impact different parameters.

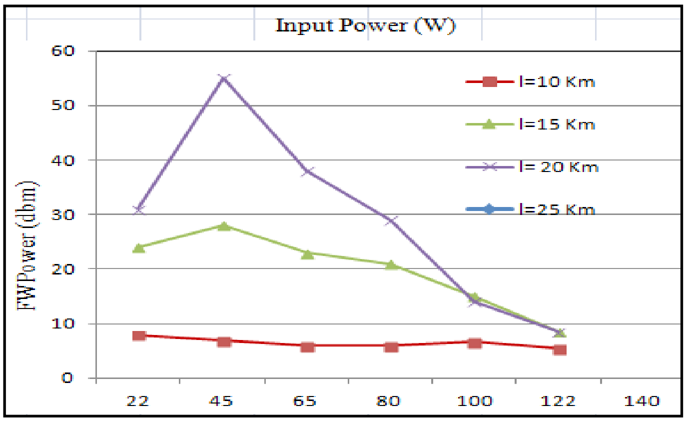

Fig 7: Comparison of Q factor and Fiber length for different channel spacing

The performance of system is measuredby measuring Q factor and BER using BER analyzer at the receiver. As shown in fig 7 Q factor decrease as fiber length increases.Fig 7 shows with increase in input power Q factor decrease. But Q factor increase with large channel spacing. Fig 8 shows the variation of Q factor with input channel spacing. Q factor decreases as channel spacing decreases and increases with increasing channel spacing. As shown Q factor is maximum at channel spacing of 100 GHz and minimum at channel spacing of 25 GHz

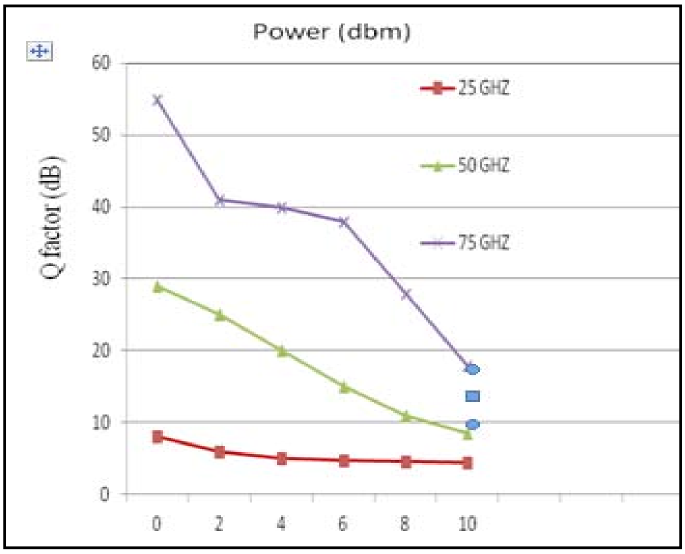

Fig 7: comparison of Q factor and input Power for different channel spacing.

IV. Conclusion

In this paper single and combined effect of various parameter such as fiber length effective area,inpu power and channel spacing have been analyzed to determine the effectiveness of FWM power. DWDM system with 120Gbps is implemented in the presence FWM to calculate and compare the BER, Q-factor and FWM power. Decreasing the BER and increasing the Q factor, decreases the four wave mixing effect and increases the system performance. is interesting to note that increasing the fiber length + effective area + channel spacing + decreasing the input power is the optimum approach to reduce the effect of four wave mixing power to lowest value. FWM power is reduced to 20% as compared to individual parameters.

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Author's Profile

Priyanka Rani: Pursuing Master of Engineeringinelectronicsandcommunication engineering (ECE specialization) from Thapar University Patiala,Punjab, India. Research interest area is optical fiber communication.