Analysis of FWM Effect in Multichannel Optical Communication System

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Abstract

Long haul multichannel optical communication system is extremely affected by crosstalk due to Four wave mixing (FWM). The FWM effect depends on channel separation and number of channels. The paper presents the design and performance analysis of FWM effect on bit error rate, Q-factor, output spectrums and eye opening by varying channel spacing and number of channels. Results show that FWM effect reduces with increase in channel spacing and decrease in number of channels. Further it can be reduced by unequal channel spacing.

Index terms— four wave mixing, wavelength division multiplexing, bit error rate

1 INTRODUCTION

In order to meet the huge capacity demands imposed on the core transmission network by the explosive growth in data communications the number of optical channels in dense-WDM optical networks is being increased. Since the gain bandwidth of EDFAs is limited, these requirements for a very large number of channels mean that the channel spacing will have to be small. The current ITU grid specifies 100 GHz channel spacing, but systems are being considered with 50 GHz to 25GHz channel spacing. At these spacing, the nonlinear effects of the optical fiber can induce serious system impairments. Four-Wave-Mixing (FWM) is another non linear effect that can limit the performance of WDM systems [1].

When high power optical signal is launched into a fiber Linearity of optical response is lost. Four-wave is due to changes in the refractive index with optical mixing power called optical Kerr effect. Four-wave mixing (FWM) is a parametric process in which different frequencies interact and by frequency mixing generate new spectral components. When new frequencies fall in the transmission window of original frequency it causes severe cross talk between channels propagating through an optical fiber. Degradation becomes very severe for large number of WDM channels with small spacing. In this paper, we have simulated the effect of FWM products in WDM environment by varying the channel spacing and number of channels.

2 II.

3 FOUR WAVE MIXING

Four-wave mixing (FWM) is a type of optical Kerr effect, and occurs when light of two or more different wavelengths is launched into a fiber. Fig. 1 is a schematic diagram that shows four-wave mixing in the frequency domain. As can be seen, the light that was there from before launching, sandwiching the two pumping waves in the frequency domain, is called the probe light (or signal light). The idler frequency f idler may then be determined byf idler = f p1 + f p2 -f probe (1)

Where f p1 and f p2 are the pumping light frequencies, and f probe is the frequency of the probe light [3]. This condition is called the frequency phasematching condition. Fig. 1 : Two channel pump wave FWM can have important deleterious effects in optical fiber communications, particularly in the context of wavelength division multiplexing where it can cause cross-talk between different wavelength channels, and/or an imbalance of channel powers [4].

FWM can transfer data to a different wavelength. A continuous wave pump beam is launched into the fiber together with the signal channel. Its wavelength is chosen half-way from the desired shift. Year ptical fibers in telecommunication systems now carry more channels and higher optical powers than ever before. Systems are operating in which the fiber carries such a high optical power density that signals can modify the transmission properties of the fiber. An optical channel can then affect how it and other channels propagate through the fiber -leading to nonlinear effects. By the term nonlinear, we mean that the optical signal leaving the fiber at a given wavelength no longer increases linearly with the input power at that wavelength.

O FWM transfers the data from signal to the idler beam at the new wavelength [5,7,9]. Applications of FWM:

i. Parametric amplification. ii.

Optical phase conjugation. iii.

Demultiplexing of OTDM channels. iv.

Wavelength conversion of WDM channels. v.

Super-continuum generation.

Four-wave mixing (FWM) (also called fourphoton mixing) is one of the major limiting factors in WDM optical fiber communication systems that use the low dispersion fiber or narrow channel spacing. Normally, multiple optical channels passing through the same fiber interact with each other very weakly. In the FWM effect, three co-propagating waves produce nine new optical sideband waves at different frequencies. When this new frequency falls in the transmission window of the original frequencies, it causes severe cross talk between the channels propagating through an optical fiber.

The number of the side bands due to the FWM increases geometrically, as shown in Fig. 2.

4 SCHEMATIC MODEL

The transmitter section consists of a laser, modulator driver, pn-sequence generator i.e. data source and modulator. The wavelength of various channels is set by keeping the difference equal to the spacing required. Then all these transmitted signals are combined/multiplexed together. Then the combined signal is amplified so that it can be transmitted over long distances without its degradation. Then the signal is transmitted over the non linear fiber which adds the nonlinearities into the signal. At the receiver side, the signal is demultiplexed. The receiver consists of a photodiode and a filter. The data source is used to generate the random input data bit sequence at the rate of 10 Gbps. The light signal modulates the input data. The modulator is driven by the modulator driver which decides the input data format. The input data format used here is NRZ raised cosine. The modulated data from all the users is combined using a combiner. The post amplifier amplifies the signal before allowing it to enter into the fiber to avoid losses. Then this signal is sent over the fiber. At the receiver, the signal is demultiplexed by using optical splitter which splits this signal into the same number of signals as were transmitted. The photodiode is used for optical to electrical conversion. Then the signal is passed through the Raised cosine filter and the final output signal is received. An optical scope is attached at the output of combiner to examine the input signal. Another optical scope is placed at the output of splitter to examine the four wave mixing effect in frequency spectrum. An electrical scope is kept at the receiver output to examine the eye diagram. Initially the four wave mixing effect has been compared for different values of channel spacing and the performance has been evaluated in terms of output spectrums, eye diagrams, BER, eye opening and Q-factor. Here, all the channels are spaced evenly but at different values like 20 GHz, 30GHz, 50GHz, 70 GHz, 75 GHz, 90GHz and Also FWM effect is analyzed for unequal channel spacing and by varying the number of channels in WDM system.

V. Using simulation setup, the value of BER, Qfactor, eye diagrams, input and output optical spectrums are measured. Optical scope measures the input and output wavelength spectrums. BER, eye diagrams and Q-factor is measured at the receiver output by using an electrical scope, Q estimator and BER estimator. shows the input optical spectrum for the spacing of 20 GHz between input channels. On changing the spacing between the different users, the peaks get shifted to the frequencies as specified in the laser. It is observed that there are no unnecessary side peaks at the input of the fiber. There are eight input channels so eight peaks appear in the input spectrum. The above spectrums shows that as the spacing between the input channels increases, the four wave mixing effect goes on decreasing. The unwanted peaks are more when the spacing is 20GHz and are less when the spacing is 95GHz. This shows that lesser the spacing between different input channels, more is the interference between the input frequencies i.e. more is the four wave mixing effect. On increasing the spacing between the input channels, the four wave mixing decreases. The comparative study of all the measured parameters for different channel spacing is as given in Table **??**.

5 RESULTS AND DISCUSSION

6 CONCLUSION

In this paper, the design, implementation and performance analysis of four waves mixing in optical communication system on the basis of channel spacing and number of channels is presented. The comparison of four wave mixing effect at various values of channel spacing revealed that 95 GHz spacing has the edge over 20 GHz spacing in optical communication system. It is found that spacing of 95GHz has the lowest BER Fig. 22 : Q factor Vs number of channels and better system performance. In a WDM system if channels are equally spaced, the new waves generated by FWM will fall at channel frequencies and thus will give rise to crosstalk. Also much channel spacing is blocked by bandwidth constraints so channel spacing must be optimized. Also FWM effect increases as number of channels increases. Hence, the higher spacing values between the input channels are recommended for long distance transmission without four wave mixing. It can be seen from the graphs of BER, Q-factor and eye opening that higher channel spacing gives the best performance as compared to lower channel spacing. Hence, it is concluded that higher channel spacing is best suitable to be employed in the optical communication systems minimizing the four wave mixing effect. Also further improvement in FWM effect can be achieved by unequal channel spacing. The results are in accordance with the study reported in [3,8].

In the transmission of dense wavelengthdivision multiplexed (DWDM) signals, FWM is to be avoided, but for certain applications, it provides an effective technological basis for fiber-optic devices. A tradeoff between advantages and disadvantages of FWM effect can be achieved by proper system design to utilize its potential to the fullest. [1] [2] [3] [4] [5] [6]

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Figure 1: Fig. 2 :

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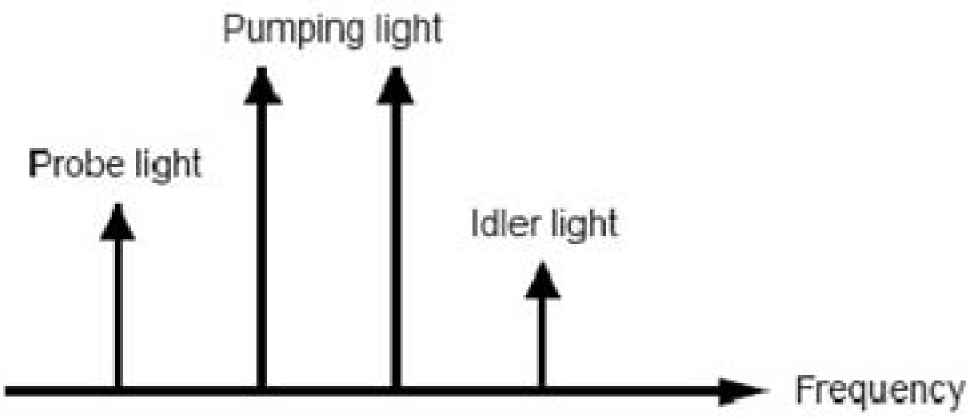

Figure 2: Fig. 4 :

[1] F © 2013 Global Journals Inc. (US)

[2] F © 2013 Global Journals Inc. (US) 95GHz.

[3] F © 2013 Global Journals Inc. (US)fiber.

[4] F © 2013 Global Journals Inc. (US)

[5] F © 2013 Global Journals Inc. (US)

[6] F © 2013 Global Journals Inc. (US)

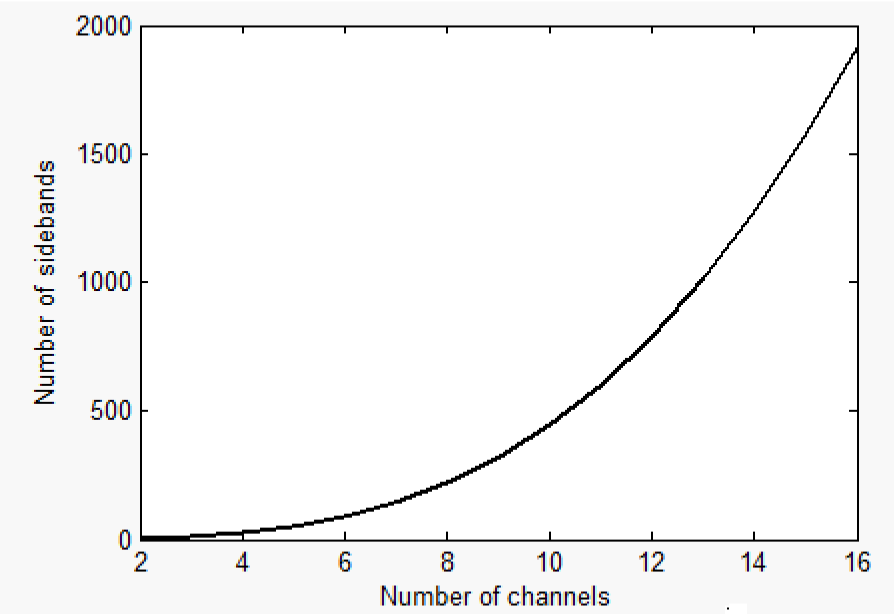

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Figure 3: Fig. 5 (

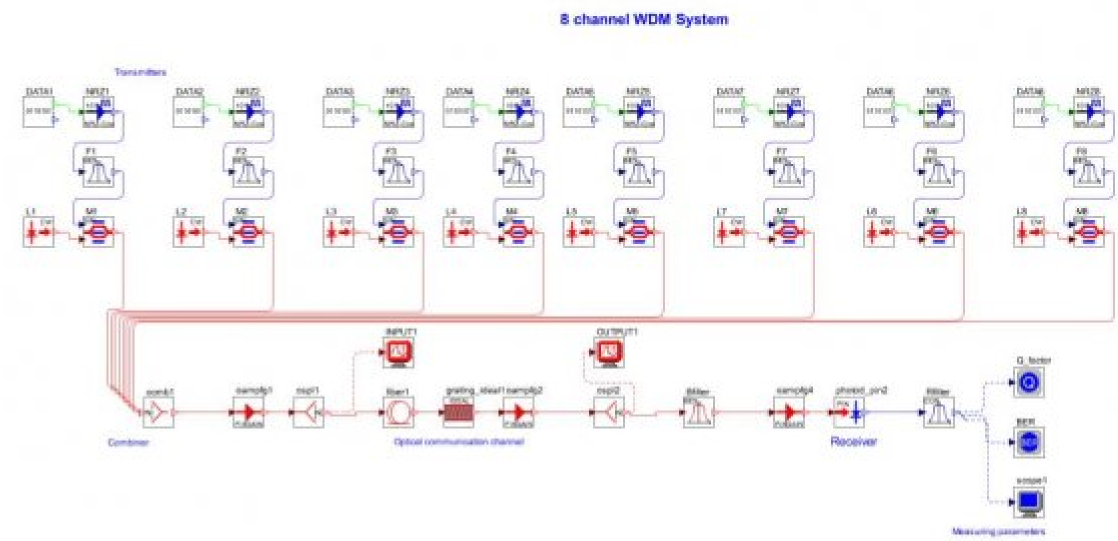

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Figure 4: Fig. 8 (

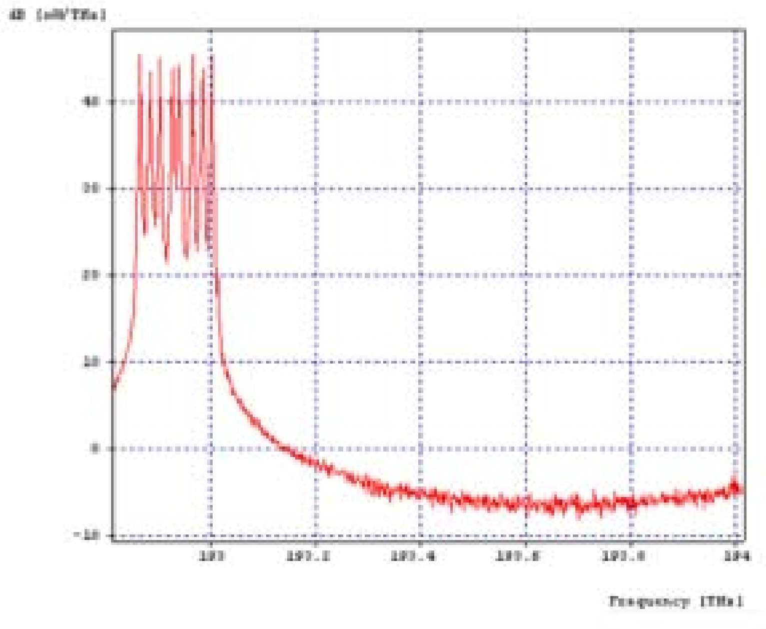

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Figure 5: Fig. 9 (

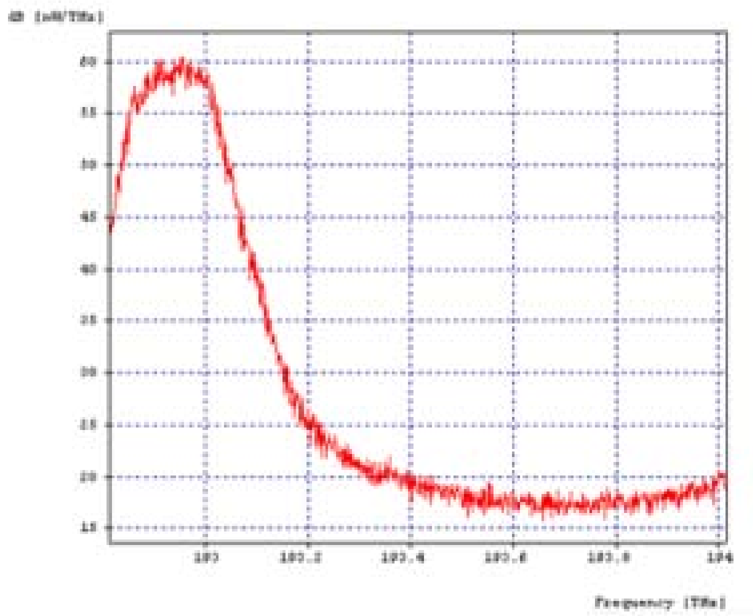

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Figure 6: Fig 5 to

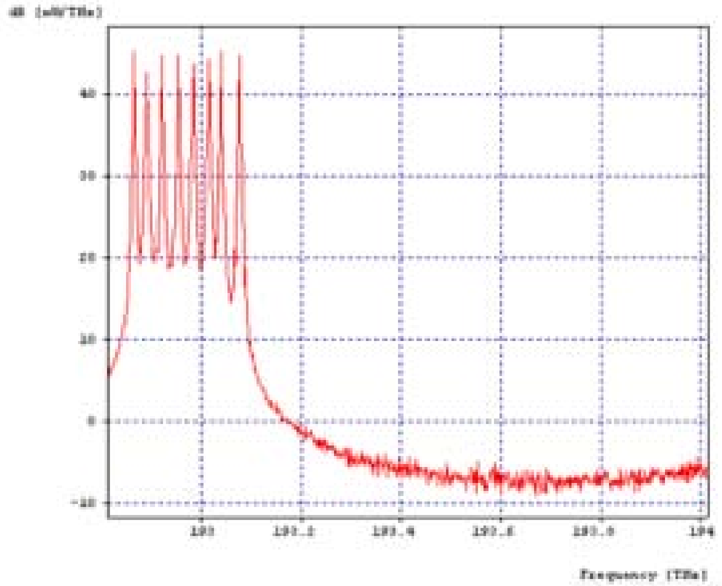

Figure 7:

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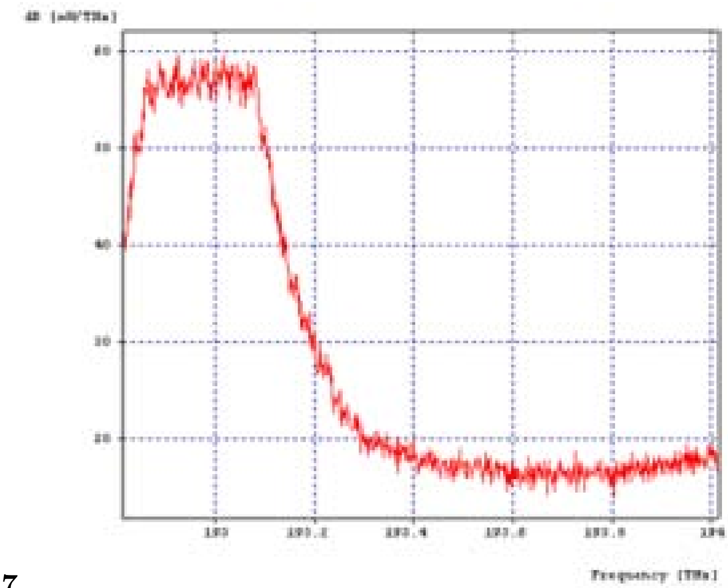

Figure 8: Fig. 17 :

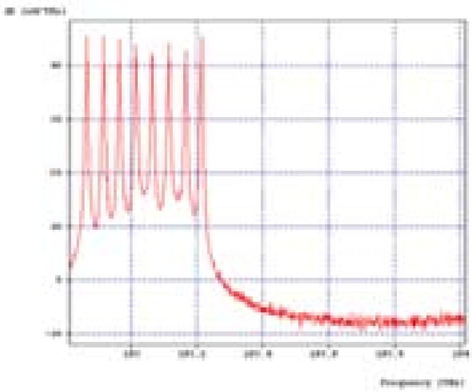

Figure 9: E+04

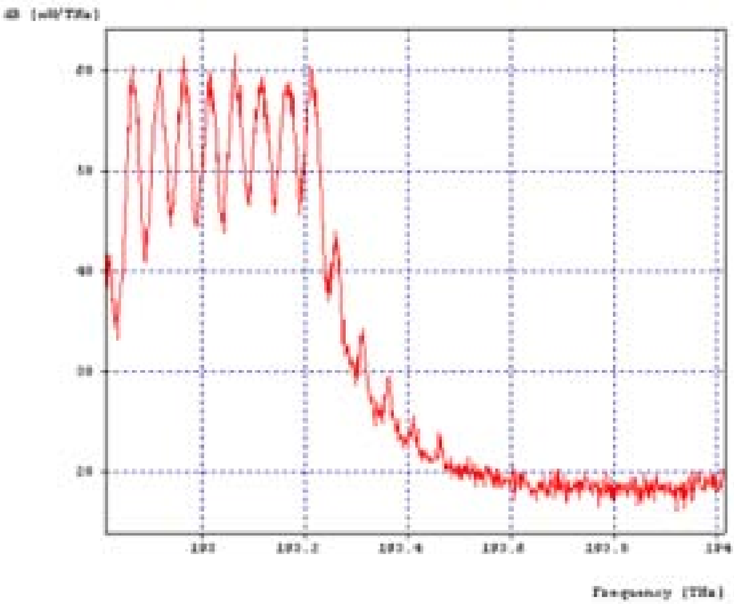

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Figure 10: Fig. 19 :

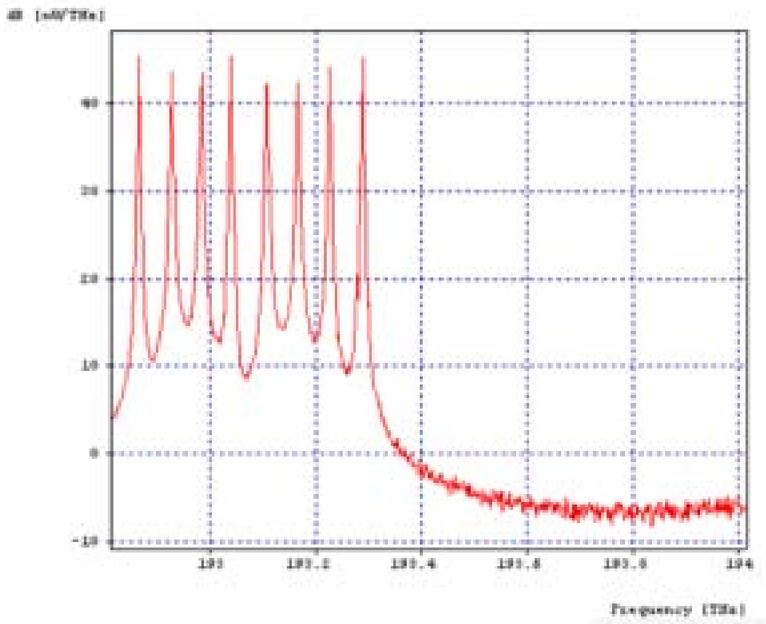

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Figure 11: Table 1 :

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