Analysis of Effect of Self Phase Modulation in Wavelength Division Multiplexing System

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Abstract— This paper is showing the non-linear effect i.e. self-phase modulation in WDM system. Nonlinear effects in optical fibers are recent area of academic research in the optical fiber based WDM system. Here we will simulate the result for optical fiber of length 1000kms.We will analyze the result as Quality Factor, Bit Error Rate at different values of dispersion. We will vary the optical dispersion from -5ps/ns/km to 5ps/nm/km and we will see the result through eye diagrams. We will also plot the graphs for different value of Quality Factors and Bit Error Rate. The result is analyzed using OPTSIM simulation software. In WDM optical system operating at a very high rates (beyond 10 Gbps), nonlinearity such as SPM, XPM, FWM play a significant role. These nonlinear effects can be counteracting through proper system design.

Key words: Self-Phase Modulation (SPM), Bit Error Rate (BER), Dispersion, Quality Factor, OPTICAL SIMULATOR (OPTSIM)

I. INTRODUCTION

In optical fiber communication systems, the information is send from one place to another in the form of light pulses. The requirements such as high data rate and large number of transmission channels have made today's fiber optic data systems very complex, expensive and lossy. But non-linear effect come into picture when requirements like high data rates, transmission lengths, number of wavelengths and optical power level increases. Non-linear effects in the optical fiber increases when we increase the data rates, transmission lengths, optical power and number of wavelengths .Because of presence of non-linearity we are not able to enhance the system speed for more than 10Gbps, research are going on and we have reached to an experimental setup of 40Gbps by reducing non-linear effects. Due to low loss optical windows it has very high bandwidth, about 30THz of the frequency (bandwidth) in the two windows are available. Sharing of both these windows gives us a WDM system which is capable of carrying 300,000channels of 10Mbps.

When the pulses have high intensity, refractive index gets modified and that leads to the modification in the pulse propagation. Intensity change tends to change in refractive index due to which velocity get change, this change in velocity produces phase change and the change in phase produced by pulse itself is known as self-phase modulation.

Different fiber characteristics like fiber loss and dispersion and the fiber nonlinearities like SPM, XPM play significant roles in limiting the performances of the fiber optic communication system. If their effects can be minimized then the performance would improve a lot. When two or more optical waves co-propagate inside a fiber, they can interact with each other through the fiber nonlinearly. Nonlinear characteristics include Self-phase modulation (SPM), Cross-phase modulation (XPM) , Four-wave mixing (FWM) , Stimulated Raman scattering (SRS) ,Stimulated Brillouin scattering (SBS)[1,2,3]

II. SELF-PHASE MODULATION

Self-phase modulation (SPM) is a nonlinear optical effect of light-matter interaction[4,5]. Phase modulation of an optical signal by itself is known as SPM. SPM is primarily due to the self-modulation of the pulses. Generally, SPM occurs in single-wavelength systems. At high bit rates, however, SPM tends to cancel dispersion. SPM increases with high signal power levels.

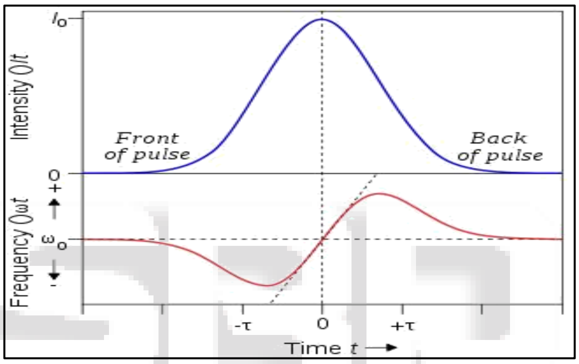


Fig. 1: A pulse (top curve) propagating through a nonlinear medium undergoes a self-frequency shift (bottom curve) due to self-phase modulation.

In fiber plant design, a strong input signal helps overcome linear attenuation and dispersion losses. However, consideration must be given to receiver saturation and to nonlinear effects such as SPM, which occurs with high signal levels[6]. SPM results in phase shift and a nonlinear pulse spread. As the pulses spread, they tend to overlap and are no longer distinguishable by the receiver. The acceptable norm in system design to counter the SPM effect is to take into account a power penalty that can be assumed equal to the negative effect posed by XPM. A 0.5-dB power margin is typically reserved to account for the effects of SPM at high bit rates and power levels.

III. SIMULATION SETUP

The figure (2) shows the simulation setup for the analysis of Self Phase Modulation in optical link having single channel. The SPM is analysed for six values of dispersion from -10ps/nm/km to 10ps/nm/km The transmitter and receiver section are connected by the dispersive fiber link. The transmitter section consists of data source, modulator driver, laser source and modulator.

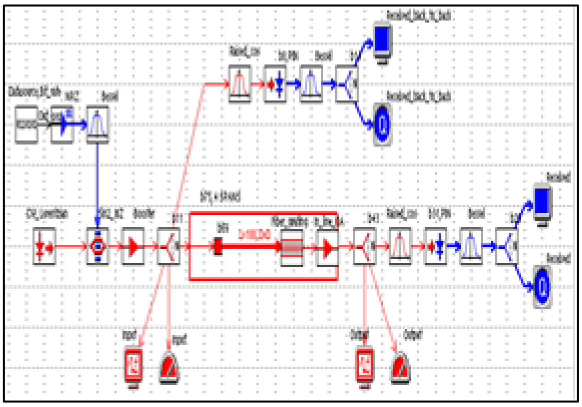


Fig. 2: Simulation Setup for Self Phase Modulation Using OPTSIM

Data source produces a pseudo-random sequence of bits at a rate of 10Gbps. The output of data source is given to modulator driver which produces a NRZ (Non return to zero) format pulse train. The transmitted signal is formed by modulating the light carrier by the NRZ data source. confinement factor is 0.35, insertion loss is 3 dB and output insertion loss is 3 dB. The various parameters for RAMAN are Raman fiber length is 10 km, operating temperature is 300 K, pump wavelength is 1480 nm and pump power is 300 mW. The light carrier is generated by Lorentzian laser source at the 1550 nm wavelength. The transmitter output is boosted up by the fixed gain Erbium Doped Fiber Amplifier (fixed_output_power).

There are two types of optical amplifiers; Semiconductor Optical Amplifier (SOA) and the Erbium Doped Fiber Amplifiers (EDFA). Due to its high gain characteristics EDFA are used these days. The shape of the gain graph is flat having a gain of 25 dB. The noise figure value is set at 4.5 dB. The transmission medium used is a standard single mode fiber of 100kms length. The receiver used in the system is the PIN (Receiver, PIN) receiver, which uses the PIN (p-intrinsic-n) diode as a detector. The pin photodiode simulated had 70% quantum efficiency. The dark current was simulated at 0.1 nA. The output of the receiver is given to the measurement devices which are fed through the electrical splitter, the electrical scope and the Q estimator. The optical spectrum of the signal is observed from optical spectrum analyzer (input and output) by splitting the signal from fiber link with the use of optical splitters. Firstly we will analyse the Q-factor using simple single mode fiber without using dispersion effect and then we will compare it with Q-factor obtained after using dispersion effects.

IV. RESULTS

The figure 3 to 6 shows the eye diagrams and corresponding value of Q-factor. We have shown two eye diagrams in each figure one is without the effect of Self Phase Modulation (SPM) and the other one is due to the effect of Self Phase Modulation (SPM). In the figures we will see that as we varies the dispersion due to the effect of Self Phase Modulation (SPM) the Quality factor becomes nonlinear. In figure 7 we have compared both the techniques with the help of a graph.

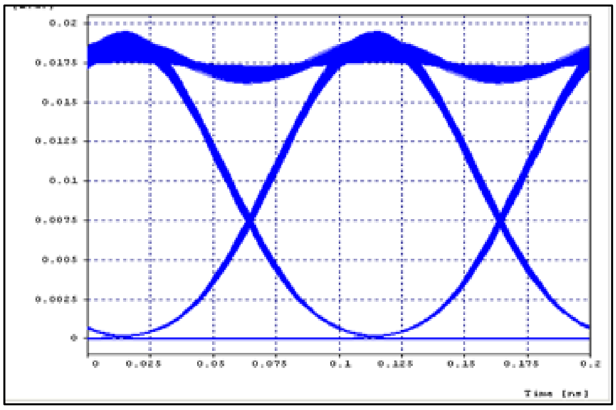


Fig. (a):

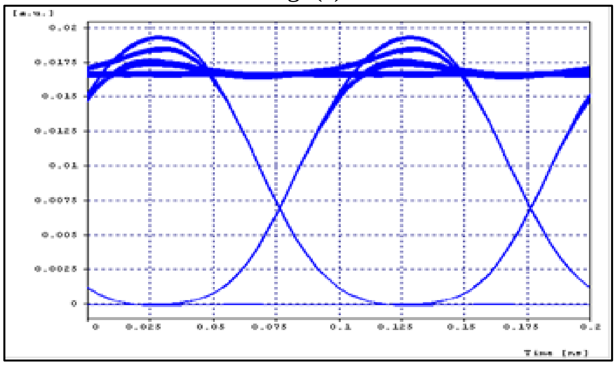
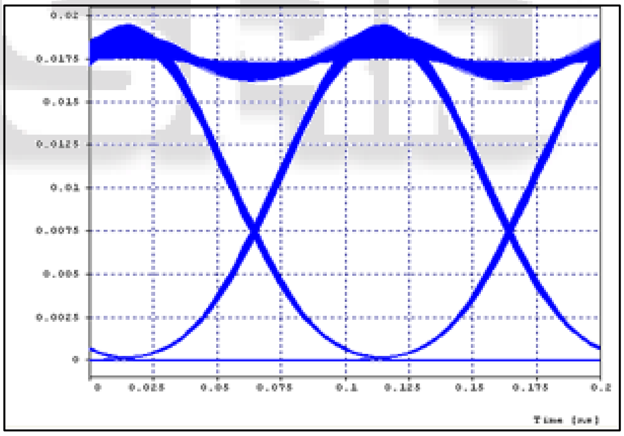


Fig. (b):

Fig. 3: Eye Diagram For Optical Dispersion at -5ps/Nm/Km (A) Eye Diagram before Self Phase M (B) Eye Diagram after Self Phase Modulation



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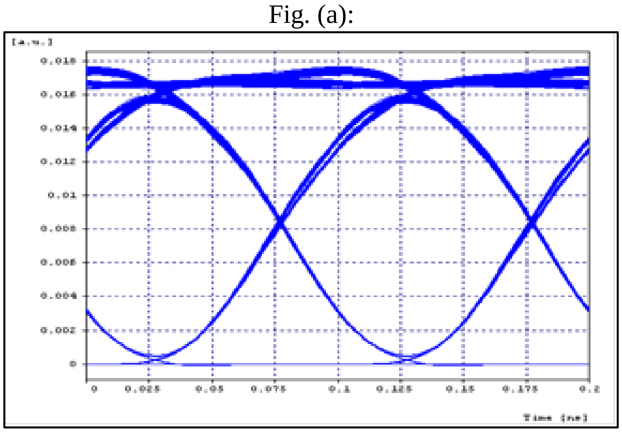
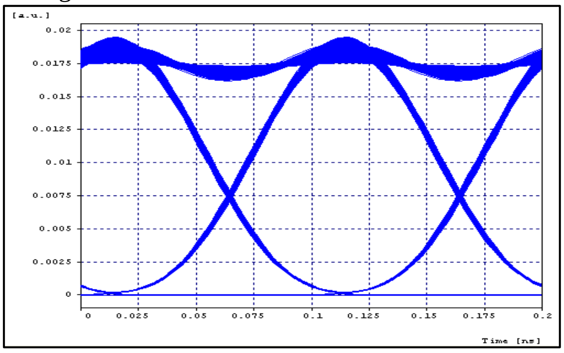


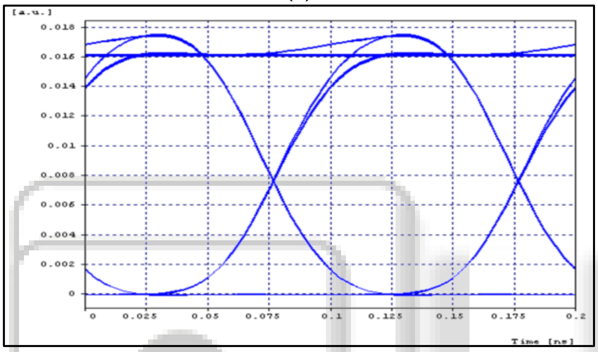
Fig. (b)

Fig. 4: Eye Diagram For Optical Dispersion At +5ps/Nm/Km (A) Eye Diagram Before Self Phase M (B) Eye Diagram After Self Phase Modulation

Channel consist of 100 Km span having two different types of DCF1 and DCF2 are used. Let assume SMF of length LSMF and DCF of length LDCF. LDCF and LSMF are kept variable. At the output, distortion of eye diagrams of the signal measured by the receiver sensitivity and optsim provides a visualization tool like BER estimator, eye display, optical and electrical scope with numerous data processing units.

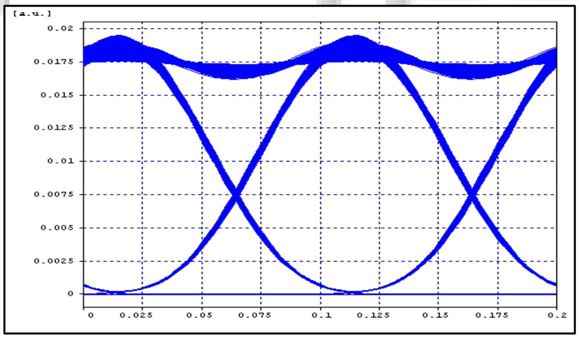


(a)

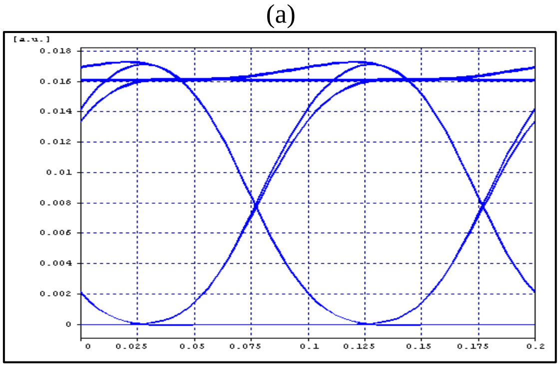


(B)

Fig. 5: Eye Diagram For Optical Dispersion At -1ps/Nm/Km (A) Eye Diagram Before Self Phase M (B) Eye Diagram After Self Phase Modulation



(a)



(B)

Fig. 6: Eye Diagram For Optical Dispersion at +1ps/Nm/Km (A) Eye Diagram before Self Phase M (B) Eye Diagram after Self Phase Modulation

The simulations are carried out in the optical simulator software Optsim, and are based on optical transmission system. The optical system consist three sections i.e., transmitter, channel(optical fiber) and receiver section. Transmitter consists of pseudo random bit generator (PRBS), non-return to zero coder (NRZ), continuous wave (CW) laser,mach-zender modulator and bessel electrical filter.

PRBS generator generate bit sequences at rate of 10 Gbps and this bit sequence is fed to NRZ coder that generates an electrical NRZ coded signal pulse. The comparison of two different type of DCF is to analyse the SPM effects on optical transmission system in terms of Eye diagrams, BER and Q value. In this Model transmission link consisting of SMF of length LSMF and DCF of length LDCF(LDCF1 and LDCF2) and maintain link at 10 dBm to investigate the Nonlinear effect.[7]

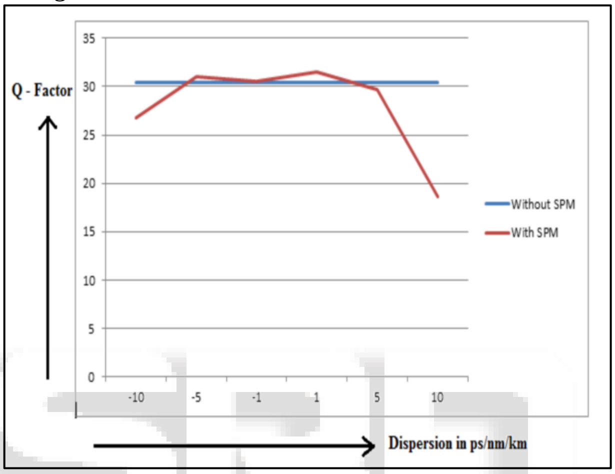


Fig. 7: Graph for Quality Factor versus Dispersion with Self Phase Modulation (SPM) and Without Self Phase Modulation (SPM)

V. CONCLUSION

The effect of Self Phase Modulation on optical fiber is reported in this paper. These effects are seen from the eye diagrams drawn for the different values of dispersion. Furthermore the graph for the Quality Factor at the different values of optical dispersion is also drawn. The above discussed results show that due to Self Phase Modulation (SPM) the Quality Factor becomes nonlinear. We can reduce the Self Phase Modulation up to some extent but we are still not able to completely remove the Self Phase Modulation from the optical fiber specially at higher bit rates, which is a topic of research and a challenge for the various scientists in the optical fiber field.

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