

Simulative Investigation of SPM Effects on Optical Transmission System

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Abstract: Optical transmission systems are of great importance in present broadband communication systems. Non linear effects deteriorate the performance of the systems and result into significant reduction in performance. This paper investigates the effects of self phase modulation based effects in optical transmission systems for different kinds of fibers viz. single mode fiber (SMF) and dispersion compensated fiber (DCF). A comparison has been drawn by studying various performance measures like BER, Eye Diagram.

Key Words: Optical system, non-linear effects, SPM, DCF, SMF, Dispersion

I. Introduction

Nonlinear effects in optical fibers have become a most prominent area of academic research in the optical fiber based WDM system. These non-linear effects arise as optical fiber data rates, transmission length, number of wavelengths and optical power level increase so as to achieve an expected optical signal to noise ratio. When input power in optical fiber is low then transmission is affected by ASE (amplified spontaneous emission) noise and when input power is high then optical fiber is limited by non-linear effects. Optical fiber commercial developed in 1980 and operate at 45 Mbps bit rate but today at 40 Gbps [1]. WDM system operate at a bit rate of above 10 Gbps, When designing optical system need to pay a special attention on Stimulated Brillouin Scattering (SBS), Stimulated Raman Scattering (SRS), Four Wave Mixing (FWM), Self-Phase Modulation (SPM), Cross-Phase Modulation (XPM) and inter-modulation [2]. This paper analyze the SPM effect, which is hold to fibers SMF (single mode fiber) and DCF (dispersion compensated fiber) both will make a combination of 100 km in the channel to investigate the result.

II. Self Phase Modulation (SPM)

Self Phase Modulation (SPM) is a non linear effect of light-matter interaction. It means that varying the signal intensity will produce likewise change in time varying refractive index. This time varying refractive index will also produce time varying phase change due to Kerr Effect [3,4,5]. The refractive index of the fiber is given by:

$$n'_l = n_l + n_{nl}I$$

n'_l is the optical fiber refractive index;

n_l is the linear refractive index;

n_{nl} is the non linear refractive index;

I is the light radiation intensity;

This variation in phase change will lead to a change in frequency spectrum which is given by-

$$\gamma = \frac{2\pi}{\lambda} \cdot \frac{n_{nl}}{A}$$

$$\phi = \gamma \cdot P \cdot L_{eff}$$

This dependence of P makes phase to vary with time.

III. Simulation Set-up

Simulation results are produced by OPTSIM simulation software. The system is divided into three major section transmitter, channel (optical fiber), and receiver.

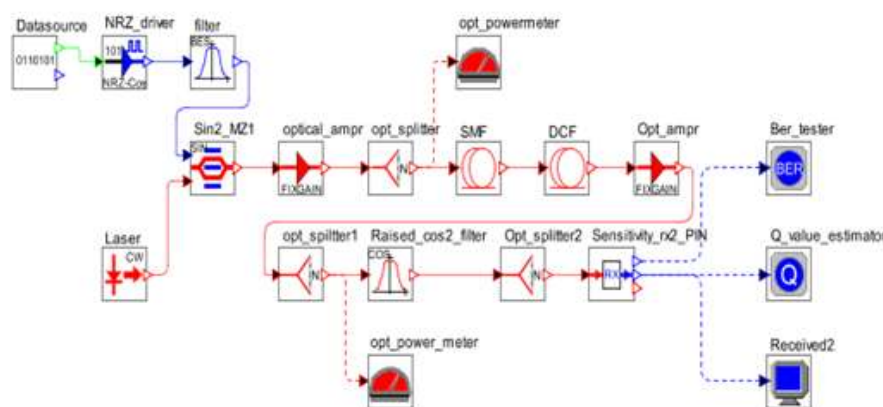


Fig. 1: Simulation setup of self phase modulation

The transmitter will consist of pseudo random bit generator (PBRs), non return to zero coder (NRZ), continuous wave (CW) laser, mach- zender modulator and Bessel electrical filter. The optical signal generated which is generated by Tx is carried by the fiber. The 100 km span is carried by the two different type of fiber SMF (100-70), DCF (0-30) by varying their combination in length. Receiver will consist of splitter, raiser cosine filter, sensitivity meter, BER estimator, Q value estimator and optical power meter.

Table 1: Simulation Parameters

Parameter	SMF	DCF
Fiber length(Km)	100-70	0-30
Fiber dispersion $D(\text{ps. (nm. Km)}^{-1})$	17	-95
Effective core area $A_{eff}(\text{micro} - \text{m}^2)$	80	20
Dispersion slope $(\text{ps nm. Km})^{-1}$	0.08	-0.1
Nonlinear refractive index $n_2(10^{-20})$	2.5	2.5
Nonlinear coefficient $\gamma(1.W. Km)^{-1}$	1.26	5.05
Attenuation (dB. Km^{-1})	0.25	0.55

According to dispersion management technique, the condition for perfect dispersion compensation is:

$$L_{SMF} D_{SMF} + L_{DCF} D_{DCF} = 0$$

$$L_{DCF} = -(D_{SMF} / D_{DCF}) L_{SMF}$$

L_{SMF} , L_{DCF} are the fiber length of SMF and DCF.

D_{SMF} , D_{DCF} are the fiber dispersion of DCF and SMF.

IV. Simulation Result and Analysis

Simulation result that are produced by OptSim include signal waveform plot, eye diagram and bit error rate (BER) plot and Q value for different fiber length. Sample mode simulation engine perform simulations in which the signal data passed between component represent a signal sample or time step at a time where one component model may only pass data to other component model once during the course of the simulation, covering the entire simulated time in one block of data, in the sample mode simulation approach a component model will pass new sample data to another component model at each time step in the simulation.

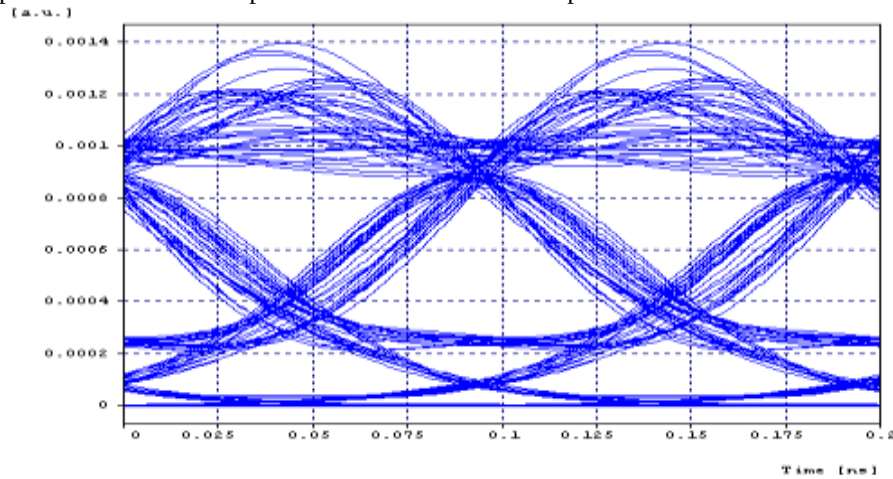


Fig. 2.1: Eye Diagram for DCF compensated SMF of DCF length 0 Km and SMF length 100 Km.

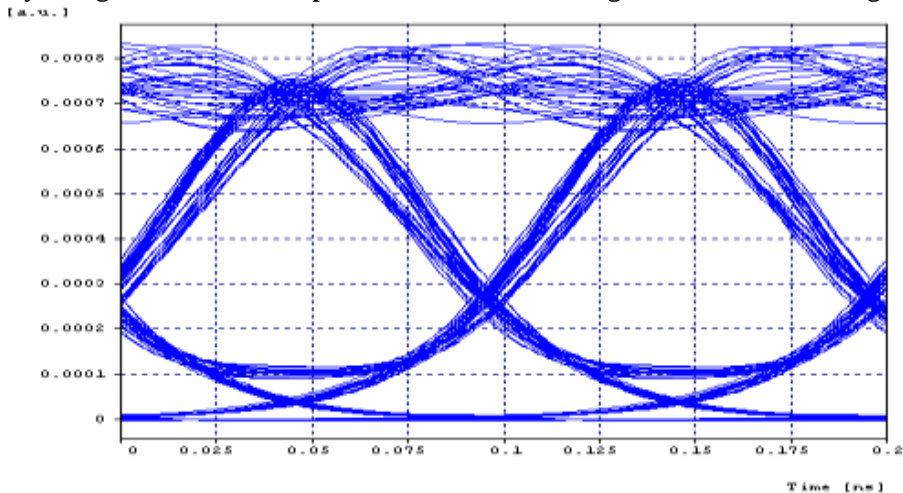


Fig. 2.2: Eye Diagram for DCF₁ compensated SMF of DCF length 5 Km and SMF length 95 Km.

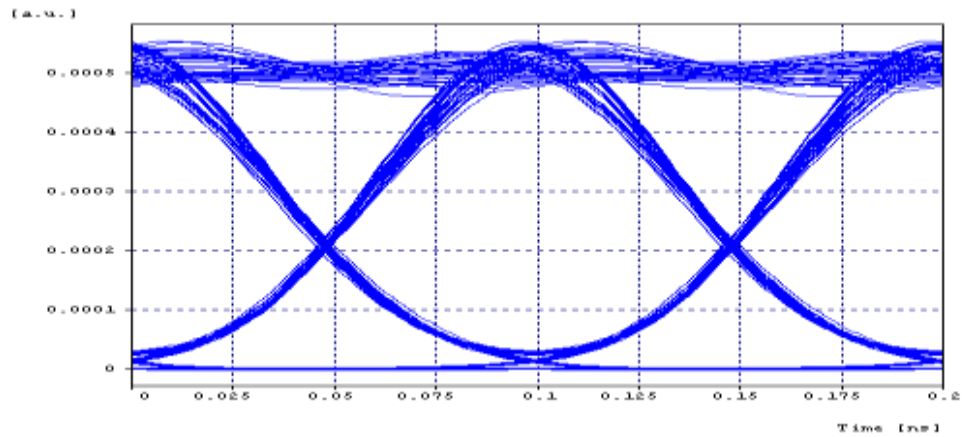


Fig. 2.3: Eye Diagram for DCF₁ compensated SMF of DCF length 10 Km and SMF length 90 Km.

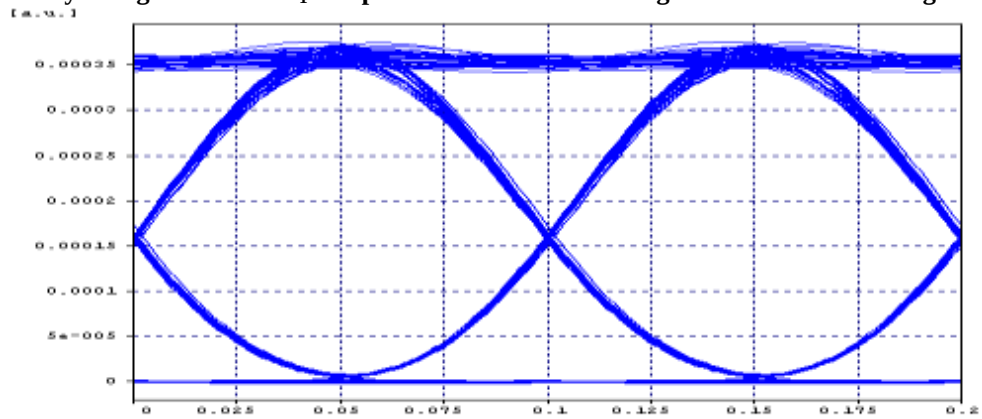


Fig. 2.5: Eye Diagram for DCF₁ compensated SMF of DCF length 15 Km and SMF length 85 Km.

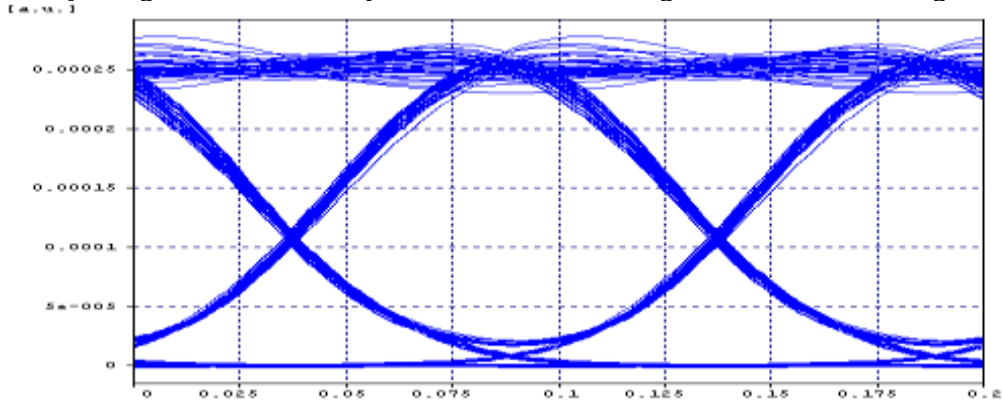


Fig. 2.6: Eye Diagram for DCF₁ compensated SMF of DCF length 20 Km and SMF length 80 Km.

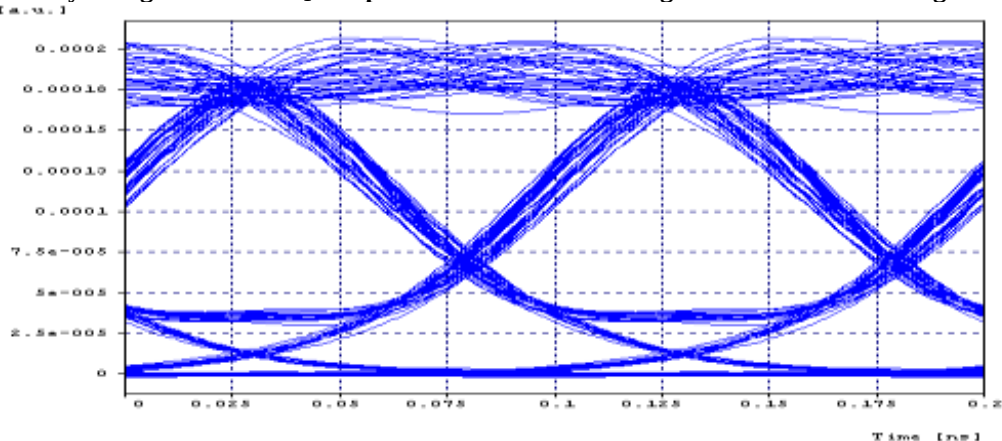


Fig. 2.7: Eye Diagram for DCF₁ compensated SMF of DCF length 25 Km and SMF length 75 Km.

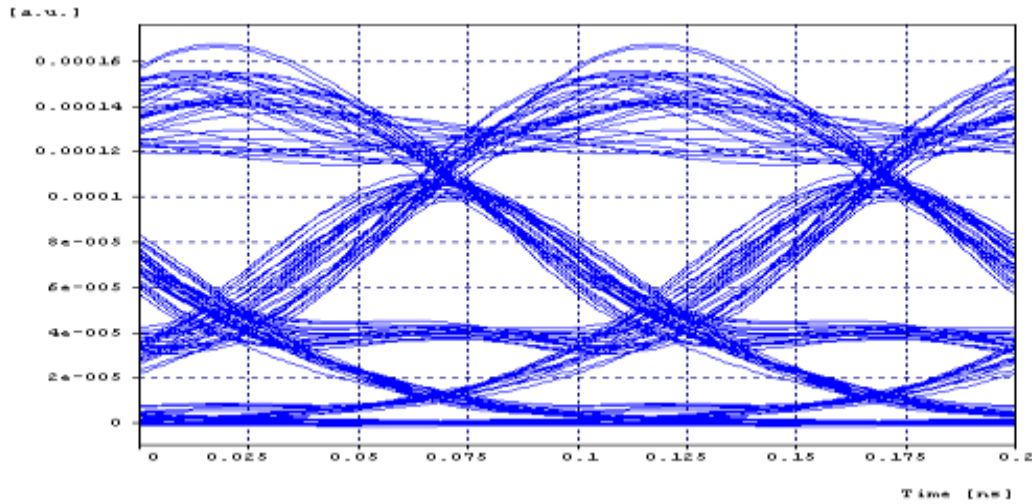


Fig. 2.8: Eye Diagram for DCF₁ compensated SMF of DCF length 30 Km and SMF length 70 Km

SMF length in Km(L_{SMF})	DCF length in Km(L_{DCF})	Amplitude unit (a.u.)
100	0	0.0014
95	5	0.0008
90	10	0.0005
85	15	0.00035
80	20	0.00025
75	25	0.00020
70	30	0.00016

V. Conclusion

The comparison of two different type of optical fiber DCF and SMF is used 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 L_{SMF} and DCF of length L_{DCF} (L_{DCF} and L_{DCF}) and maintain link at 10 dBm to investigate the Nonlinear effect. From Table 1 the only one parameter that differ with the other DCF is Fiber dispersion [$D(\text{ps} \cdot (\text{nm} \cdot \text{Km})^{-1})$]. Fig. 2.1 to Fig. 2.8 shows the comparison of eye diagrams with SMF fiber length L_{SMF} varied from 100 to 70 km and DCF length L_{DCF} varied from 0 to 30 km. The wide opening of eye diagram for the $L_{SMF} = 85$ km, $L_{DCF} = 15$ km, lower BER and higher Q Value indicate better system performance.

References

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