Effect of Cross Phase Modulation (XPM) on Optical Fiber Using Two Wavelength Division Multiplexed (WDM) Channels

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ABSTRACT: This paper shows the effect of Cross Phase Modulation, a type of nonlinearity found in optical fibers. In this paper we have simulated the results for the optical fiber of length 100kms. We will analyze the Quality Factor and Bit Error Rate (BER) at different values of optical dispersion. We will vary the optical dispersion from 4ps/nm/km to 4ps/nm/km and we will see the results through eye diagrams. We will see the effect of Cross Phase Modulation (XPM) on optical fiber with the help of graphs drawn for the different values of Quality Factor and Bit Error Rate (BER). All the results are analyzed using OPTSIM simulation at 10 Giga bits per second (Gb/s) transmission systems.

Keywords: XPM, DISPERSION, NON LINEARITIES, OPTSIM, Q-FACTOR

I. Introduction

Nonlinearity effects arose as optical fiber data rates, transmission lengths, number of wavelengths, and optical power levels increases. The only worries that plagued optical fiber in the early day were fiber attenuation and, sometimes, fiber dispersion, however, these issues are easily dealt with using a variety of dispersion avoidance and cancellation techniques. Fiber nonlinearities present a new realm of obstacle that must be overcome. These nonlinearities previously appeared in specialized applications such as undersea installations. However, the new nonlinearities that need special attention when designing state-of-the-art fiber optic systems include stimulated Brillouin scattering (SBS), stimulated Raman scattering (SRS), four wave mixing (FWM), self-phase modulation (SPM), cross-phase modulation (XPM), and intermodulation. Fiber nonlinearities represent the fundamental limiting mechanisms to the amount of data that can be transmitted on a single optic fiber. System designers must be aware of these limitations and the steps that can be taken to minimize the detrimental effects of fiber nonlinearities[1,2,3].

II. Cross Phase Modulation (XPM)

Fiber nonlinearities due to Kerr effect are a limiting factor for optical communication systems. In particular for WDM system, the most impacting phenomenon is Cross Phase Modulation (XPM). Nonlinear phase changing due to power variations in adjacent channels can strongly impact system performances [4]. In fact, also in IMDD systems where information is coded on field amplitude and phase seems not to be relevant, a phase-to-amplitude conversion due to dispersion is present [5,6]. During propagation a noisy perturbation due to XPM will accumulate together with ASE noise and other impairments limiting capacity and distance. The Effects of Cross-phase Modulation are given below.

- It leads to an interaction of laser pulses in a medium, which allows e.g. the measurement of the optical intensity of one pulse by monitoring a phase change of the other one (without absorbing any photons of the first beam). This is basis of a scheme for quantum nondemolition (QND) measurements.

- The effect can also be used for synchronizing two mode-locked lasers using the same gain medium, in which the pulses overlap and experience cross-phase modulation.

- In optical fiber communications, cross-phase modulation in fibers can lead to problems with channel cross-talk.
Cross-phase modulation is also sometimes mentioned as a mechanism for channel translation (wavelength conversion), but in this context the term typically refers to a kind of cross-phase modulation which is not based on the Kerr effect, but rather on changes in the refractive index via the carrier density in a semiconductor optical amplifier.

III. Simulation Setup

The figure (1.1) shows the simulation setup for the analysis of Cross Phase Modulation in optical link having single channel. The XPM is analysed for five values of dispersion from -4ps/nm/km to 4ps/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. Data source produces a pseudo-random sequence of bits at a rate of 10 Gbps. The transmitted signal is formed by modulating the light carrier by the NRZ data source. The 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 100 kms 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.

IV. Figures and Results

The figure 1.2 to 1.6 below shows the eye diagrams and corresponding value of Q-factor for the different values of optical dispersion. We will see the effect of Cross Phase Modulation (XPM) in each figure. As the values of dispersion varies nonlinearities in the optical fiber also varies, which gives result to Cross Phase Modulation (XPM). In figure 1.7 we have shown a graph comparing Q-Factor with dispersion. In figure 1.8 we have shown a graph comparing BER with dispersion.
Fig 1.2 Eye Diagram at -4ps/nm/km

Fig 1.3 Eye Diagram at -2ps/nm/km

Fig 1.4 Eye Diagram at 0ps/nm/km

Fig 1.5 Eye Diagram at 2ps/nm/km
Fig 1.6 Eye Diagram at 2ps/nm/km

Fig 1.7: Graph for Quality factor versus Dispersion
V. Conclusion

The effect of Cross Phase Modulation in 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 Cross Phase Modulation (XPM) the Quality Factor becomes nonlinear. We can reduce the Cross Phase Modulation up to some extent but we are still not able to completely remove the Cross Phase Modulation from the optical fiber, especially at higher bit rates, which is a topic of research and a challenge for the various scientists in the optical fiber field.

VI. References


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