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Effect of Self Phase Modulation on Three Level Code Division Multiplexing Technique

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Abstract- Recently, fibre optics has become the core of telecommunications and data networking infrastructures. The impairments factors in optical fibre communication systems which is divided into two categories: dispersion and nonlinear effects. For multiplexing technique, nonlinear effects are crucial particularly at bit rates and moderate powers. Nonlinear effects limit the maximum amount of power that can be launched into fibre span. Additionally, scattering phenomena and changes in the refractive index with the optical power are responsible for nonlinear effects in optical fibers. Self-phase modulation (SPM), Cross phase modulation (XPM), Four wave mixing (FWM), Stimulated Raman Scattering (SRS), Stimulated Brillion Scattering (SBS) are some of nonlinear effects in optical fiber communication system. In this research, effect of SPM on 40 Gb/s, Three Level Code Division Multiplexing (3LCDM), is investigated for optical fiber communication systems over 80 km. The highest SPM threshold is observed in post compensation method, which is around 10.7 dBm.

Keywords-Three level code division multiplexing, self-phase modulation, dispersion, optical communication, multiplexing technique.

I. INTRODUCTION

Multiplexing technique enables a multi input system to be more economical when transmitting over multiple fibres in most applications [1]. Wavelength division multiplexing (WDM) offers great benefits to the optical fibre communication system. In optical code division multiplexing (OCDM), each user's data are associated with a different code [2], which allows multiple users to efficiently share the bandwidth. However, the broad spectrum signals used make the signals less tolerant to dispersion [3], thus making these signals to be only suitable for shorter distance or low speed transmission. Another multiplexing technique that can support multiple users per WDM channel is duty cycle division multiplexing (DCDM) [4]. For three-level code division multiplexing (3LCDM), it is a different multiplexing technique that can support two users per channel [5,6,7]. In terms of capacity, 3LCDM is designed for two users per channel. 3LCDM system uses only RZ and NRZ line coding [5,6,7].

The performance of transmission system is limited by various optical impairment factors. One of the characteristics of optical fibers is their relatively low threshold for some of the nonlinear effects. This situation can be a serious disadvantages in optical communication [8]. Another factor is dispersion. Performance of the high-speed and long-distance data transmission system is limited by the optical nonlinear effects produced by standard single mode fiber (SSMF) and dispersion compensation fiber (DCF) [6,9]. To investigate the nonlinearity effect on 3LCDM system, dispersion of SSMF is fully compensated by using DCF [2,10]. The most important nonlinear effect in single channel system is self-phase modulation (SPM) [11]. Thus, it is important to consider SPM effect on 3LCDM signals in this study.

Rest of the paper is organized as follows, Section I contains the introduction of 3LCDM system , Section II contain the related work of SPM, Section III contain the methodology, Section IV contain the results and discussion section V explain the conclusion of research work.

II. RELATED WORK

Self-phase modulation (SPM) is associated with the power dependency of the refractive index of the fiber core. Correspondingly, the chirping effect is related to the launched power, initiating SPM effects in the systems in which the highly launched powers are used. When there is dominant nonlinearity in single wavelength and single mode transmission systems, its effect can be reduced by keeping the transmission power low (lower than SPM threshold) [12,13].

Variation in the refractive index results in an induced phase shift relative to the pulse's intensity [14, 15]. The pulse's various parts endure dissimilar phase shifts. In this way, pulse chirping can occur which consequently boosts the pulse's broadening effects resulting from CD. Correspondingly, the chirping effect is related to the launched power, initiating SPM effects in the systems in which the highly launched powers are used. When there is dominant nonlinearity in single wavelength and single mode transmission systems, its effect can be reduced by keeping the transmission power low (lower than SPM threshold) [16, 13]. SPM threshold in multiple amplitude signalling is considerably lower as compared to the binary signalling.

III. SIMULATION SETUP

This study was conducted using OptiSystem software interfaced with Matlab environment. Figure 1 shows the simulation setup. At the transmitter side in the simulation setup of 3LCDM system, each user transmits data (i.e, data1 and data2) with 20 Gb/s of bit rate at PRBS of 2^{10}-1. The system consists of one NRZ pulse generator and one RZ pulse generator. Both users have identical peak voltages at the input of multiplexer and both data are multiplexed through an electrical adder, which added up the amplitude of the input signals once they are synchronized together. The multiplexed signal is then modulated onto CW laser with 10 MHz line width that operates at 1552.5 nm wavelength using a single drive Mach Zehnder as the modulator. At the receiver side, the optical signal is detected by a PIN photodiode and passes through a low pass filter (LPF), followed by a demultiplexer. The demultiplexer functions as a clock and data recovery.

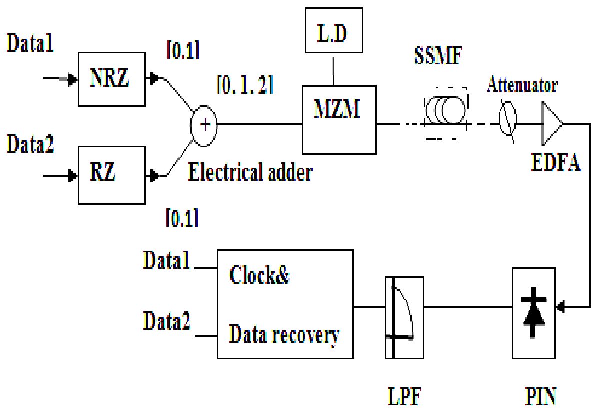

Fig.1. Simulation setup of 3LCDM

To see the performance of SPM on 3LCDM, 80 km SSMF is used with the 16.75 ps/ (nm.km) of dispersion coefficient. The dispersion of SSMF is fully compensated by using DCF with - 100 ps/ (nm.km) of dispersion coefficient. The length of inline DCF is fixed at 13.4 km to fully compensate the total dispersion of SSMF. By changing the position of DCF, the behavior of SPM effect changes. Thus, two symmetric dispersion compensation schemes, full pre-compensation and post-compensation were investigated in this study.

IV. RESULTS AND DISCUSSION

Figures 2 and 3 show the result of 100% pre and post dispersion compensation for the 2 × 20 Gb/s 3LCDM. Taking BER of 10^{-9} as the minimum required BER, 3LCDM was tested to find the optimum power that the system could tolerate to maintain its performance.

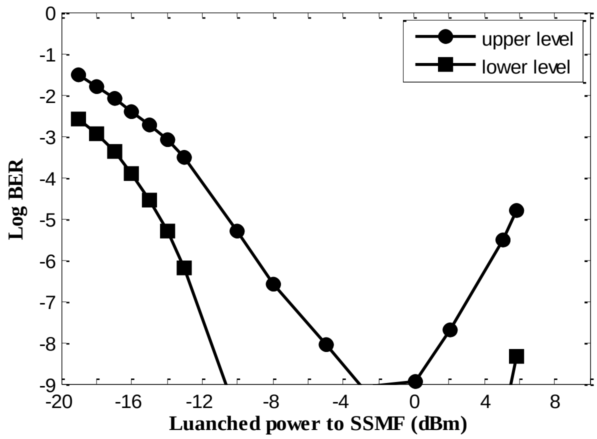

Fig.2. BER as a function of launched power in dispersion pre-compensation Scenario at 40 Gb/s

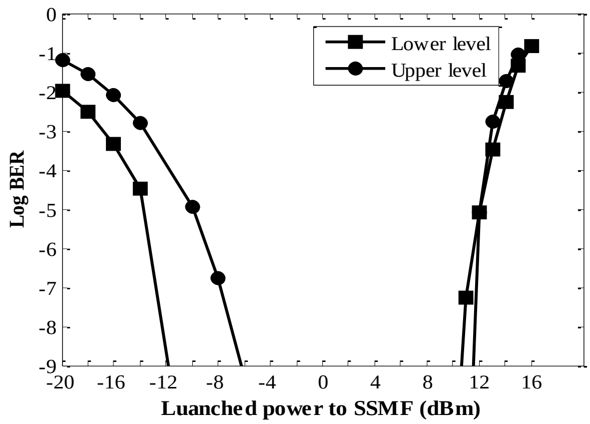

Fig.3. BER as a function of launched power in dispersion post-compensation at Scenario at 40 Gb/s

As seen in both graphs, by increasing the launched power, the performance of 3LCDM system improves until a certain point. By further increasing the launched power, the performance of 3LCDM starts to degrade. This condition is due to the dependence on power intensity for SPM. At certain higher transmitted power, SPM effect is large and it influences the balance of dispersion rapidly.

Figure 2 shows that by increasing the launched power until around - 10.4 dBm and - 3 dBm, the system achieves BER 10^{-9} at the lower and upper levels. Referring to the same BER, SPM effect can be noticed at the maximum launched power of around 1 dBm and 5.8 dBm. For Figure 3, it shows that, to achieve BER of 10^{-9}, the minimum launched power required is around - 12 dBm and - 6 dBm for the lower and upper levels respectively. The maximum launched power (SPM threshold) at BER 10^{-9} in 3LCDM channels are 10.7 dBm and 11.5 dBm at the lower and upper levels respectively. Therefore, for post dispersion compensation, 3LCDM system has to take - 6 dBm as the minimum launched power while 10.7 dBm as its maximum launch power to avoid SPM effect. It can be concluded that 100% post dispersion compensation has better performance than 100% pre compensation which results in the maximum SPM threshold power.

V. CONCLUSION

The effect of SPM on performance of 40 Gb/s 3LCDM is investigated by using two symmetric dispersion compensation schemes over 80 km SSMF. The results show that the 100% post dispersion compensation outperforms the pre dispersion compensation for this system. It can be concluded that by considering a correct dispersion compensation scheme, 3LCDM can be used in WDM for short and medium distance applications. However, the results show that 3LCDM might not be suitable for long-haul transmission systems.

Author contribution

Faranak khosravi simulated the code and collected data. Dr. Makhfudzah Mokhtar and Prof. Mohd Adzir Mahdi helped to complete analysis of the data, and finally Punitthavathi Thirunvakkarasu assisted in manuscript preparation and writing to produce a final draft article.

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