Development of Delay Line Filtration based Dispersion Management Optical Fiber System

M. Venkata, Sudhakar

Abstract: ***Next-Generation (NG) optical transmission systems require high data rate and flexible connectivity to satisfy the bandwidth requirements of customers at lower cost. Delay line filtration (DLF) schemes are good option for deployment of cost-effective dispersion mitigation scheme in optical system due to their less complexity. The problem of signal degradation in optical single mode fiber (SMF) systems is due to SMF dispersion. The transmission capacity of optical system could be enhanced when the optical-spectrum broadening caused by optical fiber is minimized. Therefore, effective optical filtering techniques are required to enhance the transmission-distance and data rate by changing the properties of the modulator output for emerging optical SMF systems. The aim of this research work is to implement 110 km dispersion-tolerant access networks by using optical delay line filtering techniques at the transmitter.***

Index Terms: ***Fiber, DLF, dispersion***

I. INTRODUCTION

Optical networks are now being strongly designed to provide high throughput and extended transmission distance, as the network providers find it difficult in keeping the escalating cost down at the same time to meet the user requirement for increased bandwidth. The long-haul optical networks allow network operators to provide a high throughput to huge number of customers at an affordable expense. Long-reach optical networks are mainly suitable for reducing the installation costs associated with customers situated in remote and rural areas. The consolidation of access and metro networks is required with the help long-reach optical networks to minimize the number of network elements. The dispersion limited distance of the modulated laser is enhanced by employing optical and electrical dispersion compensation. Optical dispersion compensation based approach like inverse dispersion fiber (IDF) and dispersion compensation fiber (DCF) was found to be costly, introduces the insertion losses. The disadvantages of these methods are either require amplifier to overcome insertion losses or it is not suitable for upgrading existed system [1]. Electronic dispersion compensation based methods increases the size and cost of the system compared to the direct modulation schemes [2]. Existing filtering techniques [3,4] at the transmitter are not meeting the requirement of long-haul optical networks and have the any of these drawback like requirement of complex fabrication process, working with short pseudo random sequence that do not represent the real data, increase the cost and size of the system, requires encoders, operating at low-data rate, and short transmission distance. However, these filtration schemes in current optical systems were found to be less efficient in dispersion compensation for long-reach access networks.

Several methods have been proposed to realize access. In spite of it, there is various research problems linked with high speed transmission devices, and long-reach transmission networks needs to be addressed. Thus the aim of this research work is to develop and analyze of optical filters that are key components in transmitter unit in increasing data rate and transmission distance of dispersion tolerant optical systems.

II. THEORY

The optical fiber communication system at 10 Gbps with DLF is presented in Fig. 1

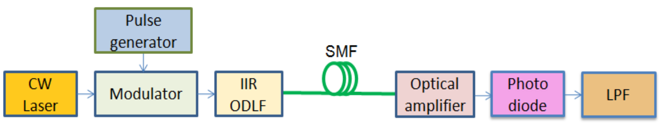

Fig.1 Optical system with DLF

Optical transmitter section comprises of four parts: NRZ signal generator, laser for CW wave, modulator and IIR optical delay line filter (ODLF). The IIR ODLF is used for shaping of modulator output. The IIR ODLF transfer function is given by

$$H_i(f) = \frac{\sum_{k=0}^{p} a_k e^{-j2\pi(\frac{f-f_c}{f_s})k}}{1+\sum_{k=1}^{p} b_k e^{-j2\pi(\frac{f-f_c}{f_s})k}} \quad (1)$$

Where a_k is the numerator coefficient, b_k is the denominator coefficient, $H_i(f)$ transmittance of the optical filter, f is the frequency, f_c is the optical filter center frequency and f_s is the sample rate. Single mode fiber (SMF) is used for transmission of optical signal. The receiver comprises of three sections: amplifier, PIN detector and Gaussian LPF. Optical amplifier is utilized for amplification of received signal at 110 km of SMF.

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PIN is used for conversion of the optical signal to electrical signal. LPF is employed for noise removal.

III. RESULTS

The CW laser is used in calculations with these parameters: line width = 10 MHz, power = 10dBm, and wavelength = 1550 nm. $LiNbO_3$ MZ modulator [5] is utilized in computations with the Extinction ratio of 30 dB. The DLF filter coefficients a_k and b_k are $-0.2 +0.4\ Z^{-1}-0.2\ Z^{-2}$ and $1+ 0.9Z^{-1}$ respectively. SMF with the following parameters are used in computations: effective core area = 80µm^2, wavelength =1550nm, length = 110 km, attenuation of 0.2 dB/km, dispersion slope = 0.075ps/nm^2/km and chromatic dispersion = 16.75ps/nm/km. Gain and noise figure of optical amplifier (EDFA) are 20 and 4 dB respectively. PIN detector having responsivity of 1 A/W and dark current of 10 nA. First order LPF with cut-off frequency of 10 GHz is employed.

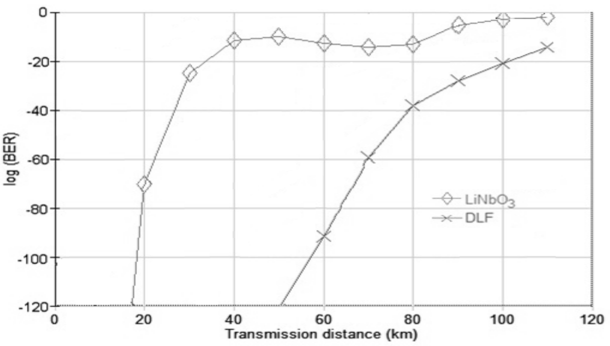

Fig.2 BER performance versus transmission distance

The BER value of the proposed DLF scheme at 84.5 km of SMF is less than 10^{-35} as shown in Fig.2. The simulated results confirm that the transmission distance of proposed scheme improved compared to MZ LiNbO3 modulator based transmitter scheme without filtration. The presented results confirm that the dispersion-restricted distance of 10 Gb/s optical system is enhanced by 30 % in comparison with without filtration scheme (LiNbO3).

The proper adjustment of CW operating wavelength, modulator extinction ratio related to the DLF parameter is required to attain enhanced eye-opening. The eye-patterns are presented for DLF and LiNbO3 scheme at 10 Gbps bit rate. The eye-diagrams of DLF and LiNbO3 schemes at 110 km are shown in Figure 3 and 4 respectively. The eye-widening values of DLF and LiNbO3 technique are 0.93 and 0.74 respectively. The comparison of DLF and LiNbO3 is shown in table 1.

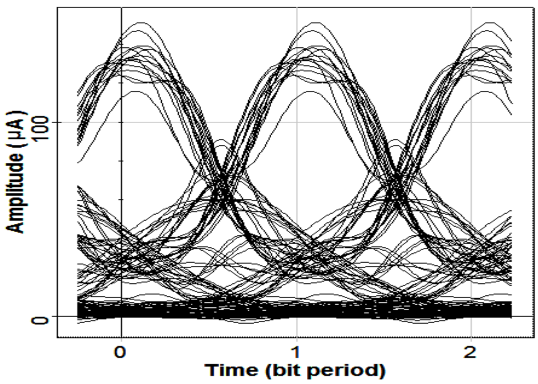

Fig.3 Eye-diagram with LiNbO3 scheme at 110 km

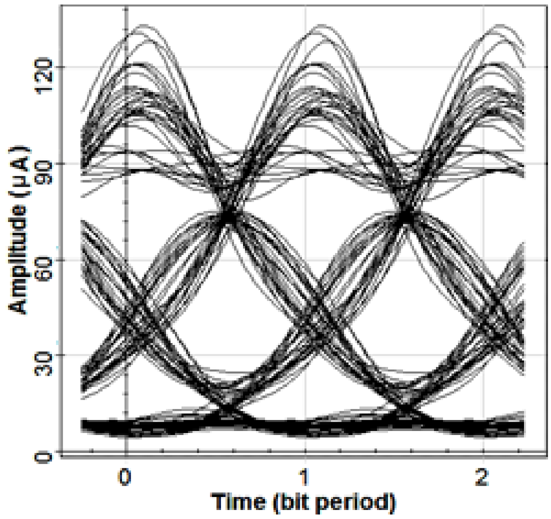

Fig.4 Eye-diagram with DLF scheme at 110 km

Table 1 Comparison of performance parameters

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parameter	DLF	$LiNbO_3$
Data rate (Gb/s)	10	10
fiber length (Km)	110	84.5
Eye-opening factor	0.93	0.74
wavelength (nm)	1550	1550
laser type	CW	CW
fiber type	SMF	SMF

The transmission distance of the optical filtering schemes is improved by 30 km when compared with LiNbO3 schemes. The current approach eye-opening is enhanced by 25% when compared to LiNbO3 based methods.

It is analyzed that the effectiveness of adopted filtering scheme is better to that of $LiNbO_3$ methods, which shows the importance of the optical filtering in transmitter in long-haul optical fiber system.

IV. CONCLUSION

We examined the capability of dispersion compensation using optical DLF at the modulator output. The effects of this filtration are investigated in the same system configuration and compared with the $LiNbO_3$ scheme. The adjustment of modulator output together with optical filter parameters are required for 110 km SMF transmission of optical signal at 10 Gb/s. The optical NRZ signal is recovered by using direct detection receiver. The simulated results confirm an enhancement in the transmission distance from 80 km to 110 km of SMF compared to $LiNbO_3$ based transmitter scheme.

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