ROBUSTNESS OF MODULATION FORMATS INCLUDING AMPLIFIER NOISE WITH AND WITHOUT DISPERSION COMPENSATION FIBER AT 10 Gbps TRANSMISSION LINK

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ABSTRACT

In this paper, we have analyzed the robustness of Non Return-to-Zero (NRZ), Return-to-zero (RZ), Chirped Return-to-zero (CRZ) and Carrier Suppressed Return-to-zero (CSRZ) modulation formats at 10 Gbps for long transmission link including noise and with & without dispersion compensation fiber. The comparative analysis among the different formats is carried out by means of obtaining its different waveforms. The investigations reveal that the performance of all the formats has improved by applying dispersion compensation fiber specifically in case of CRZ format.

Keywords: *Noise Figure, Modulation Formats, Dispersion Compensated Fiber.*

I. INTRODUCTION

For the next generation of optical communication systems to fulfill future capacity demands, state-of-the-art dispersion management will be required to effectively compensate for dispersion in a wide bandwidth and minimize non-linear signal degradation. So the need of increased capacity transmission systems with dispersion management has motivated the interest on new modulation formats with high spectral efficiencies and robustness. The modulation formats are used to improve the transmission performance and to achieve high quality transmission system. To combat both the linear and the non-linear impairments over the transmission fiber, an optimal modulation format is desired. A format with narrow optical spectrum can enable closer channel spacing and tolerate more chromatic dispersion distortion. A modulation format with constant optical power can be less susceptible to non-linear impairments like self phase modulation and cross phase modulation. A modulation format with two signal levels will be more efficient and its symbol duration will reduce the distortion induced by chromatic dispersion and polarization mode dispersion. In addition, in an optical repetitive amplified light wave system, amplified spontaneous emission (ASE) noise is another concern, that requires modulation formats more tolerant to ASE noise. There have been many optical modulation formats in the scope of above factors. As a result of intensive research activities have been done to witness the robustness of several modulation formats on the performance of optical transmission links. Various modulation formats like NRZ, RZ, CRZ and CSRZ has been taken in consideration in this paper to check the performance of optical communication system.

The Non-return-to-zero (NRZ) format requires a relatively low electrical bandwidth for the transmitter and receiver and it is not sensitive to laser phase noise and it has the simplest configuration of transceivers. NRZ modulated optical signals has the most compact spectrum. In addition, this format has been found to be less resistive to self phase modulation effect in transmission because different data patterns in a PRBS NRZ data stream require different optimum residual dispersion for the best eye opening. The RZ, return to-zero formats, the width of the optical signal is smaller than its bit period. RZ signals are more tolerant to non linearity. The reason for its superior resistance to non-linearity is probably due to its regular data pattern of optical signal. Chirped RZ (CRZ) modulation is a special case of RZ modulation realized by the implementation of the pre-chirp on the conventional RZ pulses at the transmitter side [1-4] for long transmission distance at channel data rate of 10 Gbps. CRZ modulation is basically used in long-haul under-sea transmission systems. This modulation format can reduce the waveforms distortions associated with conventional transmission formats. Carrier-suppressed RZ (CSRZ) modulation is used for high bit rate transmission systems. The main target of taking this modulation format is to reduce the non linear impacts in a transmission system and an improvement of the spectral efficiency in high bit rate systems. CSRZ modulation shows an increased dispersion tolerance [5] and it is more robust to non linear impairments [6].

As in-line dispersion compensation represents the key enabling technology for the realization of optical system, so the dispersion compensation in this paper is realized in the optical domain without electro-optical conversion of the signal, enabling better compensation of the signal because the optical phase is maintained. Dispersion compensates fiber scheme is utilized in the system having specific parameters defined.

In this paper, the tolerance of above modulation formats at 10 Gbps including amplifier noise with and without dispersion compensation has been investigated. The tolerance has been indicated, by reporting performance metrices like: Q factor and Eye diagram.

II. SYSTEM SETUP

The optical transmission link with & without dispersion compensation by using NRZ, RZ, CRZ & CSRZ modulation formats including amplifier noise is setup using OPTSIM™ and is shown in figure 1. The various system components needed for the realization of an optical transmission system are divided into three groups: Optical Transmitter, Transmission Channel and Optical Receiver. Here, in the transmission link each span comprises of Single Mode Fiber SMF (distance: 50 km, dispersion: +20 ps/nm.km, dispersion slope: 0.085 ps/nm.km^2, $ß_2$: -25.44 ps^2/km, $ß_3$:+0.179 ps^2/km, loss: 0.2 dB/km) and Dispersion Compensation Fiber DCF (distance: 10 km, dispersion: 80 ps/nm.km, dispersion slope: 0.0875 ps/nm.km^2, loss :0.5 dB/km) and amplifier having values of noise figure 6 dB.

For the realization of transmission systems with channel data rates higher than 10Gbps, the external modulation is used here because the impact of laser internal chirp on optical signal can be reduced efficiently. The external modulation is realized by the modulation of the laser light in an external modulator. This can be a mach-zehnder (MZM) or Electro-absorption modulator (EAM). The external modulator is driven by an electrical signal with corresponding data rate. Depending on the electrical driving signal and the operation regime of the external modulator, different AM based modulation formats can be realized. We have used MZM in this system so as to reduce the dispersion induced penalty in the transmission line. MZM is based on the electro-optic effect that is characterized by the variation of an applied electrical field causing refractive index changes in the modulator arms. The variation in the refractive index in the modulator arms induces a change of material propagation constant resulting in different phases in both modulator arms.

Further in the system, dispersion compensation is employed in the link on a span-by-span basis. The in line dispersion compensation is realized by the use of dispersion compensated fiber (DCF) in the system having parameters defined earlier. The DCF are characterized by a large negative dispersion and a small core diameter. The large negative dispersion values can be achieved by the variation of the fiber profile by doping the fiber cladding (e.g. by fluorine) [7], introducing an increase in the refractive index difference between the core and cladding. A significant increase of negative fiber dispersion can be achieved using sophisticated refractive index profiles like matched cladding type [8], a W-shape type enabling the realization of a negative dispersion slope .The following figure 2 shows the DCF characteristics (W-shape) and the dispersion spectra of SMF & DCF.

As optical amplifiers represent one of the crucial components in an optical transmission system, so in the system the Erbium Doped Fiber Amplifier (EDFA) is used due to the fact that it provides an efficient optical amplification in the 1.55 µm region. Since a precise narrow-band filtering both at the transmitter and receiver side is necessary so we make use of Mach-Zehnder interferometers (MZI) in the system. MZI based filters are interferometric devices in which the filtering is realized by the length variations in the MZI arms. Direct detection based receiver is used for all the investigations due to its simple realization and robustness. The operations principles and state of the art technologies are introduced as well as mathematical models of conventional transmission components used for numerical investigations.

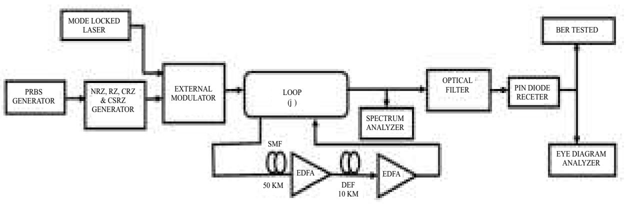


Fig. 1: System Configuration

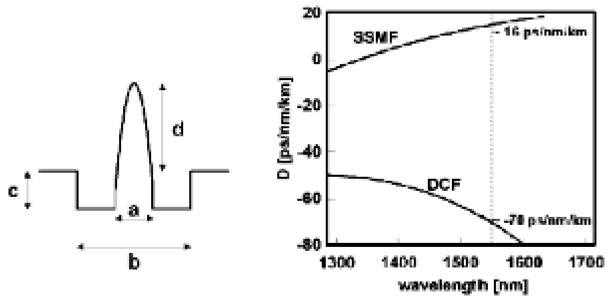


Fig. 2: DCF Characteristics and Dispersion Spectra of SMF & DCF

III. RESULTS & DISCUSSIONS

The system is analyzed here and the performance of the various modulation formats considered is checked with & without dispersion compensation under different conditions. Two cases are discussed; one for all the formats with and without dispersion compensation by taking quality factor Q^2 (dB) and second case is for all the formats with eye diagram as performance metrices.

Case: 1: In this case the performance evaluation for different data formats at 10Gbps, NF = 6dB with & without dispersion compensation for 9 spans and single span has been discussed.

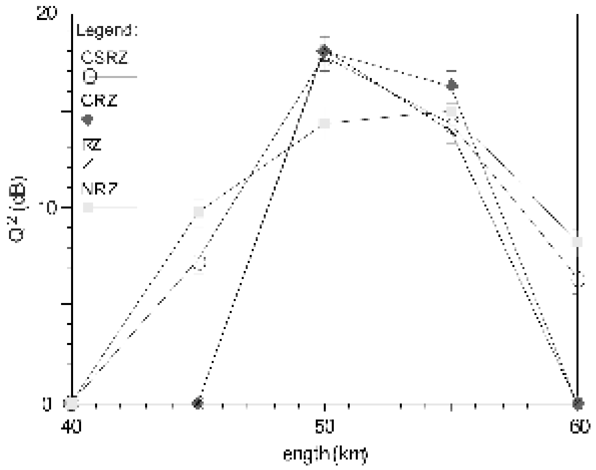


Fig. 3 (a)

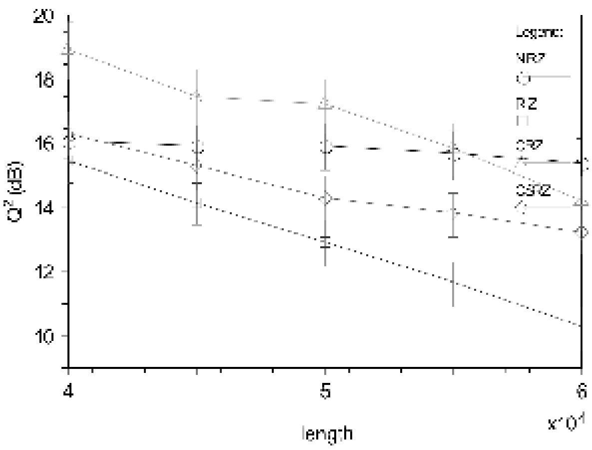


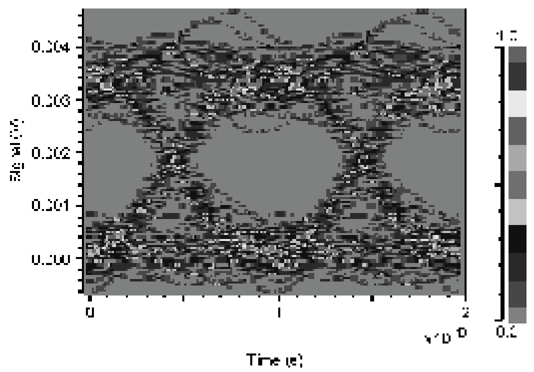
Fig. 3 (b)

Figure 3: (a) Q^2 (dB) without Dispersion Compensation

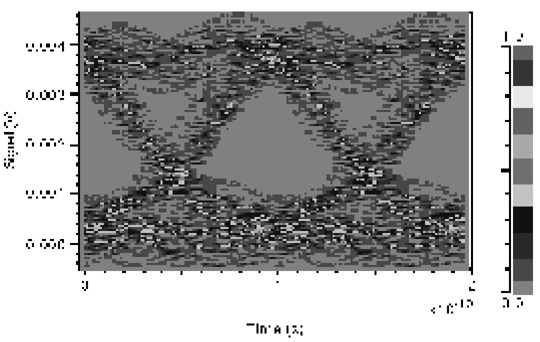
(b) Q^2 (dB) with Dispersion Compensation

Figure 3(a) & 3(b) demonstrate the value of Q^2 (dB) for all the considered formats versus length of the fiber taken at different intervals without dispersion compensation and with dispersion compensation at a distance of 45 to 60 km respectively. From the figures it is clear that highest Q^2 (dB) of the order of [0,0]; [7,7]; [9.5, 8] ;[0,8] and [14.1, 11]; [15.1, 12.9]; [16, 15.5] ;[17.5, 14] has been obtained in case of RZ, CSRZ, NRZ and CRZ modulation formats without dispersion compensation and with dispersion compensation respectively. After 55km the value of Q^2 (dB) gradually decreases with increasing the distance. So it is observed that CRZ modulation format in comparison to NRZ, RZ & CSRZ ts indicated better performance specifically at a distance of 45 km & 60km where the value of Q^2 (dB) increases from 0dB to 17.5 dB at 45km and from 8 dB to 14 Db at 60 km. so performance of CRZ format is more robust.

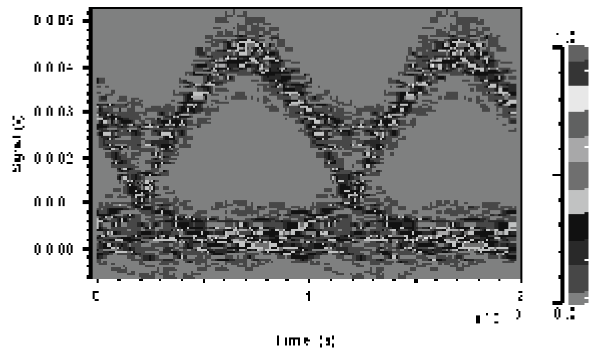
Case- II: In this case the performance evaluation of all the formats at 10Gbps with & without dispersion compensation and NF=6dB has been observed in the form of eye diagram.



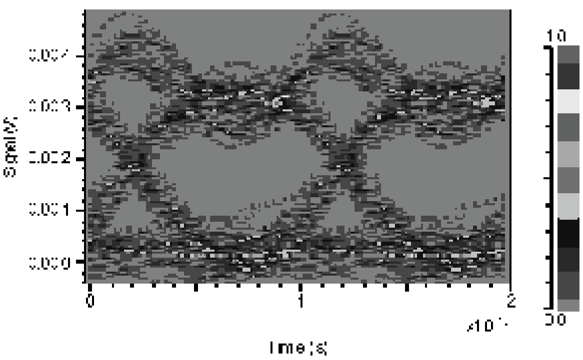
(a)



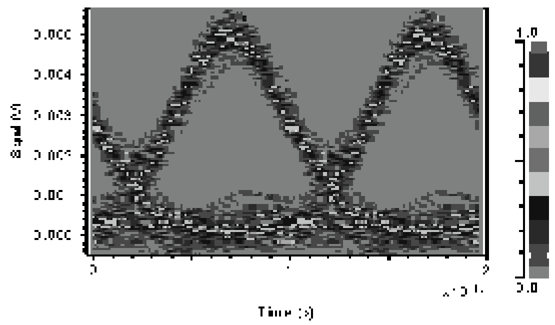
(b)



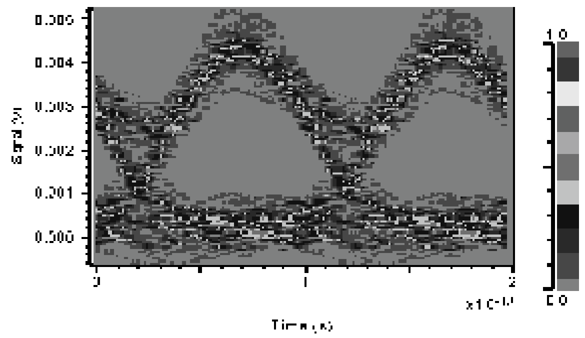
(c)



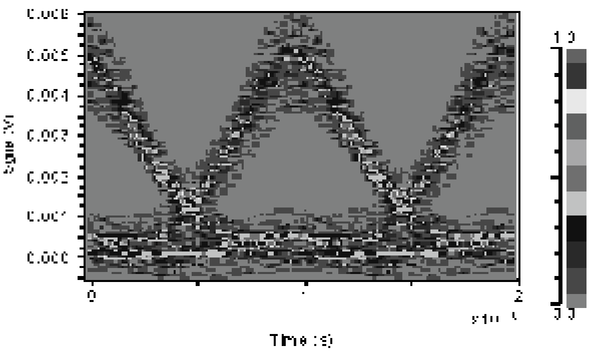
(d)



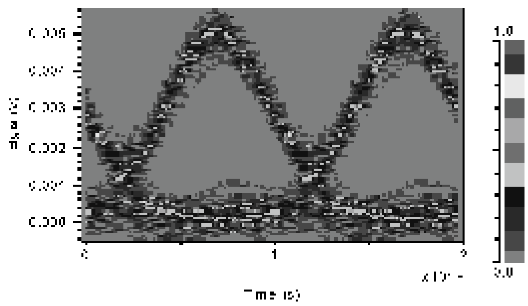
(e)



(f)



(g)



(h)

Figure-4(a) NRZ without DCF (b) NRZ with DCF (c) RZ without DCF (d) RZ with DCF (e) CSRZ without DCF (f) CSRZ with DCF (g) CRZ without DCF (h) CRZ with DCF

Therefore from the above eye diagrams for all the modulation formats with & without dispersion compensation it is clear that with dispersion compensation, the eye opening is improved in all the cases but the maximum value of eye opening is given by CRZ format followed by RZ, CSRZ & NRZ formats. So the CRZ format in comparison to all the other formats is showing optimum performance.

IV. CONCLUSION

The simulation results for the transmission link for NRZ, RZ, CRZ & CSRZ reveals that there is significant improvement in terms of Q-factor in the performance of CRZ modulation format by using dispersion compensated fiber. This fact has been further proved by taking eye diagrams of all the formats with & without dispersion compensation. So it is recommended that CRZ transmission links may be preferred where high Q-factor is required.

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