Comparison of Advance Data Modulation Formats in 4×10Gbps WDM Optical Communication System using YDFA, EDFA and Raman Amplifier

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Abstract- In this paper, comparison of various advance data modulation formats in 4×10Gbps wavelength division multiplexing (WDM) optical communication system using YDFA (ytterbium doped fiber amplifier), EDFA (erbium doped fiber amplifier) and Raman amplifier has been carried out. The advance modulation formats under investigation include NRZ (non return to zero), RZ (return to zero), CSRZ (carrier-suppressed return to zero), DRZ (duobinary return to zero) and MDRZ (modified duobinary return to zero).The WDM system has been analyzed for 10Gbps over 100km fiber. It has been observed that MDRZ transmitter gives superior results followed by DRZ and CSRZ also RZ performs better than NRZ. On comparing amplifiers, YDFA and EDFA show comparable results. MDRZ performs better than DRZ and CSRZ in both the amplifiers. In Raman amplifier CSRZ outperform DRZ but both are inferior to MDRZ. The best results have been reported for EDFA with MDRZ modulation format, where the maximum Q factor of 18.57dB is achieved. The performance degradation over a fiber in optical system is due to nonlinearities. MDRZ show high immunity towards nonlinearity. It is determined that MDRZ format seems to be best choice for the transmission distance beyond 100km.

Keywords – CSRZ, DRZ, MDRZ, WDM

I. INTRODUCTION

The increasing demand of transmission capacity has motivated to scrutinize advance modulation formats. Because of the rapid growth of capacity requirement on long distance transmission, fiber-optic communications system is advancing into high data rate and wavelength division multiplexing (WDM). In order to maximize the system capacity and minimize the performance degradation caused by transmission impairments, system engineering and optimization are important. Advance modulation formats operate better in wavelength division multiplexing. Besides NRZ and RZ other modulation formats which were studied include CSRZ, DRZ and MDRZ. Ytterbium amplifier provides amplification over wide wavelength range. Spectral properties are the main dissension between EDFA and YDFA [1]. RZ data modulation format show better results with EDFA [2]. The main prosecution of YDFA include power amplification, fiber sensor applications, free space laser communication. Early results obtained suggest that YDFA have very cogent fraction of Yb^{3+} ion population, quenched to very short lifetime. In the absorption and emission spectra of YDFA have some complications, which do not arise in EDFA.

Rudiger Paschotta et al. [1] define various important applications of ytterbium amplifier such as broad gain bandwidth and high efficiency. This paper also discuss stimulated Brillouin scattering, in which high brillouin gain generate high brillouin wave. Yugnanda Malhotra et al. [2] investigated spectral loss variations for different modulation formats. These investigations show that Manchester encoding uses double bandwidth than NRZ also NRZ raise cosine has highest power levels with very less noise spikes at high bit rates. Kim et al. [3] analyzed NRZ and RZ optical signal in an optically preamplifier receiver and measured the dependence of PMD penalty on receiver characteristics. The results concluded that RZ signal are more tolerant to first order PMD than NRZ signal for typically receiver bandwidth. A. Mecozzi et al. [4] studied the properties of various compensation schemes to cancel the effect of timing and amplitude jitter. The observation suggested that symmetrical compensation scheme completely cancel the effect of timing and amplitude jitter. Reduction in nonlinear penalty is also being achieved using in line amplifiers.

Ajay k. Sharma et al. [5] studied robustness of various modulation formats at 40Gbps. The performance is categorized using Q-factor. They investigated non linearity and noise show robustness up to 450km at 40Gbps.

At high bit rate, CSRZ show better results than NRZ and RZ. D. Dahan et al. [6] demonstrated a detailed numerical investigation of point-to-point 40 Gbps 40 channel WDM transmission system for three different modulation formats. In this paper PMD and dispersion slope tolerance has been calculated. They showed that backward pumping distributed Raman amplification with NRZ, RZ, CSRZ show better results. Malti et al. [7] studied advance modulation format at different bit rates. Results show that with the increase in bit rate system performance decreases. It is also observed that MDRZ show better performance as compared to DRZ and CSRZ at high bit rates. At 2.5Gbps CSRZ is better than DRZ and MDRZ Simulation results show that at bit rate 5Gbps MDRZ show optimum performance at input power = 15dBm. Anu sheetal et al. [8] obtained simulation analysis of asymmetric XGPON transmission using NRZ and RZ modulation formats. It was observed that for co-existing system of XGPON and GPON RZ is superior to NRZ, providing high immunity towards non linearity.
Simranjit et al. [9] investigated the performance DWDM system consisting of hybrid amplifier for different modulation formats such as NRZ, RZ and DPSK. The outcome of results indicated that RZ is more adversely affected by nonlinearities where as NRZ is affected by dispersion. Peter M. Krummrich [10] studied robust optical transmission systems for various advance modulation formats. Less spectral width improves performance of modulation formats in case of dispersion. NRZ formats show better performance than RZ with respect to dispersion tolerance. Simranjit et al. [11] demonstrated hybrid optical amplifier with different modulation format. In long haul communication RZ show better results than NRZ. The results show that the Raman amplifier degrades the performance. Anu Sheetal et al. [12] presented simulation results of high capacity DWDM system using different modulation formats. The results show that MDRZ show faithful transmission in long haul communication. Also at high bit rates MDRZ is superior to DRZ and CSRZ. Sheetal et al. [13] analyzed that nonlinear phase noise decreases the noise limited transmission distance at higher power levels.

Up till now the research for CSRZ,DRZ and MDRZ format is available mostly for EDFA and Raman amplifier. Here we have extended the work reported in Refs. [2,12]. In this paper CSRZ, DRZ, MDRZ, NRZ, RZ modulation formats are analyzed using ytterbium amplifier. We have also compared the modulation formats on the basis of Q value and BER for different transmission distance ranging from 20km-100km at constant input power. In section II, transmitters of modulation formats are explained. Section III explains system description, in section IV results have been discussed and at last in section V Conclusions are made.

II. TRANSMITTERS OF MODULATION FORMATS

Non return to zero (NRZ) transmitter

This modulation format has simplest configuration. Commercially NRZ modulator is widely used. The optical signal generated by continuous wave (CW) laser is ON-OFF keyed by Mach-Zehnder modulator (MZM) [15]. The modulation bandwidth in this case is 2B (bit rate). The optical spectrum of NRZ transmitter signal is shown in Figure 1(a).

Return to zero (RZ) transmitter

The optical signal generated by CW laser is ON-OFF keyed by MZM. This signal is again generated by raised cosine signal to generate RZ transmitter [15]. The modulation bandwidth for RZ is 4B (bit rate). The optical spectrum of RZ transmitter signal is shown in Figure 1(b).

Carrier suppressed return to zero (CS-RZ) transmitter

CSRZ show high resistance towards self phase modulation and group phase dispersion [15]. In case of CSRZ there is π shift between adjacent bits. Therefore DC component is absent in CSRZ. CSRZ consists of two modulators, first modulator generates chirp- free RZ optical signal and second modulator prove π shift between adjacent bits. Most importantly, CSRZ reduces efficiency of four-wave mixing in WDM system [15]. The optical spectrum of CSRZ transmitter is shown in Figure 1(c).

Duobinary return to zero (DRZ) transmitter

The optical spectrum of DRZ transmitter is shown in Figure 1(d). Duobinary signal is generated by creating NRZ duobinary signal using a duobinary precoder with delay of one bits, NRZ pulse generator and duobinary pulse generator. The output pulse generator is feed into the first MZM. This first modulator is cascaded with second MZM modulator, which is further driven by sinusoidal electric signal with phase = -90°, frequency = 40GHz . The duobinary precoder used for generation of duobinary signal is composed of an exclusive-or gate with delay feedback path [12].

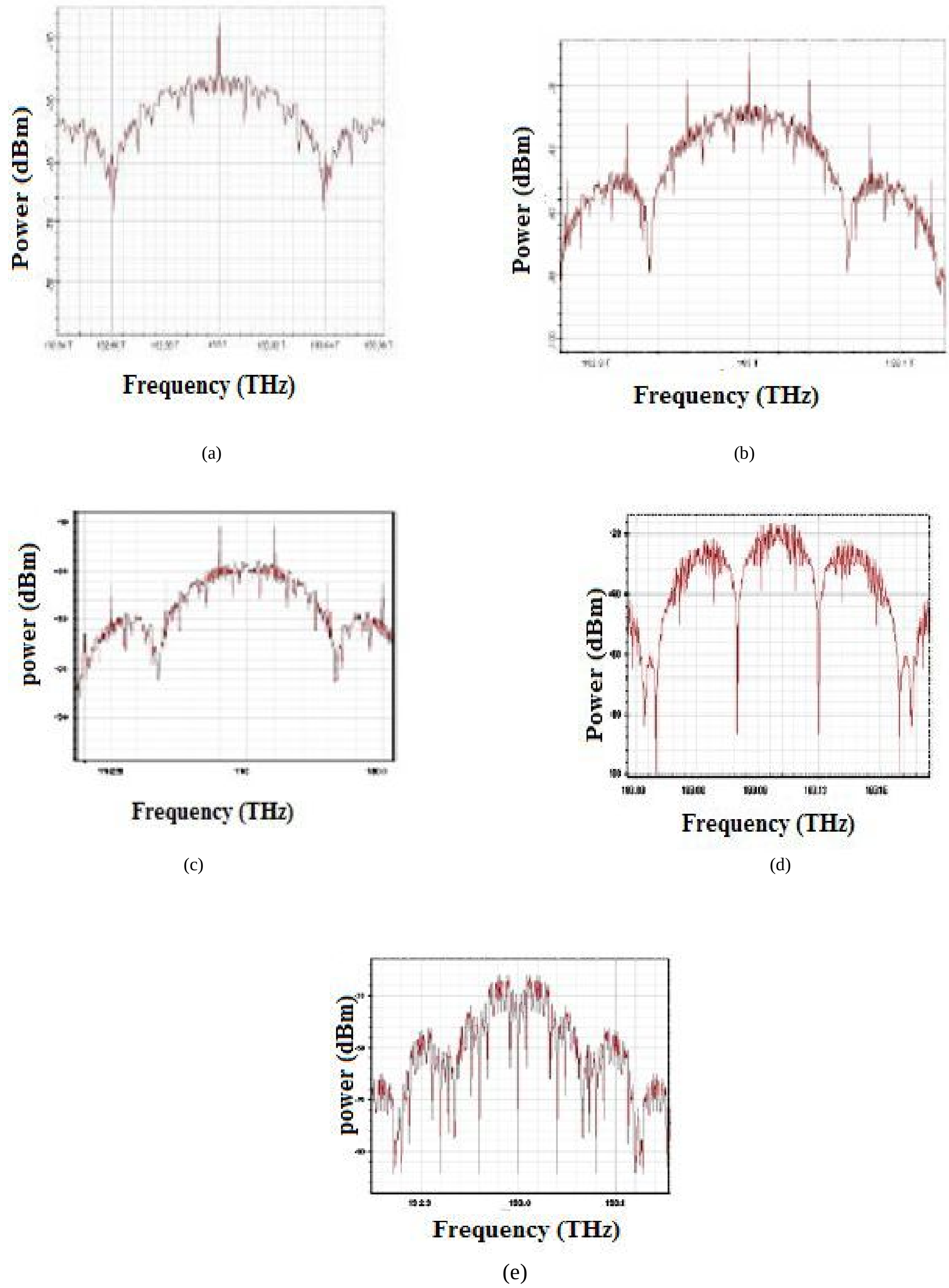


Figure 1. Frequency spectrum of (a) NRZ transmitter, (b) RZ transmitter, (c) CSRZ transmitter, (d) DRZ transmitter, (e) MDRZ transmitter.

Modified duobinary return to zero (MDRZ) transmitter

The MDRZ signal is produced first by creating NRZ duobinary signal with the help of delay and subtracts circuit. This NRZ duobinary signal drives the first Mach-Zehnder Modulator. First MZM cascaded with second MZM, which intern is driven by sinusoidal electrical signal. The main feature of MDRZ and DRZ is that it suppresses the pulse to pulse interaction and also ghost pulses [12,13].The optical spectrum of MDRZ is shown in Figure 1(e).

III. SYSTEM DESCRIPTION

Figure 2. Show schematic of WDM optical system with ytterbium amplifier, EDFA, Raman amplifier using various advance modulation formats. The system is composed of transmitter, fiber, amplifier and receiver. The WDMtransmitter consists of CW laser, data modulators and a multiplexer. Each output of CW laser is fed into data modulator (discussed in section II). The emission frequency ranges from 193.1-193.4THz. In case of RZ the optical multiplexer have bandwidth of 4 times the bit rate, while as for NRZ it is 2 times the bit rate, while as for CSRZ, DRZ, MDRZ optical MUX have bandwidth of 16GHz. The optical link consists of SMF and amplifier.Various fiber parameters are: dispersion = 16.75ps/km-nm, dispersion slope = 0.075ps/km-nm^2, effective core = 80μm^2, nonlinear refractive = 2.6×10^{-20}m^2/w. The operating wavelength and channel spacing are defined by ITU-T.

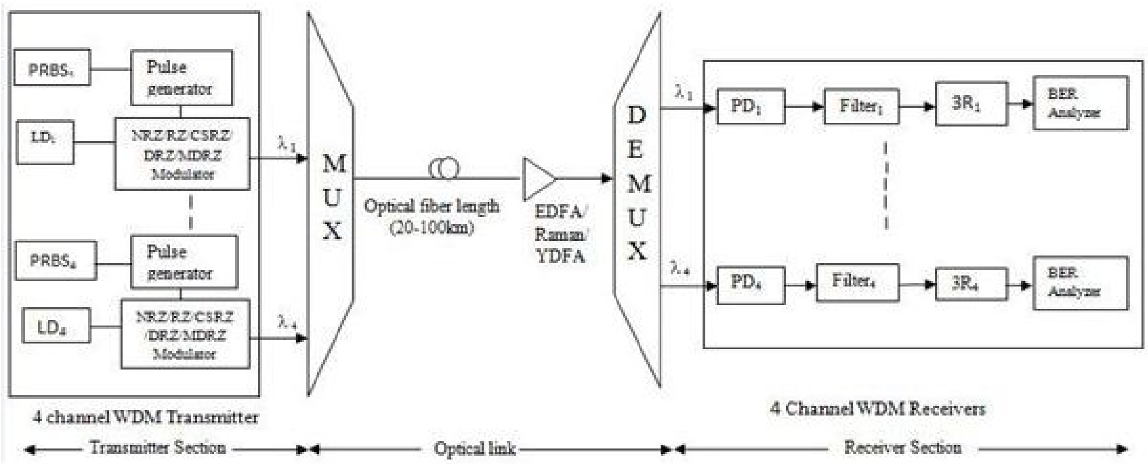


Figure. 2. Schematic diagram of WDM optical system using various modulation formats.

In the receiver end, the signal is demultiplexed and detected by photodiode. The converted electrical signal is fed to the low pass bessel filter and 3R regenator. Low pass bessel filters with parameters: 0.75$^{\times}$ bit rate cut off frequency, depth = 100dB, order of the filter = 4 is used. Thereafter 3R regenerator is simply used to regenerate the signal which is directly connected to the BER analyzer. BER analyzer is used to generate eye diagrams, BER, Q values etc.

IV. RESULTS AND DISCUSSIONS

The five modulation formats have been compared at 10Gbps using different amplifiers. To analyze the system the results of the second channel (193.2THz) have been taken. In case of 10Gbps system the worst Q value is obtained from third channel (193.2THz) and fourth channel (193.4THz) as they experience high non linearity owing to FWM effect. Roubstness of NRZ, RZ CSRZ, DRZ and MDRZ modulation formats at 5 and 10 Gbps has been investigated using ytterbium amplifier, EDFA and Raman amplifier.EDFA and YDFA shows analogous results with various modulation formats. Both the amplifiers show good results for MDRZ format. DRZ shows better results than CSRZ while RZ is superior than NRZ. This results are supported by the work reported in Refs. [12,14].In case of DRZ, the results obtained at 193.2THz are the excellent. At 10Gbps, DRZ shows better results for input power = 18dBm. As the input power is increased, Q-factor starts increasing but after certain value of input power it starts decreasing. This simply can be understood from the fact that in case of WDM system performance improves with the increase in input power but starts decreasing due to nonlinear effects coming in to play such as XPM and FWM. This show good agreement with the results of Ref. [12]. As the bit rate is increased from 5 to 10Gbps the value of Q-factor starts decreasing, as at higher data rates and powers the system is vulnerable to fiber non linearities. DRZ format shows optimum value of BER and Q-factor at 18dBm for 50 km fiber length. In case of Raman amplifier CSRZ show improved results than DRZ but both are inferior to MDRZ. Eye diagrams of various modulation formats with YDFA, EDFA, Raman amplifier are shown in Figure 3, 4 and 5 respectively.Graphs showing Q value for all data modulation formatsare shown in Figure 6 and Figure 7.

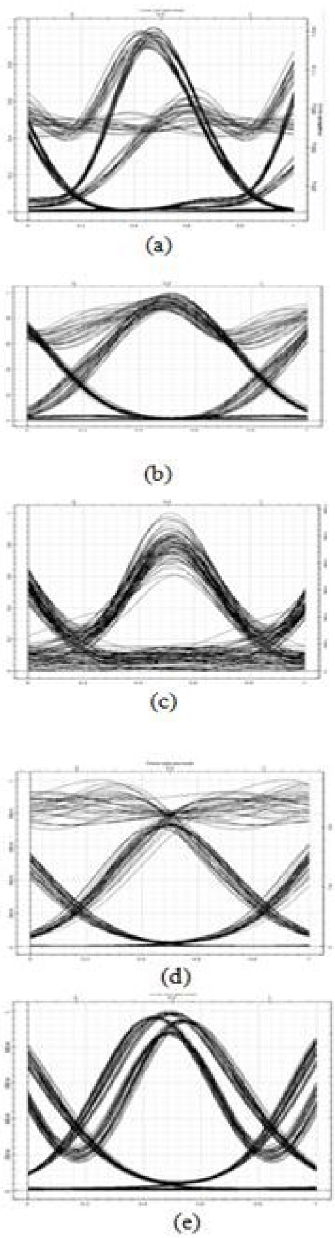


Figure 3. Eye diagram over transmission distance 50km ofYDFA (a) NRZ, (b) RZ, (c) CSRZ, (d) DRZ, (e) MDRZ.

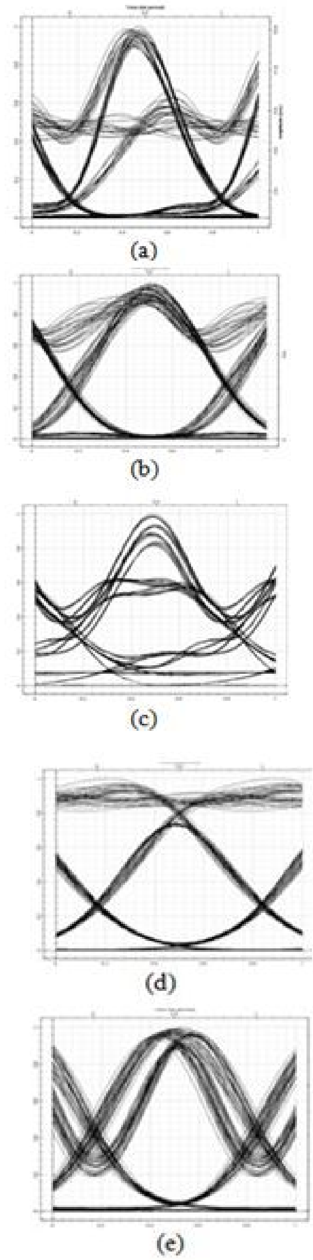


Figure 4 .Eye diagram over transmission distance 50km of EDFA (a) NRZ, (b) RZ, (c) CSRZ, (d) DRZ, (e) MDRZ.

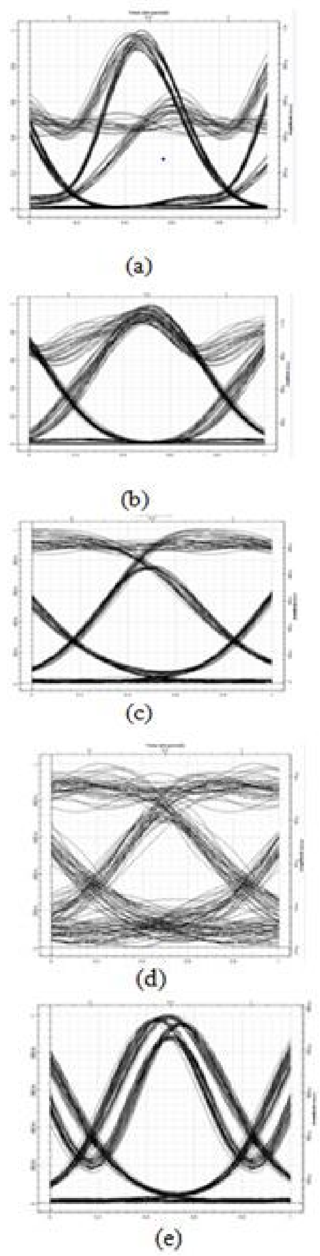
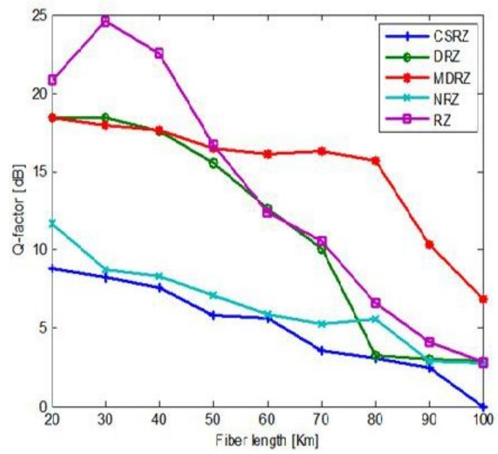
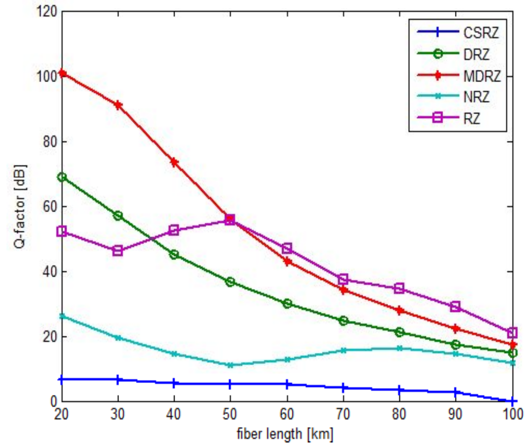


Figure 5 Eye diagram over transmission distance 50km of Raman amplifier (a) NRZ, (b) RZ, (c) CSRZ, (d) DRZ, (e) MDRZ.



(a)



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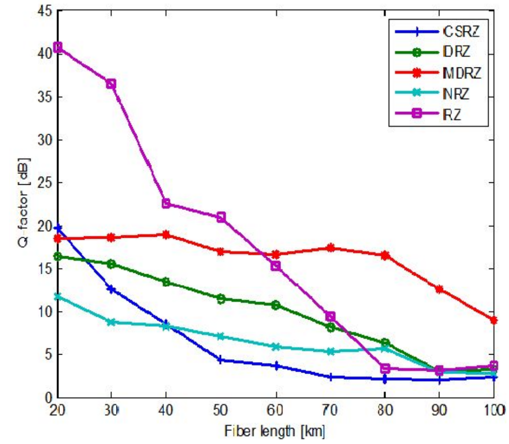

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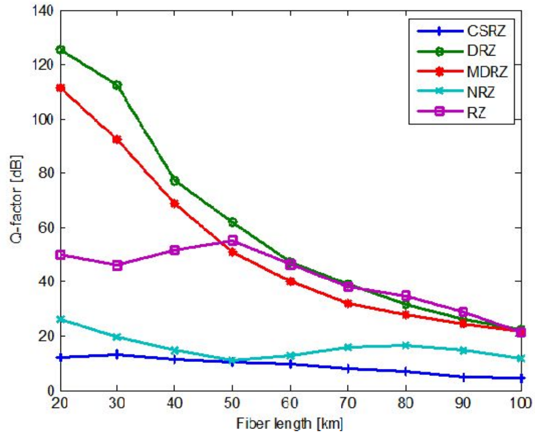

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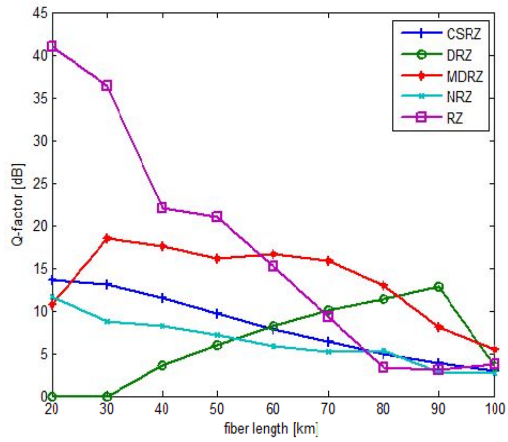
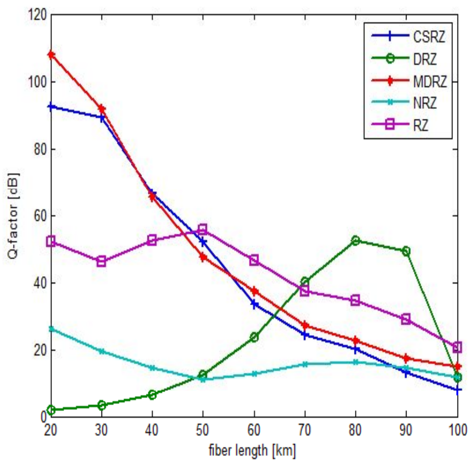


(c)



(c)

Figure. 6. Q value as a function of fiber length at 10Gbps (a) YDFA, (b) EDFA, (c) Raman amplifier.

Figure 7 . Q value as a function of fiber length at 5Gbps (a) YDFA, (b) EDFA, (c) Raman amplifier.

Table-1 Q value [dB] for EDFA when SMF length = 50km

Bit rate	NRZ			RZ			CSRZ			DRZ			MDRZ		
	YDFA	EDFA	Raman	YDFA	EDFA	Raman	YDFA	EDFA	Raman	YDFA	EDFA	Raman	YDFA	EDFA	Raman
5Gbps	10.97	11.04	10.96	55.30	55.60	55.10	5.26	10.32	52.11	36.65	61.99	12.60	55.93	51.14	47.66
10Gbps	7.12	7.11	7.12	16.79	21.09	21.05	5.81	4.38	9.62	15.56	11.41	5.96	16.52	17.02	16.12

On taking into account conventional modulation formats, RZ shows good better results as compared to NRZ format at different bit rates for various amplifiers. This shows good accord with Ref. [16] at different bit rates with different amplifiers. In case of RZ formats it has been observed that the value of Q-factor decrease rapidly after certain value of SMF length. This affect is due to increase in nonlinearties. This show good concurrence with Ref. [1].

Thus on summarizing the results obtained at different values of SMF length from 20-100km suggests that MDRZ is better than DRZ and CSRZ. While as on considering conventional modulation formats RZ show better results than NRZ. These results show good accord with Ref. [1,12,14].

From Table 1, it can be concluded that EDFA is better than YDFA at 5Gbps for all the formats. However at 10Gbps YDFA can be prefered over EDFA for CSRZ and DRZ.In case of Raman amplifier, at 5Gbps CSRZ show much better results. This is due to the absence of ASE and thermal noise. While as MDRZ show better results than DRZ. At 10Gbps the performance of CSRZ decreases rapidly. In case of conventional modulation formats such as NRZ and RZ, RZ show superior results than NRZ. These results obtained are also consistent with the results reported in Ref. [6].

V. CONCLUSION

In this paper, different advance modulation formats using ytterbium amplifier, EDFA and Raman amplifier. MDRZ show paramount results than DRZ and CSRZ. Superior performance suggests that MDRZ works better in long haul communication. Also, as the fiber length is increased,the performance of modulation formats decreases. In case of Raman amplifier CSRZ show better results than DRZ. MDRZ show high immunity, towards non linearity as it suppresses pulse to pulse interaction and ghost pulses.It is determined that MDRZ format seems to be best choice for the transmission distance beyond 100km.

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