Journal of Information Engineering and Applications www.iiste.org
ISSN 2224-5782 (print) ISSN 2225-0506 (online)
Vol 2, No.2, 2012

Study in variable duty cycle return to zero pulse with multiplexed channels for SMF's

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Abstract

In this paper analysis has been done with varying return-to-zero (RZ) pulsed duty cycle, differential phase shift keying 640Gbps (16x40Gb/s) multiplexed channel optical transmission system using different SMF's viz standard Single mode fiber (SSMF), Non Zero Dispersion shifted fibers (normal NZDSF and anomalous NZDSF fiber), Corning SMF.Optical transmission used for sixteen users operates at 40Gbps per channel, 0.20nm spaced sixteen channels and fiber span analysis is done for test length of 200km. We tested system for detailed performance study for its behavior with different duty cycles for optical RZ pulse, results showing lowest bit error rate for 0.80 duty cycles among selection of 0.5, 0.8.0.99 for four types of SMF's tested for optical communication. Single repeater less mode fiber length is increased from 60km at duty cycle 0.5 to NZDSF fiber length of 140km at duty cycle 0.99.Results are also compared through 10dB Q improvement and corresponding improvement in average eye opening pattern. NZDSF fiber shows much improvement in average eye opening diagram for 0.99 duty cycle compared to other fibers tested and other duty cycles tested.

Key words: DWDM, ASE, RZ, DPSK, OSNR.

1. Introduction

The capacity of optical communication systems can exceed 10Tb/s because of large frequency associated with the optical carrier. In modern and high-tech communication system, the plan of new generation networks is increasing efficiency, supporting the large number of subscribers and sub channels in networks. Long-haul optical transmission systems spectral capacity of have been increasing at a rate exceeding the Moore's Law and demand for higher bandwidth has been enhancing even faster. Optical capacity of fiber can be increased by minimizing fiber loss, or increasing the OSNR, reducing the channel spacing, increasing the low loss window to fit more WDM channels, or making better use of the existing window by employing higher order modulation formats [1].Fueled by the seemingly inexhaustible human appetite for more bandwidth per user and, by the new requirements that are far less predictable than they have been before, the bandwidth utilization moved ever forward. Before the invention of optical fiber the transmission medium has always been the scarcest resource [2]. Closely coupled to the generation, processing, and storage of digital information is the need for data transport, ranging from short data buses all the way to long-haul transport networks. In an effort to make the most efficient use of resource, various technologies have been developed so that multiple users can be supported in the same transmission medium. This concept is called "multiplexing". Various multiplexing and modulation schemes are developed to increase the transmission capacity of wavelength division multiplexing (WDM) systems [3–7].but further increment in transmission capacity over a single WDM channel is limited by the electronic and optoelectronic components. In addition to that, bit and symbol synchronization for clock-and-data recovery becomes an important issue in such high-speed system. This issue is partly solved by using return-to-zero (RZ) line coding, which facilitates bit level synchronization. Increasing the per-channel bit rate from 10Gb/s up to 40Gb/s is seen today as a way to achieve a very high spectral efficiency without the need to resort to expensive dense wavelength-division multiplexing (DWDM) filter technology.

While studying intensity-modulated direct-detection optical systems there arise two possible modulation formats i.e. Non return-to-zero (NRZ), in which a constant power is transmitted during the entire bit period and other return-to zero (RZ), in which power is transmitted only for a fraction of the bit period. Duty factor of a single pulse is the ratio of signal pulse width to bit duration. Dependency of the 10-Gb/s/ch long haul transmission performance on the signal pulse duty factor was studied by several researchers, Consideration that which format having with better receiver sensitivity, was addressed more than 20 years ago by Personick [8], periodically resurfaces. Now important point is that which one is better, was carried by studying its performance.Personick and further Marcuse [9] for amplified systems have studied the comparison of RZ and NRZ assuming an ideal transmission medium, and concentrating on receiver performance. The transmission impairments introduced by the optical fiber dispersion and other nonlinear effects were studied for both modulation formats, and it was demonstrated that NRZ is in generally more robust against degradations due to fiber propagation. The dependence of the 10-Gb/s/ch long-distance transmission performance on the signal pulse duty factor is studied by numerical calculations and experiments [10].

Traditional non return-to-zero (NRZ) code-pattern would not have met the demand, while needing other new modulation formats. The shapes and duty cycles of optical pulses used for optical data generation will be different depending on the way that the pulses are generated, thus leads to variation on the transmission performance for a given fiber link.

A multiplexing technique, which is based on duty-cycle division, was also studied for channel multiplexing and demultiplexing performed electrically at the single user bit rate, which is very economic. But study was limited to three-user system and lower bit rate per channel [11].Consequently it is very important to study the impact of optical pulse shape variation on the transmission of dense wavelength division-multiplexed (DWDM) signals and duty cycle influence the optical transmission performance. Such characteristics can provide guidelines on how to choose and operate pulse sources properly. Here in this paper there is performance study for duty cycle selection, will be better with sixteen user 40Gbp/s/ch WDM (640Gbps) optical communication system. Comparison for the performance at 40Gbit/s based WDM transmission using return to zero differential phase shift keying modulation format in terms of its optical transmission performance and characteristics. The impact of fiber type is also investigated using different types of fibers viz NZDSF, DSF, standard SMF, YYCorningSMF for varying duty cycle is tested optical communication. Thus, we can obtain an idea of better duty cycle with high spectrum efficiency and high tolerance for optical noise and nonlinearity effect.

2. Theory

The technology of RZ code come up recently, which is used in high-speed optical transmission systems. In the pulse sequence of the RZ code, the transition area that connects ‘‘1’’ amplitude of electric field has an independent time envelope. Because the modulation format of RZ has a different transition all the time in the code bits, it can bring more ‘‘neatness’’ optical signal in order to unscramble the receiver. The advantage of RZ is the low average of optical power and higher ability for anti-nonlinearity effect and anti-polarization mode dispersion (PMD) [12]. The RZ code is also more conducive to clock recovery. Because the consecutive ‘‘1’’ of NRZ is a whole, the eye pattern of RZ code stretches more, the anti-error-code performance becomes better, and improves the 3 dB of the optical signal-to-noise ratio (OSNR).

Chromatic dispersion at 1550nm is very high that led to development of dispersion shifted fiber, which is designed to have zero dispersion and reduced pulse spreading due to chromatic dispersion in the1550nm band. However dispersion shifted fibers are affected by noise induced as a result of nonlinearities causing four wave mixing. But all these penalties are minimized if a small chromatic dispersion is present in the fiber since the different interacting waves then travels different group velocities, this led to development of nonzero-dispersion fibers (NZDSF).In such fibers chromatic dispersion present is in between 1 to 6ps/nm-km in the 1.55 μm wavelength window. This reduces the penalties due to nonlinearities while retaining most of its advantages of dispersion shifted fiber. Nonzero-dispersion fibers (NZDSF) overcome nonlinear effect by moving the zero-dispersion wavelength outside the 1550nm operating window. Practical effect of this is to have a small but finite amount of chromatic dispersion at 1550nm, which minimizes nonlinear effects such as four wave mixing, self phase modulation and cross phase modulation in WDM. For a channel is intensity modulated with bit rate R = 1/T, and the ‘‘one’’ symbols are transmitted using rectangular pulses with duration ρT. The parameters ρ, $0<\rho\leq 1$, is the duty cycle. The peak power of each pulse is Pp=P/ρ, where P is the average power transmitted on a ‘‘one’’ bit.

The following single span of an amplified system is considered for simplicity, with length L. The fiber has loss a, effective length Le = $(1(1-e^{-\alpha L \mathrm{Ae}})/\alpha$, and effective core area A_e. The chromatic dispersion D may vary along the link, according to a prescribed dispersion map. This was studied by Personick[10] that the optimal input pulse for an IM/DD optical communication system is an impulse. Using PIN receivers the sensitivity is 2 dB better than for NRZ. Duty factor of a signal pulse is the ratio of signal pulse width to the bit duration. In a preamplifier receiver using an "Integrate and dump" filter, the sensitivity depends upon the average received power and not only on the duty cycle [13].But, if a more general electrical filter shape is allowed, Personick's considerations for pin receivers carry over to pre-amplified receivers. It has been verified using the simulator explained in [14]. Reasoning that with RZ the pulse energy is concentrated in a shorter time interval, providing a broader eye opening for the same filter bandwidth or the possibility of large noise rejection for the same intersymbol interference. Improvement in sensitivity of 2-dB, although not negligible and is the only advantage that RZ offers over NRZ.

Table 1. Transmission characteristics of ITU-T recommended used fibers

ITU-T	Fiber Name	D in Ps/nm/km	Effective core area in 10^{-12} m^2
G.652	Standard SMF	16	81.7
G.652	yy-CorningSMF28e	-16	85
G653	DSF(DS Anomalous)	2	55
G.655	Lucent True wave	4.5	55

Effect of chromatic dispersion is to introduce a delay among the spectral components of the signal. Because the lower the duty cycle ρ, the higher the bandwidth, it is expected that the effect of dispersion is larger for smaller ρ. One better estimate for the dispersion length, here defined as the length at which the eye opening has a relevant penalty, can be obtained assuming that the pulse is composed of two overlapping pulses separated in frequency by R. Very serious degradation results when fiber dispersion separates the two pulses in time by, therefore

$$L_D=\frac{c \quad \rho}{\lambda^2 R^2 D}$$

Where c is the light speed in free space and λ is the wavelength. Note that for, above eq^n gives L_D R^2 D/ ρ $1.2X10^{20}$ $m^{-1}s^{-1}$, which for conventional fiber (16ps/nm/km) and for a bit rate of 10Gb/s results in 75km.

3. Simulation modeling

Designing of WDM communication system requires careful consideration of different transmitter and receiver characteristics. The transmission setup is depicted in Figure (1), used optical communication system consists of sixteen 40Gbps per channel return to zero optical pulse differential phase shift keying transmitters WDM channels with highest peak optical frequency 193.15[THz], highest peak power 15.957984dB [mW/THz]. The laser outputs were combined with equal polarizations, and simultaneously modulated using a dual-drive MachZehnder modulator to generate an RZ differentially phase shift keyed (DPSK) signal. The 40Gb⁄s RZ data pattern was PRBS $2^7 - 1$, since the electrical multiplexer generated intersymbol interference which caused errors even in purely electrical back-to-back operation for long data patterns. Modulated signals are multiplexed thereafter passed through optical splitter then passed for pre amplification, thereafter it passes to fiber loop in which we use four different types of fiber. Fiber propagated signals post amplified and splitter which goes through multistage Lorentzian optical filter having -3dB two sided bandwidth fixed 80Ghz at receiver end and passed through a set of sixteen DPSK detectors in combination with Bessel electrical filter having 10poles and -3db bandwidth set at 60Ghz . The detected optical signals are passed through a set of eye scope which shows eye patterns, set of other performance parameters like jitter, Q-value, and bit error rate values. The fiber length is varied in the presence of nonlinearities and polarization mode dispersion.

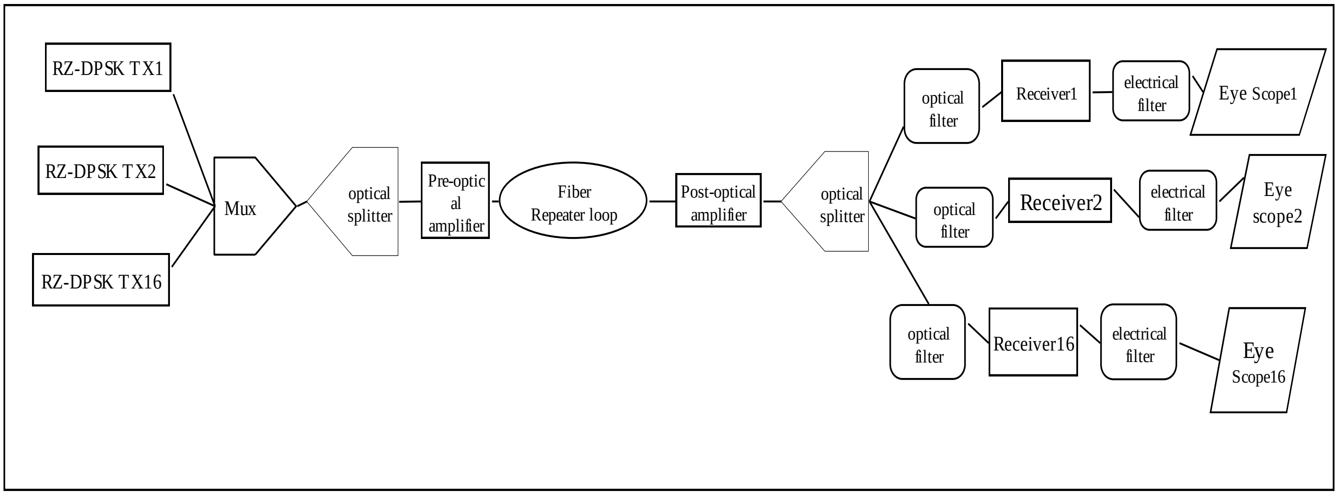

Figure 1.optical communication system 16-channel 40Gbps per channel

4. Results and discussion

Optical communication system with sixteen channels to be simulated show in figure (1), optical spectrum plotted shown in figure (2).

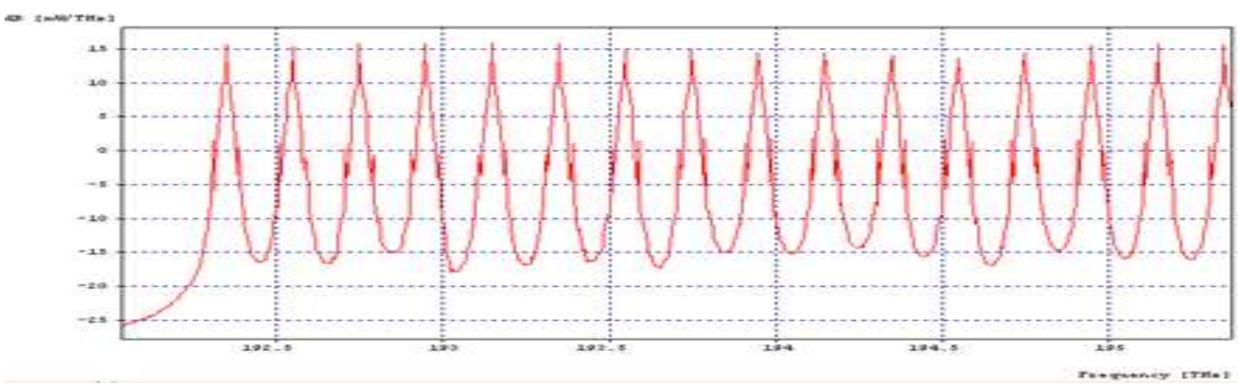

Figure 2. Optical spectrum sixteen user system

Performance study for sixteen channels return to zero optical puldse with 40Gps per channel has been simulated for done using different types of fiber in variable length of 200km with different duty cycles 0.5, 0.80, 0.99. Performance metrics for duty cycle of 0.5 Q values and bit error rate goes below 10dB after 60km for NZDSF (Lucent True wave) fiber and for DSF (DS_Anomalous), standard SMF Q value and BER goes below 10dB just after 40km but for CorningSMF28e fiber Q value and BER goes below 10dB before 10km of fiber length for the same 0.5 duty cycle. On observing results of 0.8 duty cycle we observe that NZDSF (Lucent True wave) fiber shows Q value and BER degrades(below 10dB)after 160km. It is observed that 0.99 duty cycle return to zero pulse shows Q value and bit error rate performance for the NZDSF (Lucent True wave) fiber goes below 10dB after 140km and as compared to other fibers tested for performance study, and CorningSMF28e shows least improvement in Q and bit error rate as compared to other fibers tested at 0.99 duty cycle. We can conclude that for 0.80 duty cycle shows better performance (Q value and BER,better eye pattern) as performance degrades after 160 km(Q value below 10dB) also we can say that while using communication link with NZDSF(Lucent True wave)shows better performance as compared to other fibers tested for performance study. For duty cycle of 0.99 RZ optical pulses DPSK when we see for 100km of fiber length BER is highest and lowest 10^{-5} and 10^{-16} ,for DSF(DS_Anomalous)

BER is highest and lowest 10^{-5} and 10^{-16} , for standard SMF highest and lowest 10^{-5} and 10^{-10} ,for Corning SMF28e highest and lowest 10^{-5} and 10^{-8}. When there is increase in the duty cycle 0.8 of RZ optical pulse decreases BER for Standard SMF in 16 channel communication WDM link. On comparing for a length of 100km we see that BER is highest and lowest 10^{-5} and 10^{-20} among observations taken for eight channels for NSDSF (Lucent True wave) for DSF BER is highest and lowest 10^{-5} and 10^{-13} for standard SMF highest and lowest 10^{-5} and 10^{-10} ,for Corning SMF28e highest and lowest 10^{-5} and 10^{-8}. When we decrease duty cycle (0.5) of pulse it is observed that performance degrades at very early communication distance (fiber length) for all fibers tested. Also when we increase duty cycle of pulse (>0.8 i.e. 0.99) performance degrades but slightly earlier length of fiber than for duty cycle 0.99.

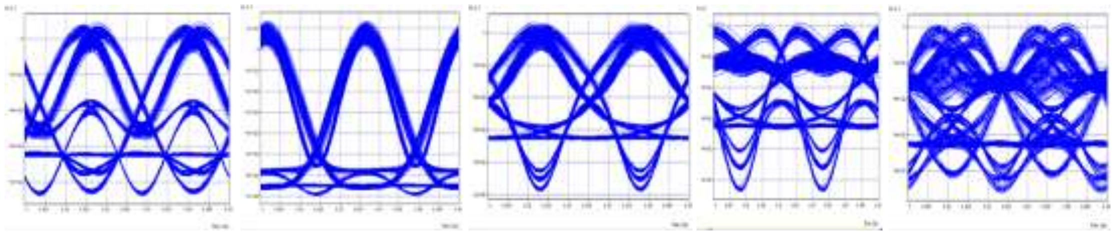

Figure 3. Eye pattern channel 4, 6, 8, 10, 12 at 200km with duty cycle 0.50- lucent True wave fibers

In above figure (3) results are shown for 200kilometers length with 0.50 duty cycle selection for Lucent True wave fiber we observe that losses are high for some channels which are randomly selected with this length and duty cycle.

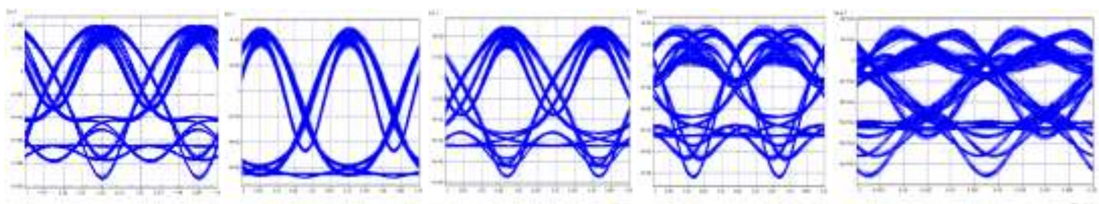

Figure 4. Eye pattern channel 4, 6, 8, 10, 12 at 200km with duty cycle 0.80- lucent True wave fibers

In above figure (4) results are shown for 200kilometers length with 0.80 duty cycle selection for Lucent True wave fiber we observe that losses are minimized for all channels which are randomly selected with this length and duty cycle.

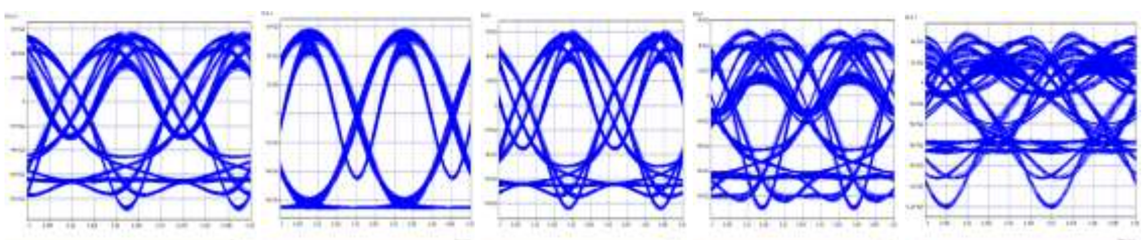

Figure 5. Eye pattern channel 4, 6, 8, 10, 12 at 200km with duty cycle 0.99- lucent True wave fibers

In above figure (5) results are shown for 200kilometers length with 0.99 duty cycle selection for Lucent True wave fiber we observe that losses are comparatively less for channels, randomly selected with this length and duty cycle. Eye pattern and Q vs length plot for different SMF's are shown in different figures.

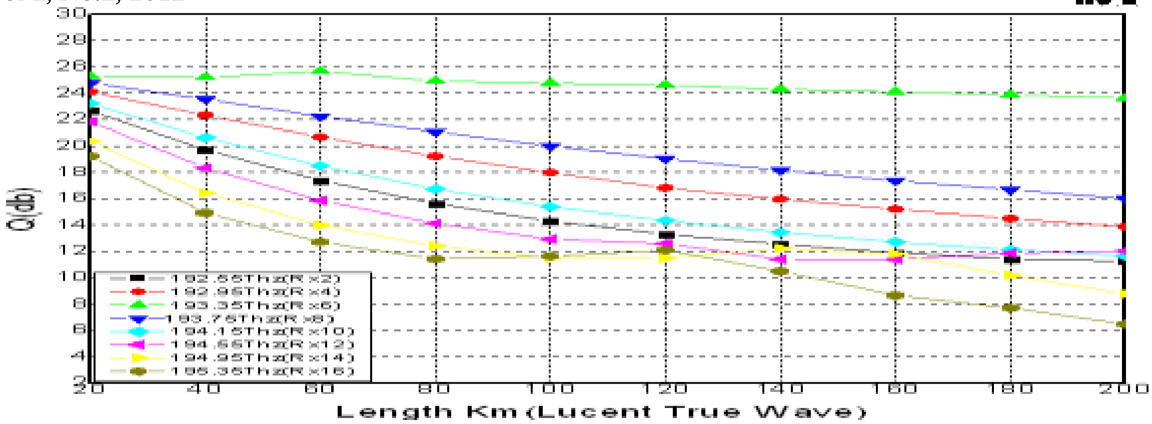

Figure 6. Q vs. length plot for lucent true wave fiber for different channels with duty cycle 0.99

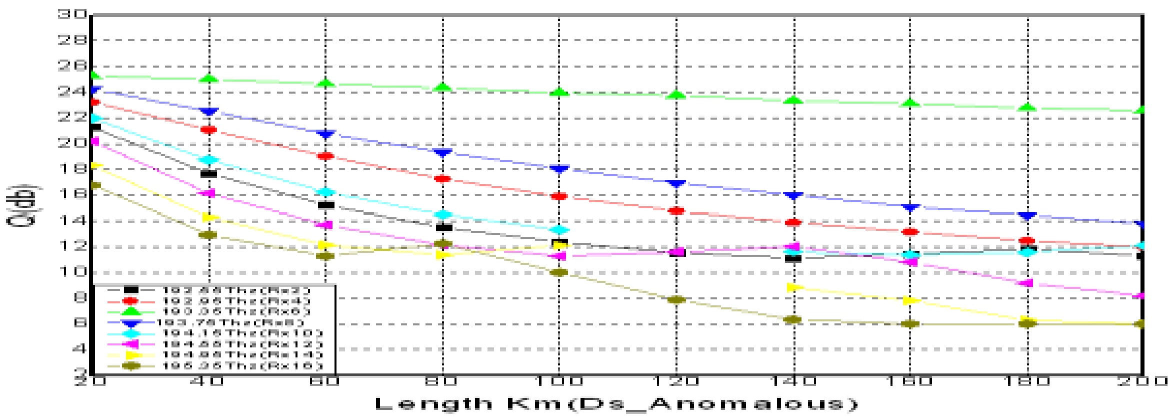

Figure 7. Q vs. length plot for DS_Anomalous fiber for different channels with duty cycle 0.99.

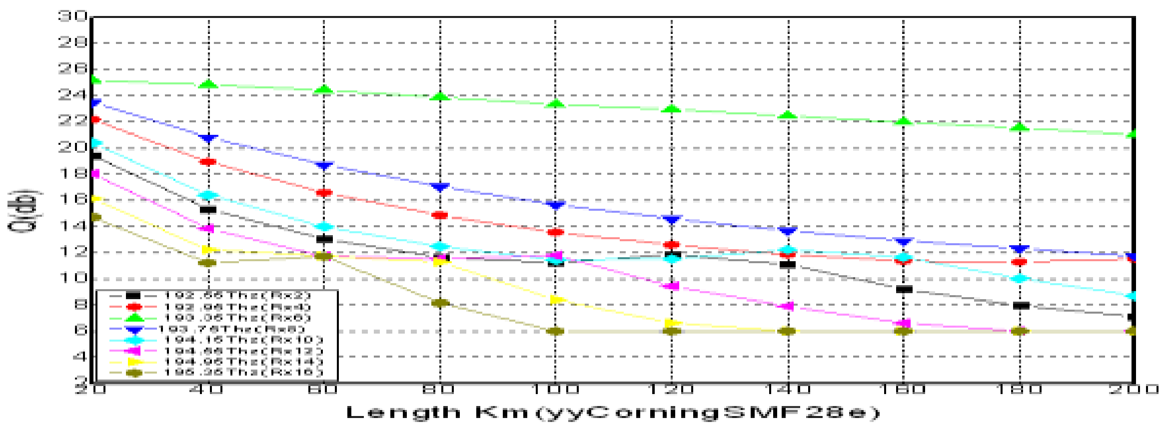

Figure 8. Q vs. length plot for yyCorningSMF28e fiber for different channels with duty cycle 0.99

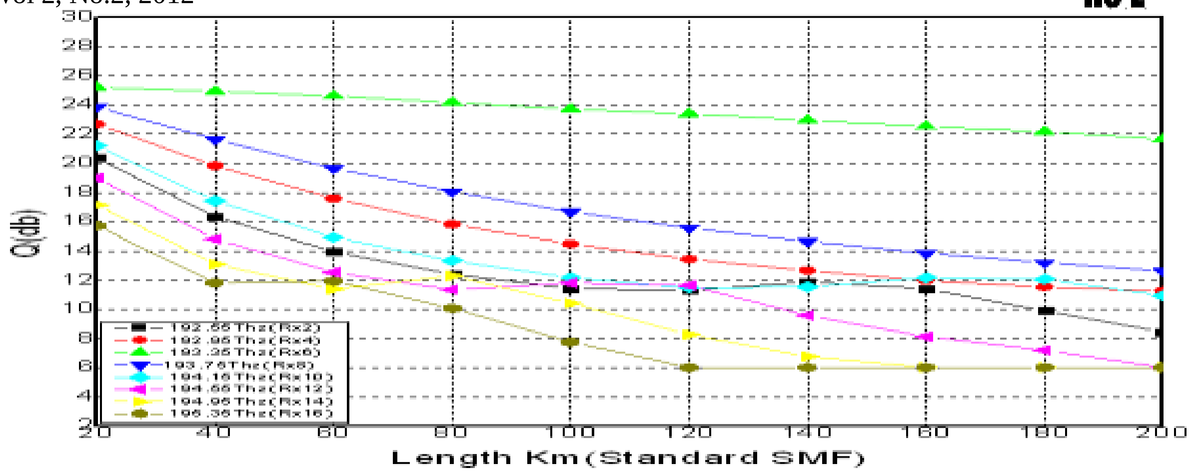

Figure 9. Q vs. length plot for standard SMF fiber for different channels with duty cycle 0.99

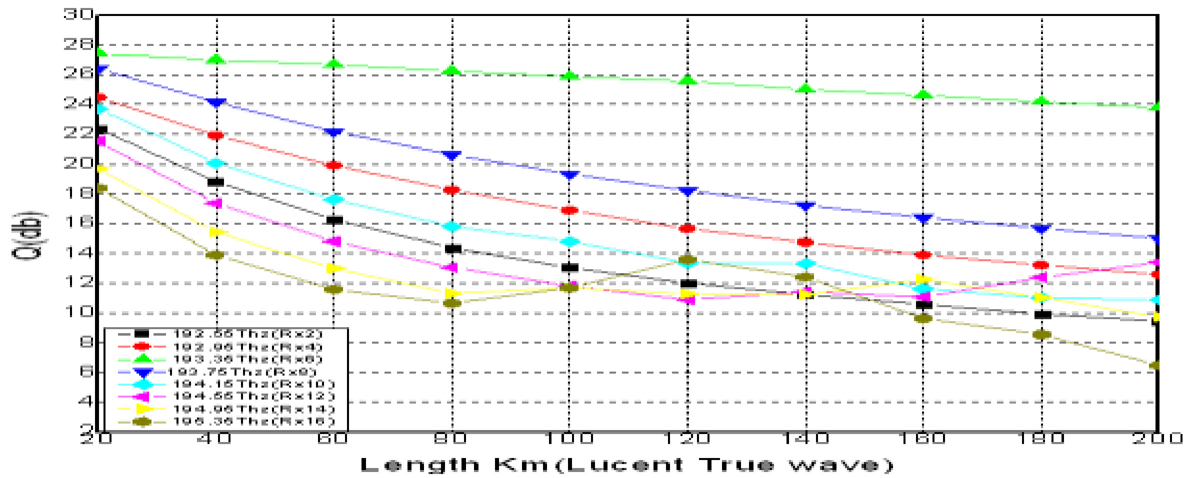

Figure 10. Q vs. length plot for lucent true wave fiber for different channels with duty cycle 0.80.

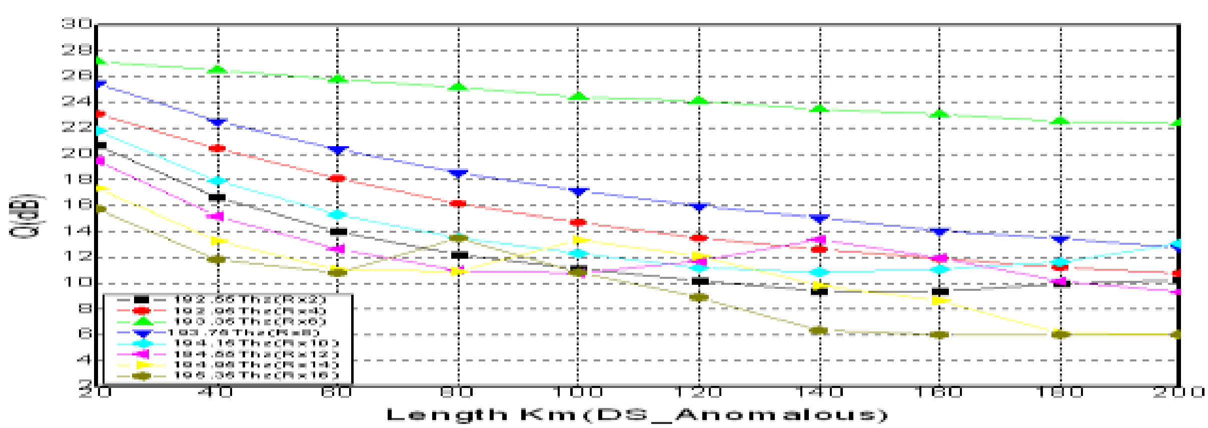

Figure 11. Q vs. length plot for DS_Anomalous fiber for different channels with duty cycle 0.80.

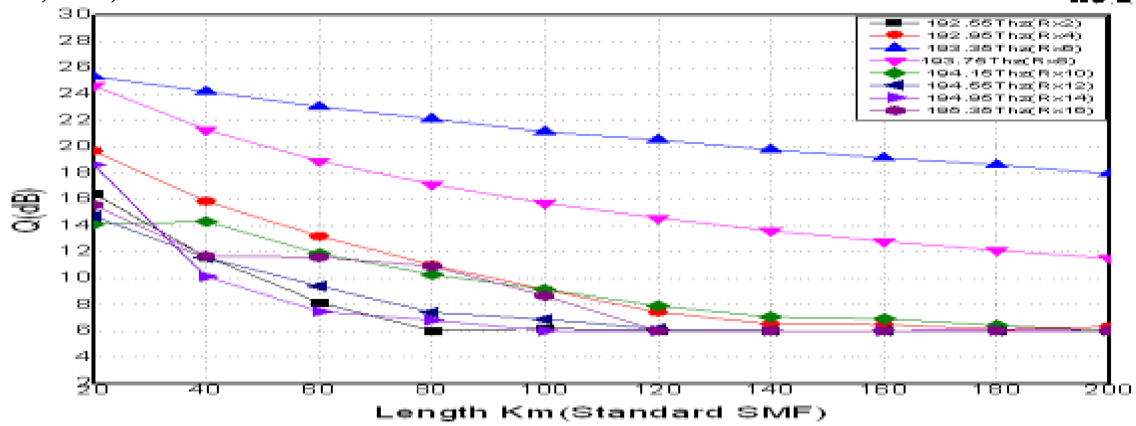

Figure 12. Q vs. length plot for standard SMF fiber for different channels with duty cycle 0.80.

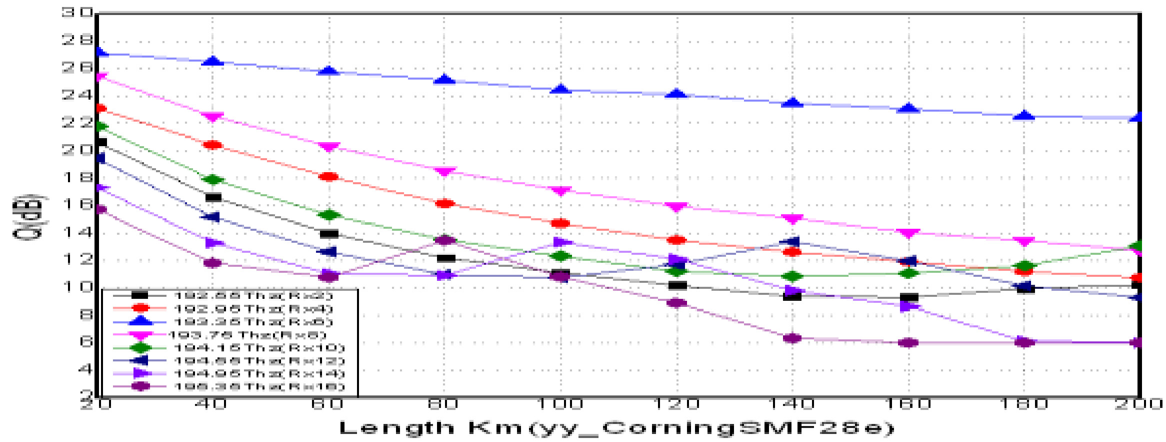

Figure 13. Q vs. length plot for yyCorningSMF28e fiber for different channels with duty cycle 0.80.

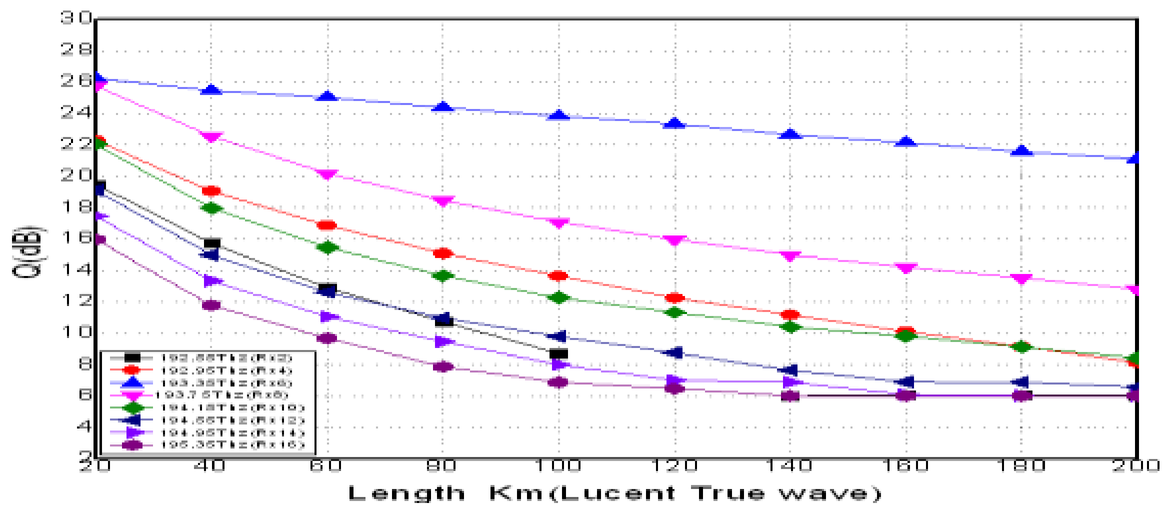

Figure 14. Q vs. length plot for lucent true wave fiber for different channels with duty cycle 0.50.

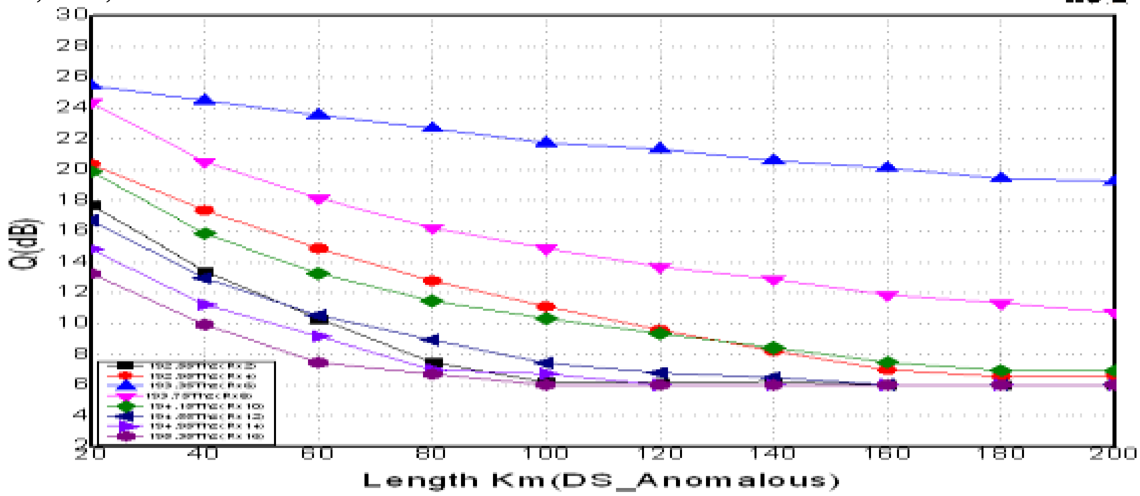

Figure 15. Q vs. length plot for DS_Anomalous fiber for different channels with duty cycle 0.50.

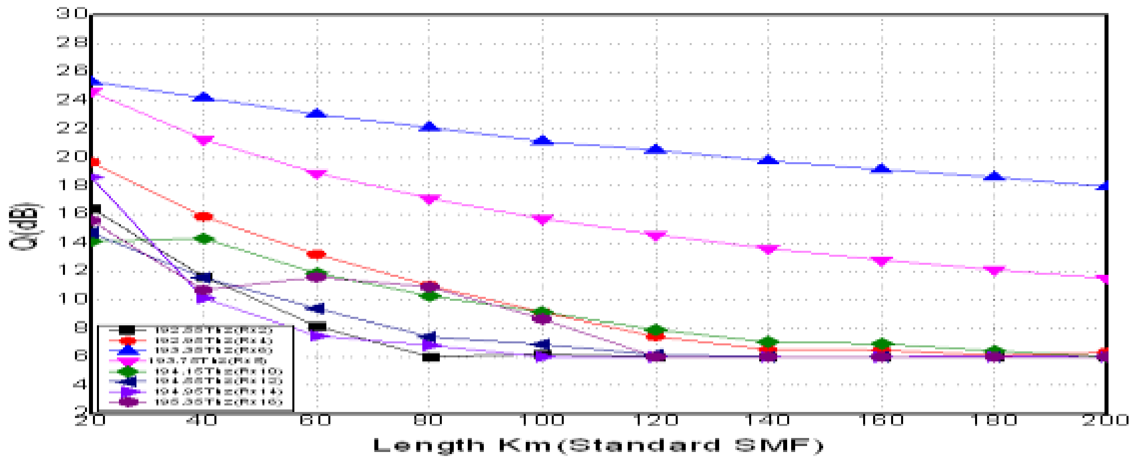

Figure 16. Q vs. length plot for standard SMF fiber for different channels with duty cycle 0.50.

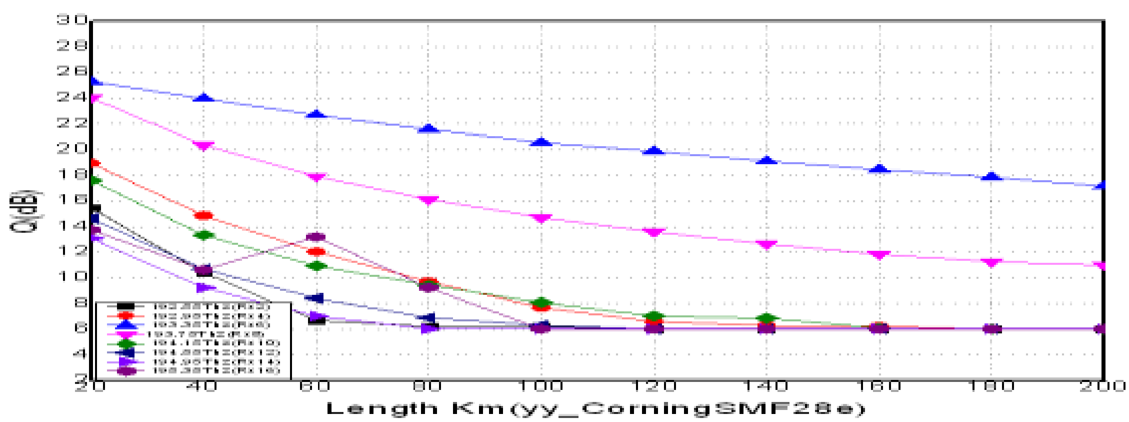

Figure 17. Q vs. length plot for yyCorningSMF28e for different channels with duty cycle 0.50.

5. Conclusion

On comparing various results we see that for varying duty cycle 0.5, 0.8, 0.99 for 16-channel WDM 640Gbps WDM optical system with different fibers we see that 0.80 duty cycle shows better Q and BER for length of fiber chosen for simulations. NZDSF fiber shows better performance in Q-value and average eye opening diagrams among all other fibers tested for performance comparison for varying duty cycles (0.5, 0.8, 0.99) as compared to others fiber tested and CorningSMF28e fiber shows higher BER and low Q for length of communication used. The BER trend when seen for each case of duty cycle under consideration, at higher duty cycle 0.99 the transmission viability is up to 140km for duty cycle 0.8 it increases to 160 km(higher Q),for 0.5 duty cycle it decreases 80km while considering for NZDSF fiber . Timing jitter figure showed that lesser width or duty cycle give lesser timing jitters (i.e. less at 0.5 duty cycle). The overall viability is increased for 0.8 duty cycle to range 160-180 km but it reduces to 140-160km for 0.99 duty cycle and viability even further reduces to 40-60km for 0.5 duty cycle Q value in relation to average eye opening indicate parallel variation.

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