

Comparison of soliton and Gaussian system at a bit rate of 40 Gb/S

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ABSTRACT

In recent days, optical communication has been playing a vital role in the communication sector because of its high speed transmission and larger efficiency. Especially in case of long haul communication, optical transmission of data is much more efficient than other means of communication systems. But, in long haul communication usage of amplifiers is making the whole system quite expensive. So, minimization of numbers of amplifiers with optimal transmission efficiency is one of the major research topics of current days. In this research paper, two types of optical pulses have been used to analyze performance in long haul communication in a virtual environment (Software). Here, it has been shown that, using Soliton pulse allows using less number of Optical Amplifiers rather than Gaussian Pulse for maintaining optimum optical transmission efficiency. Using both of the optical pulses, Quality Factor and Bit Error Rate (BER) has been compared and analyzed.

This paper presents performance comparison of different data formats for variable amplifier spacing in 40 Gbps optical soliton transmission RZ soliton, RZ rect and RZ super Gaussian are the various data formats which are compared in this paper. Their performance comparison is based on the factors such as Quality factor, Bit error rate (BER), Timing Jitter, Eye opening and Eye closure. It has been studied that in all the data formats RZ soliton gives the highest value of Q factor and BER.

Keywords: Data format; amplifier Spacing; Q-factor; BER; Modulator Driver; RZ soliton; RZ supergaussian.

1. INTRODUCTION

In case of high speed communication within long distance optical communication is always a better choice to make. In recent days, for communication purpose, especially in long haul optical communication Gaussian Pulse is used. But, the number of amplifiers used in optical fiber is quite larger in using Gaussian pulse. Hence, the system becomes much more complicated and expensive. So, there researcher tried to find an option to make the system more efficient and cost effective. It has been found that, if the Soliton Pulse is used in case of optical fiber communication instead of Gaussian Pulse, the number of Amplifiers required decreases. Hence the system becomes more efficient and easy to design. Here, the researcher has implemented the system in OptiSystem (Version 13) Software to analyze and compare an optical communication system using both Gaussian Pulse and Soliton Pulse. And for both of the cases, Bit Error

With the development of the optical fiber transmission system, optical soliton transmission has become the main area of research. For high-speed optical communication system, the system reliability is degraded by dispersion and fiber nonlinearities. Optimum balancing between dispersion and fiber nonlinearities depends on the pulse shape. So the selection of the proper modulation format becomes very deciding factor. Non linear effects are power dependent and occurs in fiber because refractive index with change in intensity of light.

. The non-return-to-zero (NRZ) was the dominant modulation format for the last years. The reasons for using NRZ in the early days of fiber-optical communication were it requires a relatively low electrical bandwidth and minimum optical peak power per bit interval for given average power. But this modulation format is not suitable for high bit rate and long distances. However at high bitrates, it has been shown that RZ modulation formats supersede the NRZ and offer several advantages as they tend to be more robust against distortions [1]. In comparison to NRZ data format, RZ modulation is more tolerant to dispersion [1]. At higher bit rates RZ modulation format is preferred over NRZ because they are less susceptible to fiber nonlinearity. Effect of nonlinearity on different modulation format has already been done by O. Sinkin et al. [2]. Different modulation formats such as NRZ, RZ rect, RZ raised cosine, RZ soliton and RZ super Gaussian have different properties and advantages based on their pulse shape. In NRZ rectangular driver, the output signal remains high for the entire bit duration when "1" is applied to the driver and remains low during the entire bit when a "0" is applied. Switching may be instantaneous between the two levels depending upon the time slope. In the RZ rectangular driver when a "1" is transmitted, the output signal remains high for a time equal to the product of the duty cycle by the bit time then it goes down to the low level for the remaining time. When a "0" is transmitted, the output is at the low level for the entire bit duration. In RZ raised cosine data modulation format switching between the two levels is not instantaneous it follows a raised cosine shape with a given roll-off. RZ supergaussian generates a supergaussian pulse when 1 is transmitted. In RZ soliton When a "1" is transmitted it generates a soliton pulse and the output signal is set to the Low Level for the entire bit time when a "0" is transmitted [6].

This paper gives the idea about for how much distance the amplifier can be used with different modulation format before repetition. The performance of the RZ rect, RZ soliton and RZ

super Gaussian has been investigated for different performance measure such as Q- factor, BER, Noise Figure, Eye Opening and Timing Jitter.

2. THEORETICAL DESCRIPTION

I Soliton Pulse

Right from the very beginning the necessity of communication is felt by human beings. To establish communication channels are used. Fiber is one of the best channels that is used for communication. But there is a problem named dispersion which is evident for both high bit rate and as well as for long hauls communication system. In order to solve this problem we use optical solitons because it is the system where for very long distances pulses can preserve their shapes.[15]. Soliton can also be termed as a solitary travelling wave which is represented by a nonlinear partial differential equation. Soliton Path has following characteristics. [16]

II Gaussian Pulse In mathematics and physics Gaussian path is used quite regularly. The exceptional characteristics that it possess is that it can be exactly integrable over $[-\infty, \infty]$ but it cannot be evaluated in closed form over finite limits. [1] In quantum field theory, Gaussian integrals can be of two kinds. In the first one ordinary real or complex variables are used, and in the second one Grassmann variables are involved. In order to calculate the path integral description of fermions (particles having half integral spin) Grassman variables are used.

III Application of Gaussian Pulse

Applications of the Gaussian Pulse are: –

In motion planning Probability Roadmap Planners (PRMs) has got very bright potentials. Gaussian sampling strategy has been used for Probability Road Planners which has given a much better coverage of the difficult parts of the free configuration space.[4,5] – Diffusion tensor imaging (DTI) is the imaging technology which is non-invasive and which generates a global mapping of local brain diffusivity. It is Tractography in diffusion tensor imaging which estimates connectivity in the brain through observations of local diffusivity. A probabilistic numeric has been used to estimate connectivity between regions of interest and contribute a Gaussian Process tractography algorithm. This process allows for both quantification and visualization of its posterior uncertainty. [6][7] – In all semi classical calculations of fluctuating systems Gaussian path integral evaluation is mainly needed. Especially when we face a ratio of functional a ratio of functional determinants of second-order differential operators Gaussian path integral is needed [8]

3. Parameters compared

The most widely used performance measures are the Q-factor, BER, noise figure, eye opening, eye closure and jitter.

3.1. Q-factor

Q-factor measures the quality of signal-to-noise ratio (SNR). There are only two possible signal levels in binary digital communication systems and a different average noise is associated with each of these signal levels. This means that there are essentially two discrete signal- to-noise ratios[11].

3.2 BER

The performance of the optical communication system evaluates the BER value of the electrical signal according to the options set for the sampling instant and the decision threshold.

3.3 Eye opening and Eye closure

The eye opening is the difference between the minimum and maximum value of the samples related to a logic “1” and logic “0” respectively, measured at the sampling instant. The average eye opening is the difference between the mean values of the samples related to a logical “1” and samples related to a logical “0”, measured at the sampling instant.

3.4 Jitter

The jitter value is the standard deviation of the received signal maximum with respect the specified sampling instant. The signal maximum depends on the decision threshold, therefore the jitter may be evaluated by using optimum values of the decision threshold and sampling instant.

4. RESEARCH METHODOLOGY

Two of the Optical Pulses have been used for propagation in a long haul communication system of almost about 250 Kilometers distance. For both Soliton Pulse and Gaussian Pulse, numbers of optical amplifiers have been calculated for optimum optical efficiency. It has been found that, number of amplifier is larger in case of Gaussian Pulse than Soliton Pulse. So, usage of Soliton Pulse is making the communication system more economical than using Gaussian Pulse keeping the optical efficiency at an optimum level.

To obtain the optimum result a very precise mathematical tool is required which takes into account all important phenomena including fiber loss, chromatic dispersion, polarization mode dispersion (PMD) and Kerr non-linearity and amplified spontaneous emission accumulation. Using OptSim, it is possible to model very closely a real long haul system to achieve realistic results. For performance comparison of different modulation formats at 40 Gbps bit rate an optical soliton transmission system is set up as shown in fig.

Transmitter section as shown in the fig. 1 is a compound component and consists of the data source, modulator driver, optical soliton source and external sine amplitude modulator. For performance comparison various modulator driver such as NRZ rect, RZ rect, RZ soliton, RZ supergaussian, RZ raised cosine are used. Transmitter section for the NRZ rect modulation driver is shown as

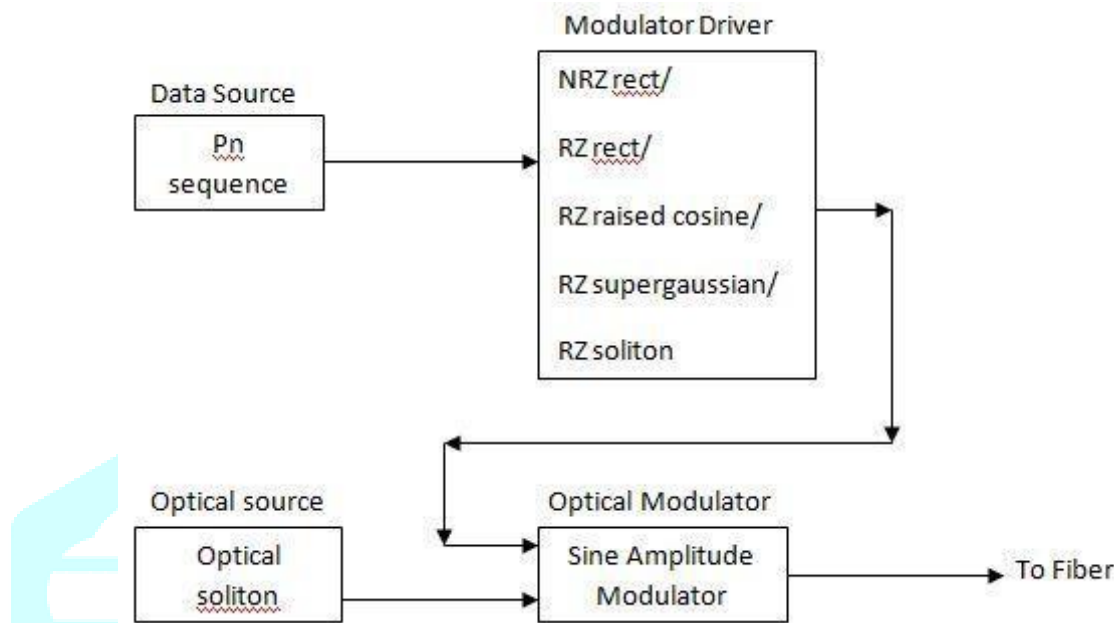


Figure 1: Transmitter section with various modulator driver.

The data source is generating signal of 40 Gbps with pseudo random sequence. Modulator driver converts logical input into electrical input. Performance parameters of different data formats like NRZ rect, RZ rect, RZ soliton, RZ supergaussian and RZ raised cosine has been studied by using these modulator drivers. A soliton source of center emission wavelength of 1550 nm, center emission frequency 193.4149 THz, Full width half maximum (FWHM) of 20 ps and peak power of 30 mW is used to generate optical pulses of “sech” shape [18]. The time between two pulses is taken to be 25 ps. A sine amplitude modulator is used to modulate the optical signal according to pseudo noise sequence. For calculating the amplifier spacing with different data formats, a fixed gain amplifier having gain 12 dB with fiber of varying lengths (50,100,150,200,250 km) is used. Fiber taking all non linear effects into account and dispersion of 0.2 ps/nm/km is used. The PIN photo detector of quantum efficiency 0.7 is used having responsivity of 0.875 A/W and dark current of 0.1 nA. electric scope is used to see the eye diagram and to calculate q factor, BER, eye opening and jitter. Optical power meter and optical probe with splitter are used for calculating signal power and output power.

4. RESULTS AND DISCUSSION

The performance of NRZ rect, RZ rect, RZ soliton, RZ supergaussian and RZ raised cosine data formats for variable amplifier spacing at 40 Gbps optical communication system is analyzed. Table given below present the summary of different parameter values for various data formats at 40 gbps system.

Table 1: Comparison Of Performance Of The Various Data Formats For 40 Gb/S Optical Soliton Transmission System.

| Parameter | Amplifier spacing (km) | RZ rect | RZ supergaussian | RZ soliton |
|---|------------------------|---|---|--|
| Q factor(dB) BER Eye opening Eye closure Jitter | 50 | 26.0349 1.e-40 0.1893 0.5269 0.00047 | 32.6866 1.e-40 0.2119 0.1458 0.00029 | 32.708 1.e-40 0.2104 0.2281 0.00028 |
| Q factor(dB) BER Eye opening Eye closure Jitter | 100 | 21.6062 1.692e-32 0.0157 0.8757 0.00053 | 25.7229 1.e-40 0.0204 0.5745 0.00028 | 25.7285 1.e-40 0.0194 0.5783 0.00028 |
| Q factor(dB) BER Eye opening Eye closure Jitter | 150 | 14.0289 3.398e-07 0.0016 3.8987 0.00084 | 16.9770 6.010e-13 0.0018 2.4603 0.00083 | 16.9886 5.66e-30 0.00092 2.6792 0.0008 |
| Q factor(dB) BER Eye opening Eye closure Jitter | 200 | 6.0206 0.0275 0.0021 21.9201 0.0059 | 7.6219 0.0107 0.0035 16.6072 0.0042 | 7.6228 0.0106 0.0002 18.7865 0.0042 |
| Q factor(dB) BER Eye opening Eye closure Jitter | 250 | 6.0206 0.0275 -0.00083 27.035 0.0052 | 6.0206 0.0275 -0.00092 19.7795 0.0060 | 6.0206 0.0275 -0.0018 26.8400 0.0059 |

Figure 3 shows the variation of quality factor at different amplifier spacing for different data formats. The RZ soliton shows the highest value of the Q factor which is 32.708 dB followed by RZ super Gaussian, RZ raised cosine and RZ rect with the Q values 32.6866, 30.0650, 26.0349 dB respectively. RZ supergaussian also shows the good value of Q-factor.

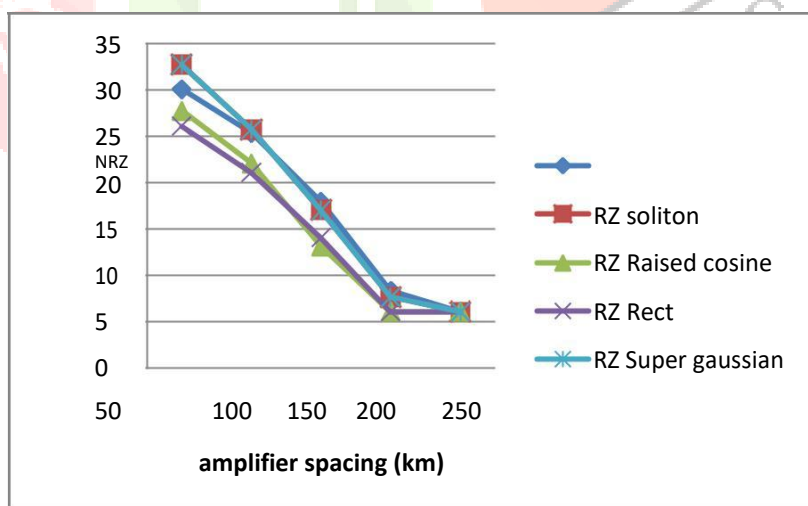


Figure 2: Q-factor vs Amplifier spacing

The bit error rate variation of the various data formats with variable length before the amplifier is used is shown in the figure 4. For 50 km length all the data formats show the minimum bit error rate. But for 100 km and 150 km BER values of the RZ soliton data format is much better than other formats as shown in Table 1. By further increasing the length, performance of the system degrades to very large extent and BER values comes becomes very high.

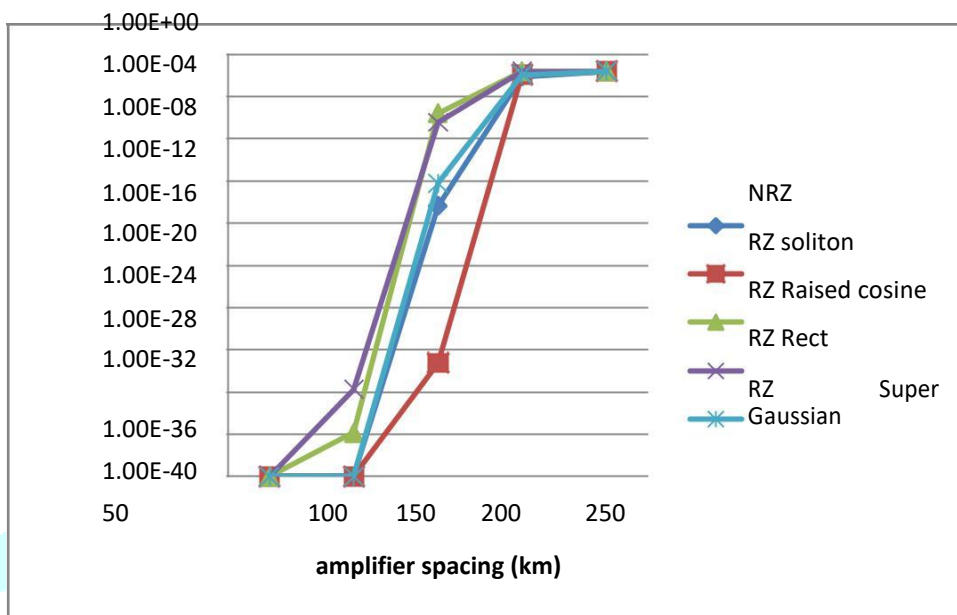


Figure 3: BER vs Amplifier spacing

The variation in eye opening for different data format is, 0.1893 to -0.0008 for RZ rect, 0.1230 to -0.00053 for 0.2119 to -0.0009 for RZ supergaussian and 0.2104 to -0.0018 for RZ soliton as shown in fig 5. The value of Eye opening must be high for better results. NRZ rect shows the highest value of the eye opening.

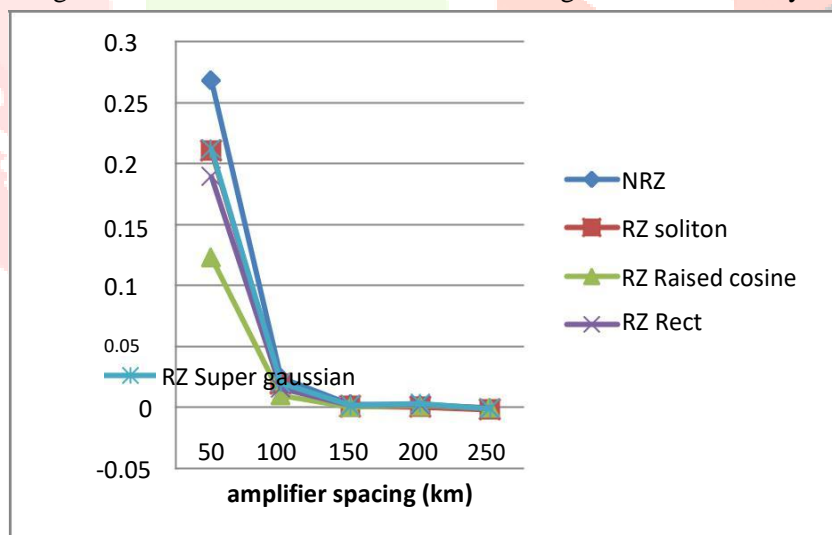


Figure 4: Eye Opening Vs Amplifier Spacing

Figure 5 shows the variation of eye closure with amplifier spacing of the fiber. From the results it is noted that RZ supergaussian shows the minimum value of the eye closure for 50 km length. But for 100 km amplifier spacing RZ soliton also shows the good value of eye closure as shown in Table 1.

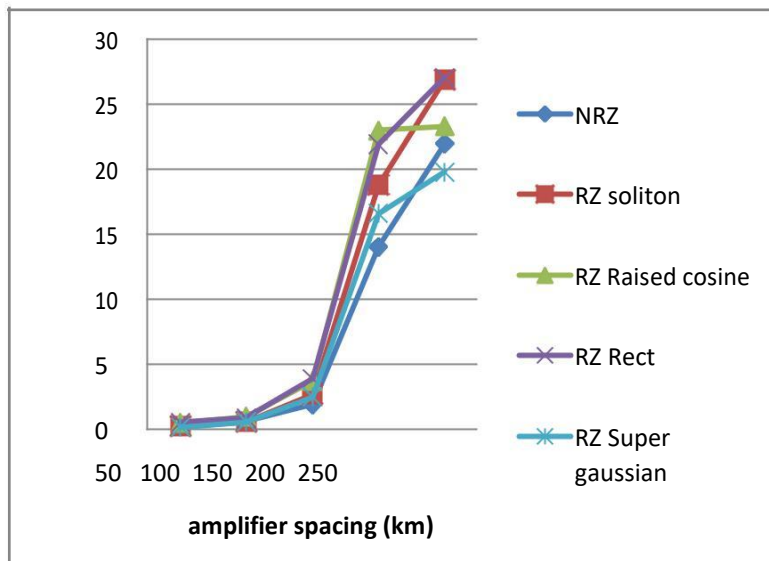


Figure 5: Eye Closure Vs Amplifier Spacing

The timing jitter of the various data formats increases with the increasing amplifier spacing. From Table 1 and Figure 6 it is clear that RZ soliton and RZ supergaussian shows the minimum value of the jitter.

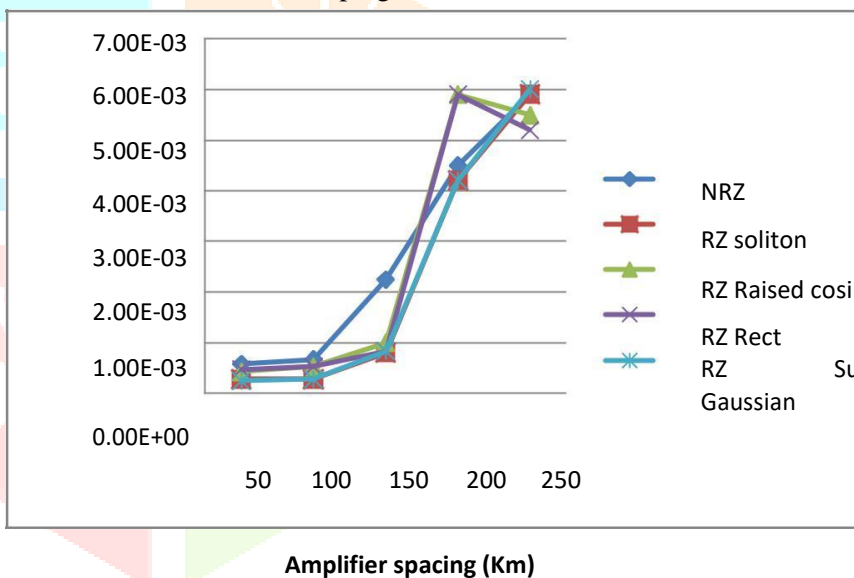


Figure 6: Timing Jitter Vs Amplifier Spacing

5. CONCLUSION

In this paper, the performance of the data formats has been studied for variable amplifier spacing in 40 Gbps soliton transmission link. The results for different data formats such as NRZ rect, RZ rect, RZ soliton, RZ raised cosine and RZ super Gaussian has been presented in Table 1. In case of RZ soliton, the highest value of Q (32.708 dB), good eye opening, lowest eye closure, lowest BER and lowest value of Jitter has been reported, which makes it the best choice among all the data formats at 40 Gbps transmission. In the comparative study, it is noted that parameter values are reasonably good for RZ super Gaussian but they are reported to be the best for RZ soliton. Simulation results and performance comparison in Table 1 shows that RZ soliton data format is most suitable at 100 km amplifier spacing.

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