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Dual Polarization-Based Transmitter Configuration Improving Q-Factor for a Single-Mode Fiber Link

Mir Shakeel Ahmad, Harmandeep Kaur, Tanika Thakur

Abstract: ***The requirement of the modern application is to transmit wide bandwidth of signal with the low latency. The optical fibers provide wide transmission bandwidth along with very little delay as well as choice on choosing transmission medium for high data rate. However, Stimulated Brillouin Scattering (SBS) is a nonlinear optical effect that restricts power level into a fiber to few milliwatts. It degrades the Q-factor and consequently the bit error rate of an optical fiber link. For suppression of SBS, various approaches have been used previously such as PSK, ASK, FSK, CSRZ-DQPSK etc. Among all the previous techniques, CSRZ-DQPSK transmitter is considered as the most efficient one for suppression of SBS. However, it consists of some drawbacks such as low spectrum efficiency, susceptibility to phase variation and short communication range, due to which requirement arises of upgrading the previous work. Therefore, in the proposed work (i.e. CSRZ-DP-QPSK), DP-QPSK scheme is used which makes the system more efficient as it has high spectrum efficiency and improved sensitivity. Also, the communication range is elongated in present work. The performance evaluation of CSRZ-DP-QPSK approach has been performed in terms of Q-Factor, BER, and threshold. Also, the comparative analysis of the proposed approach with conventional approaches has been performed and from the obtained results it has been demonstrated that proposed work is more efficient than conventional one as it has better SBS tolerance and improved BER.***

Keywords: ***Optical Fiber, SBS (Stimulated Brillouin Scattering), DP-QPSK transmitter approach, Q-factor, BER.***

I. INTRODUCTION

The optical fibers are used as the medium of communication in the telecom sector and in the networking of computers due to its flexibility and it can also be made in the form of bundles. Optical fibers can be used for long-range transmission as light has the capability to travel in fiber that too with a negligible loss which is much seen in electrical cables. So fewer numbers of repeaters are required for long-range communication. Optical fibers have great immunity against electrical interference. Any type of cross talk is not possible in cables, therefore, noise entrance is not possible. Fibers that are not armored don't allow the flow of electricity through them. This is a great solution to use and protect the fibers in conditions which are having a high level of voltage [1].

The basic type of fiber optic system for communication is quite simple like LAN. Also, the fiber optic system can be quite complex and costlier. However, the basic fiber optic system can be built inexpensively with the help of visible-light LED, plastic fiber, some electronic circuits, and a silicon photodetector. For designing the communication system, it is essential and beneficial to know about the distance of communication and the amount of required data to be transmitted. This helps us in estimating the required components for designing a communication system [2].

The optical fibers provide a number of benefits such as:

- Long-distance signal transmission
- Large bandwidth, small diameter, and lightweight
- Non-conductivity (Dielectric in nature)
- Provide Security Surveillance Systems
- Economical

However, Optical fiber suffers from various types of non-linearity when a field of high strength comes in contact with molecular or acoustic vibrations. Wave mixing, SRS, SBS, SPM, and XPM are types of non-linearity faced in optical fibers [3]. System performance is degraded because of these nonlinearities.

SBS is the non-linear type of scattering that doesn't allow the power insertion inside the fiber. Whenever non-linear interaction happens in the pump and stokes field via acoustic wave, then SBS takes place. Light again is scattered back by the waves inside the optical fiber. Power transmission gets saturated. However, with an increase in input power, transmission power is also increased. It also inserts fluctuations in received optical power and results in an enhancement in noise inside the photodetector. So, Q-factor is degraded and the bit error rate is produced. Thus, there is a need for careful design consideration while maintaining a suitable level of power in the optical systems having a long length of fiber [4].

For the suppression of SBS, various authors had introduced a number of approaches which are discussed in the next section:

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* Correspondence Author
Mir Shakeel Ahmad*, Department of ECE, Swami Vivekanand Institute of Engineering and Technology, Banur, India.
Email: shakeelbatwini@gmail.com
Harmandeep Kaur, Department of ECE, Swami Vivekanand Institute of Engineering and Technology, Banur, India.
Email: hshergill13@yahoo.com
Tanika Thakur, Department of ECE, Swami Vivekanand Institute of Engineering and Technology, Banur, India.
Email: tanithankur17@gmail.com

II. LITERATURE REVIEW

The combination of high-power optical fiber transmission and coherent detection leads to great advantage with respect to length between repeaters. Though, nonlinear optical effects restrict the power level in fiber to few milliwatts.

To suppress the non-linearity impact, author in paper [5] reported the initiation of stimulated Brillouin scattering with the help of phase-shift keying at 1320 nm

In [6], the effect of nonlinearity, phase noise and chromatic dispersion on 10-Gb/s optical DQPSK system were assessed via computer simulations.

The author in the paper [7] did research and analysis of SBS suppression effect and CBC effect in the multi-tone CBC system. In order to have the desired amount of results in suppressing SBS, it was proposed that the frequency-time interval for multi-tone laser seed must be large enough or it must be higher than SBS gain BW.

The author in paper [8] presented a set of differential equations to define the interplay between first-order stoke, pump and signal in a multi-core fiber amplifier. The model takes into account the dependence of SBS on the pump induced temperature distribution along the fiber.

Author of the paper [9] did an experiment and based on that discussion was done for analysis of limitations in input power because of SBS in the SMF.

In the paper [10], the author gave suppression for SBS using enhanced SBS power for the threshold level by using the PM and technique of optimization of fiber.

In paper [11], the author analyzed the SBS effect in an optical fiber transmission system and various schemes for removing this effect were analyzed. The author suggested two novel schemes for the elimination of the mentioned effect.

Author of paper [12] studied the impact of SBS and effective core area and the brillouin gain coefficient on OOK and PM modulation techniques.

In paper [13], the author had analyzed the SBS gain and threshold features using PSK, FSK and ASK modulated light for estimation of the input power conditions set by SBS.

In paper [14], the authors used SBS finite-difference model depending on the work done in the previous models.

The author of the paper [15] analyzed SBS tolerance of the 2 minimized CSRZ-DQPSK transmitter configurations and compared it with the traditional 3 MZM approach. Link performance has been assessed for a data rate of 10 Gbps in a single-mode fiber link of 50 Km. This approach is more efficient than all the previous ones. However, it also consists of some drawbacks that make the system inefficient and degrades its performance.

III. PRESENT WORK

Optical sources with high power levels and narrow spectral distributions are required for the high capacity optical networks. However, Stimulated Brillouin Scattering (SBS) is the non-linear type of scattering which doesn't allow the power insertion inside the fiber. It degrades Q-factor and produces BER.

In previous works, various approaches have been used for suppression of Stimulated Brillouin scattering such as PSK, ASK, FSK, CSRZ-DQPSK, etc. Among all the previous techniques, CSRZ-DQPSK transmitter is considered as the most efficient one for suppression of SBS as it provides better dispersion tolerance and is robust towards nonlinearities. However, in this previous approach, DQPSK transmitter is used which has low spectrum efficiency and it is more sensitive to phase variation. Thus, it is required to upgrade the previous DQPSK approach.

Thus, in the proposed work, the DP-QPSK scheme is used instead of DQPSK which makes the system more efficient. DP-QPSK has high spectral efficiency and also is less sensitive towards phase variation.

Also, in the previous work, the link performance is evaluated in a 50 Km single-mode fiber link only. However, in some cases, the communication range of more than 50km can be required. Thus, in the proposed approach the communication range is elongated. With the increase in distance, the power of the signal can get reduced due to the addition of noise in the signal. It can degrade the quality factor. Thus, in order to overcome this issue which can arise with an increase in distance, the amplification is implemented in the proposed system. With the amplification, the quality factor of the system gets enhanced.

Thus, with the help of the proposed work, the more efficient system can be achieved.

IV. RESULTS AND DISCUSSIONS

As discussed in the above section, in the proposed work, the DP-QPSK scheme is used that can help to achieve an efficient system by suppressing SBS and helps to overcome the drawbacks of the previous system. The proposed approach has been implemented and the different simulation parameters have been considered for evaluating the performance of the proposed approach such as bit rate, fiber length, input power, laser frequency. The results obtained after implementing the proposed approach are represented and discussed in this section as follows.

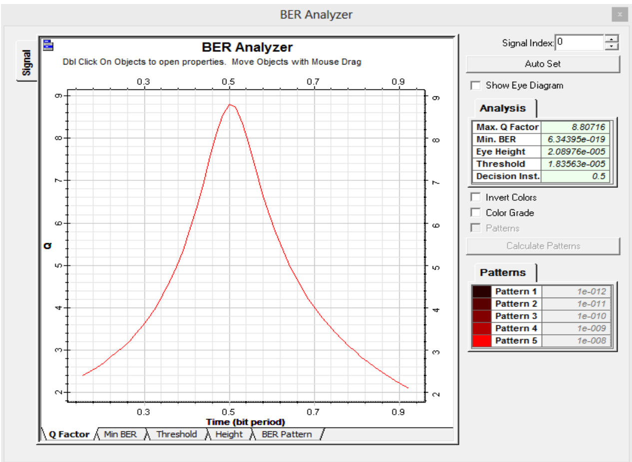

Fig. 1. Q-factor analysis of proposed approach

In the proposed work, the Q-factor is calculated for the received data and the results of the proposed approach in terms of Q-factor are delineated in the graph of fig. 1. From the graph, it can be seen that initially, the quality factor increases with the time and by reaching a threshold at 0.5 sec, it then started decreasing gradually. The maximum quality factor is observed to be 8.80716. The Q-factor of the system should be high which leads to efficient system, thus, it implies that proposed approach has enhanced quality factors and thus helps to achieve an efficient system.

The bit error rate (BER) of the proposed approach is calculated and the results obtained are exemplified in fig. 2. In the graph, the values of BER are illustrated along the y-axis and the value of time is represented along the x-axis. It is clearly observable from the graph that initially BER decreases gradually with time and after 0.5 sec, it started increasing. The minimum BER of the proposed approach is recorded to be 6.34395e-019.

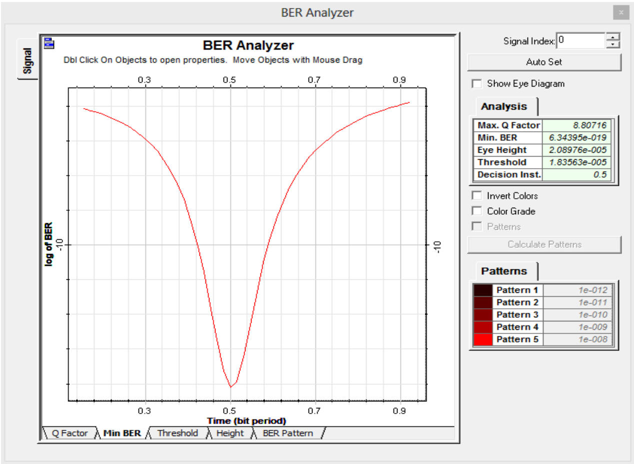

Fig. 2. BER analysis of proposed approach

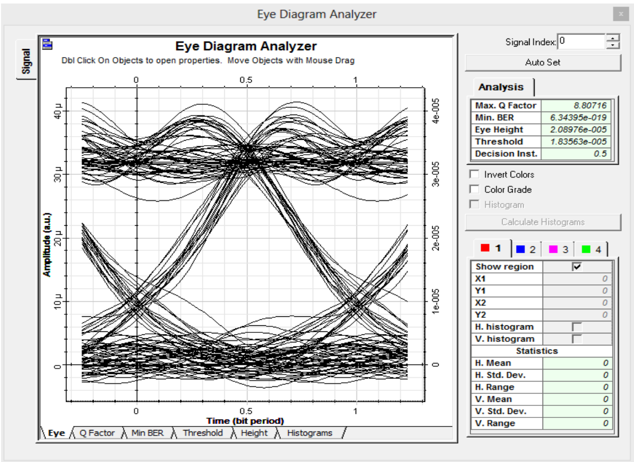

Fig. 3. Received eye diagram of proposed transmitter

The fig. 3 illustrates the received eye diagram at an input power of -10 dBm, fiber distance of 50 km and laser frequency of 193.1 Hz. In this graph, the y-axis represents the amplitude which varies from 0 to 40µ and the x-axis shows the time which varies from 0 to 1 sec. An analysis of the eye diagram indicates a successful transmission as evident from the clear and well-defined eye-opening in fig. 3.

The comparison analysis between the proposed approach and conventional approach has been performed in terms of Q-factor and the results obtained are recorded in table 1.

Table 1 represents the Q-factor value of the proposed and conventional approach at different input power values. From the obtained values, it is comprehensible that in all the conventional approaches, the Q-factor is initially high and with increase in input power, the Q-factor decreases. However, in case of proposed approach, the Q-factor increases with the increase in input power and by reaching at input power of 7dBm, it decreases but only to small extent. The Q-factor of the proposed approach is higher than all the three conventional approaches at every different input power value. Thus, it implies that proposed system is efficient in terms of quality factor.

Table- I: Comparison analysis in terms of Q-factor

Input Power (dBm)	CSRZ-DQPSK (1 MZM)	CSRZ-DQPSK (2 MZM)	CSRZ-DQPSK (3 MZM)	Proposed
-10	-13.8	-14	-14.1	-18.19
-9	-13.8	-14	-14.1	-25.82
-8	-13.8	-14	-14.1	-35.33
-7	-13.8	-14	-14.1	-46.03
-6	-13.5	-13.9	-14.1	-56.64
-5	-13.5	-13.9	-14.1	-65.92
-4	-13.5	-13.9	-14.1	-72.93
-3	-13.5	-13.9	-14.1	-77.61
-2	-13.1	-13.9	-14.1	-80.29
-1	-13.1	-13.5	-14.1	-81.34
0	-12.7	-14.2	-14	-81.29
1	-12.7	-14	-13.5	-80.38
2	-12.7	-14.2	-12.8	-78.99
3	-12.1	-14.1	-12.1	-77.01
4	-12	-11.8	-12	-74.61
5	-11.9	-11.1	-11.9	-71.64
6	-11.8	-9.8	-11.8	-68.12
7	-11.3	-11.8	-11.3	-64.03
8	-11.1	-11	-11	-59.33
9	-9.8	-9.8	-9.8	-54.02

Also, the comparison analysis between proposed approach and conventional approach has been performed in terms of BER and the results obtained are recorded in table 2.

Table- II: Comparison analysis in terms of BER

Input Power (dBm)	CSRZ-DQPSK (1 MZM)	CSRZ-DQPSK (2 MZM)	CSRZ-DQPSK (3 MZM)	Proposed
-10	7.5	7.7	7.7	8.8
-9	7.5	7.7	7.7	10.59
-8	7.5	7.7	7.7	12.48
-7	7.5	7.7	7.7	14.31
-6	7.4	7.6	7.7	15.92
-5	7.4	7.6	7.7	17.2
-4	7.4	7.6	7.7	18.11
-3	7.4	7.6	7.7	18.7
-2	7.3	7.6	7.7	19.02

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-1	7.3	7.5	7.7	19.15
0	7.3	7.5	7.6	19.14
1	7.3	7.5	7.5	19.03
2	7.3	7.5	7.3	18.86
3	7.3	7.51	7	18.62
4	7.2	7.49	6.6	18.32
5	7	7.48	6.4	17.95
6	6.9	7.47	6	17.49
7	6.8	6.8	5.6	16.95
8	6.7	6.6	5.4	16.3
9	6.3	6.3	5.1	15.53

In table II, the values obtained by comparing the proposed and traditional approaches in terms of BER are represented. For the analysis, the input power values from -10 dBm to 9 dBm are taken into consideration. The obtained values represent that BER of all the conventional approaches i.e. CSRZ-DQPSK 1 MZM, 2MZM and 3MZM, increases with the increase in input power. However, in the proposed approach, the BER decreases with an increase in power and by reaching input power 1 dBm, it then started increasing.

The proposed approach has minimum BER than all the conventional approaches and minimum BER leads to a more efficient system, therefore, it implies that the proposed approach leads to an efficient system in terms of Bit Error Rate (BER).

Thus, from all the obtained results it has been observed that the proposed approach is more efficient than conventional ones.

V. CONCLUSION AND FUTURE SCOPE

In this paper, the CSRZ-DP-QPSK transmitter approach is used for the suppression of SBS. In the proposed work, the performance analysis of the proposed approach has been performed by considering different parameters such as Q-factor, BER, and threshold. For the input power -10 dBm, laser frequency 193.1 Hz and fiber length of 50 km, the SBS threshold obtained is 1.83563e-005 dBm, the maximum Q-factor is obtained as 8.80716, minimum BER is 6.34395e-019 and the eye height of 2.08976e-005 is obtained. Also, the comparative analysis between the proposed approach and conventional transmitter approaches i.e. CSRZ-DQPSK (1 MZM), CSRZ-DQPSK (2 MZM), CSRZ-DQPSK (3 MZM) has been performed in terms of Q-factor and Bit Error Rate at different input power values. The results obtained represent that the Q-factor of the conventional approaches decreases with an increase in input power and the BER increases with an increase in input power. However, in the case of the proposed approach, the Q-factor increases with an increase in power and BER get minimized as power value increases. Higher Q-factor and minimum BER leads to an efficient system. Thus, results demonstrate that the proposed approach is more efficient than all the conventional approaches as it has a higher Q-factor and minimum BER.

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AUTHORS PROFILE

Mir Shakeel Ahmad is an M-Tech scholar and is pursuing his master's degree in the field of Electronics and Communication Engineering from Swami Vivekanand Institute of Engineering and Technology, Banur, Punjab.

Harmandeep Kaur is an assistant professor in the Electronics and Communication Engineering department at Swami Vivekanand Institute of Engineering and Technology, Banur, Punjab.

Tanika Thakur is an assistant professor in the Electronics and Communication Engineering department at Swami Vivekanand Institute of Engineering and Technology, Banur, Punjab. She has 6 years of teaching experience and she has a specialization in the field of wireless communication.