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Performance Analysis of ASK and PSK Modulation Based FSO System Using Coupler-Based Delay Line Filter under Various Weather Conditions

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Abstract

Free space optical communication (FSO) proves to be very effective and efficient technology for wireless communication. This work basically deals with the designing of FSO systems. Further, a comparative study has been made to ascertain which modulation technique proves better for communication. This paper investigates the performance of ASK and PSK modulation based FSO system by varying different FSO parameters under several conditions including haze, rain, mist and fog. Finally, simulation results are analysed and discussed.

Keywords

FSO, Bit Error Rate (BER), Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), Attenuation

1. Introduction

Nowadays, a very high-quality service demand for multimedia services is increasing drastically. Optical fibres have been used for so many years to fulfil this demand. But the shortcoming of these fibres is that it is not suitable for remote areas deployment and enhances the cost of the system. So, an alternative approach to meet the desired requirements is free space optics (FSO) technology. FSO uses optical wireless links to offer point to point communication in outdoor terrestrial regions with clear line of sight (LOS). FSO system has an optical transceiver unit which has a bi-directional functionality. Each unit involves an optical source, telescope which transmits light through free space, which behaves as a communication channel in it, to another telescope and receives the information [1].

Advantages of FSO include high reuse factor, robustness, easily deployable, license free band, no signal interference. FSO system is used for various applications, such as in LAN networks for campus connectivity with Gigabyte Ethernet speeds, in metropolitan area network, spacecraft communication, video surveillance, back-haul for cellular networks like 5G etc. [2].

Unfortunately, FSO links are prone to inhomogeneities produced by the temperature and pressure in the atmosphere. This causes atmospheric turbulence effect. This results fluctuations in the received signal, called as scintillation effect or turbulence-induced fading. This is analogous to fading in RF system. Due to this, FSO suffers with the drawback of less reliable link connectivity mainly for distances more than 1000 metre and is sensitive to various weather conditions [3] [4] [5].

2. System Architecture

2.1. ASK Modulation Technique

The block diagram of the proposed FSO system using ASK modulation technique is shown in **Figure 1**. It can be divided into 4 stages. First stage is transmitter which contains an optical source, bit sequence generator, pulse generator and AM modulator. Here pulse generator encodes the digital data of bit sequence generator and its output modulated the carrier signal of optical source using amplitude modulator. Second stage is delay line filter. It is utilised to compensate the dispersion effects which, in turn, reduces the effects caused by atmospheric turbulence, fading etc. the coupling coefficients of the coupler present in this filter can change the dispersion slope. Hence, dispersion and dispersion slope value of the filter can be designed accordingly [6] [7]. The third stage is FSO channel as described earlier. The final stage is the receiver where the optical detector detects the signal and converts it into the electrical signal.

2.2. PSK Modulation Technique

The block diagram of the proposed FSO system using PSK modulation technique is shown in **Figure 2**. It consists of 4 stages. First stage is transmitter stage.

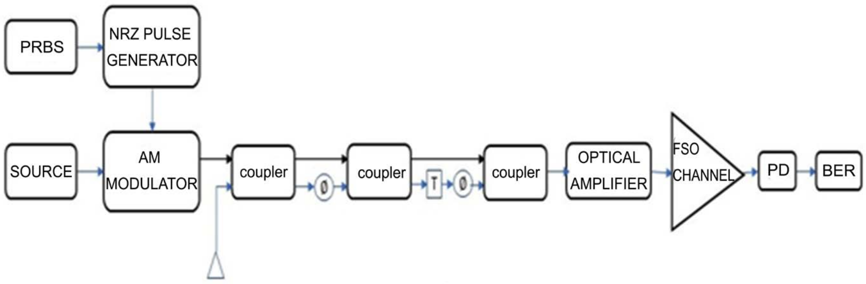


Figure 1. Configuration of ASK modulation technique setup.

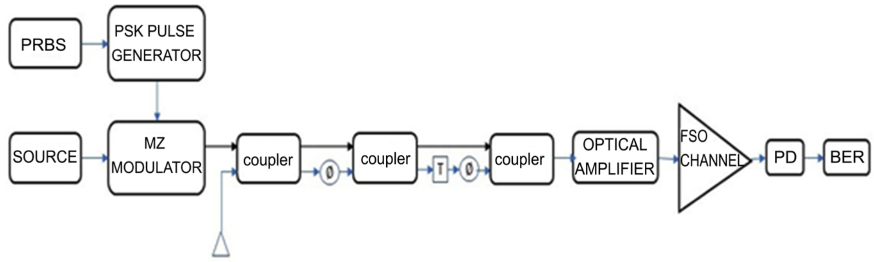


Figure 2. Block diagram of the proposed PSK modulated FSO system.

In this PSK pulse generator encodes the digital data of bit sequence generator. Encoded data modulates the optical carrier signal using phase modulator. Second stage is delay line filter used to compensate dispersion effects and reduce the turbulence and fading caused by it. The stage is FSO channel where atmosphere acts as the channel. Fourth stage is the receiver stage for the detection of the optical signal and converting it into an electrical signal.

3. Simulation Setup

3.1. ASK Modulated FSO Design Simulation

A design of ASK modulation FSO system was simulated and modelled for performance analysis under various weather condition using OptiSystem software shown in Figure 3. The optical transmitter consists of Pseudo-Random Binary Sequence (PRBS) generator representing data bits of bit rate 10Gbits/sec. The output of this is encoded with Non-Return to Zero (NRZ) pulse generator. A continuous wave laser of 60 dBm and wavelength 1550 nm is modulated by the encoded bits using optical amplitude modulator. The output of the modulator is the optical signal which is fed into the delay line filter using x-couplers. The first coupler decomposes the input signal into two, depending on the coupling coefficient. One of the split signals is phase shifted and the other one is kept as it is. Then they are recombined at the second coupler. These are again split and time delayed and phase shifted. Finally, at the third coupler, they are combined to receive the compensated signal. The free space optics medium (FSO channel) with different range and attenuations has been considered and analysed. The optical receiver consists of PIN photodiode and a 3R-regenerator. The PIN photodiode converts received optical signal into the corresponding electrical signal [8]. The 3R-regenerator obta in the original bit sequence. The oscilloscope visualizers and bit error rate (BER) analyzer are used to analyse the results obtained.

3.2. PSK Modulated FSO Design Simulation

A design of PSK modulated FSO system was simulated and modelled for performance analysis under various weather conditions using Opti-System software. Figure 4 shows the simulation structure of proposed PSK modulated FSK system. In the optical transmitter, data bit of 10 Gbits/sec is generated using PRBS generator which is then encoded with the help of PSK pulse generator. CW laser of 60 dBm and 1550 nm wavelength was used to generate optical

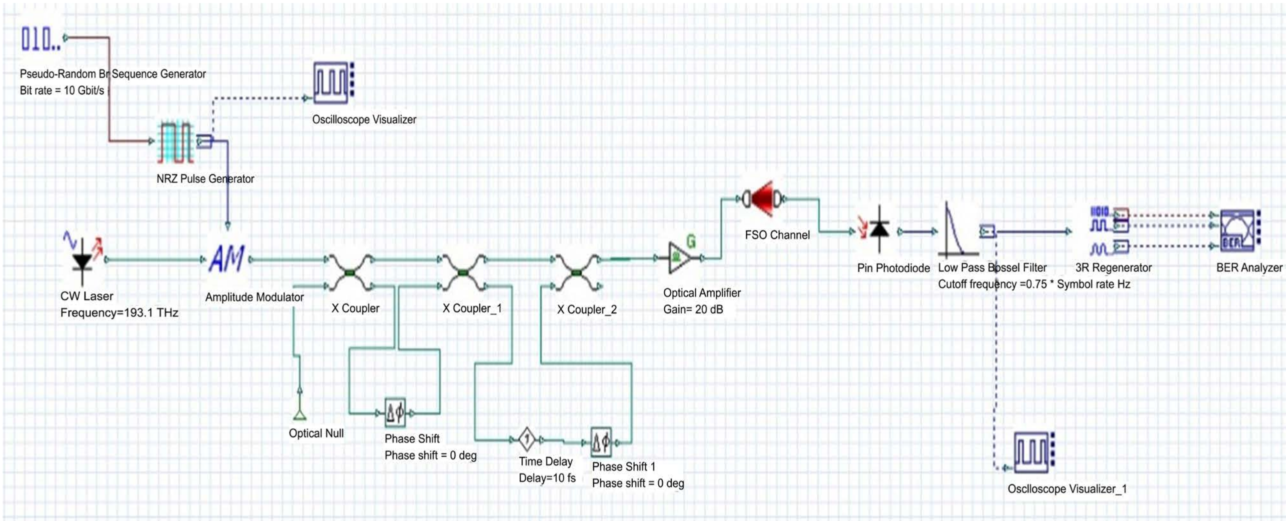


Figure 3. Simulation structure for ASK modulated FSO system.

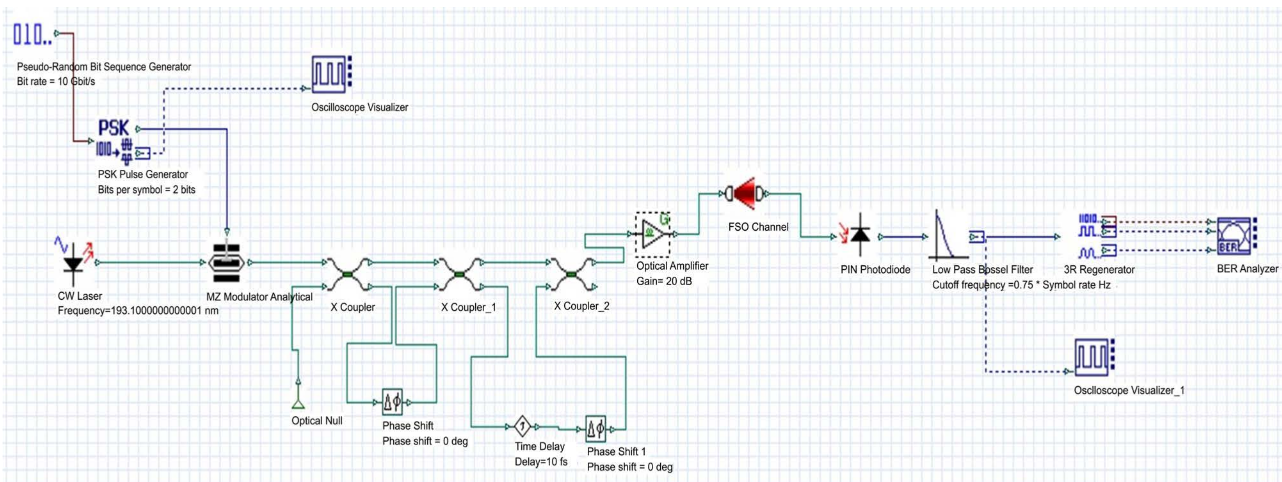


Figure 4. Simulation structure for PSK modulated FSK system.

carrier signal output of PSK pulse generator modulates the optical carrier signal phase resulting in the PSK modulated signal. Modulated signal is passed through the delay line filter to improve the performance of the FSO system as explained earlier. Compensated signal is passed through the FSO channel. The performance is analysed by taking different ranges and attenuation values of the FSO channel corresponding to different weather conditions. The optical receiver has PIN photodiode and a 3R-regenerator to obtained original bit sequence in electrical signal form. Finally, the performance is analysed with the help of oscilloscope visualizers and BER analyzer.

3.3. FSO System Parameters under Various Atmospheric Conditions

The author in [9] [10] described the effects of several weathers conditions for different atmospheric turbulences including rain, fog, haze, etc on FSO systems and given the maximum visibility range and attenuation present for such weather conditions. Table 1 contain FSO system parameters under various conditions. Free space optical system parameters for various weather conditions like haze, rain-mist, snow and medium Fog are included in Tables 2-5 respectively.

Table 1. Free space optical system parameters under various atmospheric conditions.

ATMOSPHERIC CONDITION	ATTENUATION (dB/km)
HAZE	10.94 - 20.68
Rain	6.0 - 30
Mist	28.56 - 31.45
Snow	40
Mid-Fog	70

Table 2. Result analysis for Haze condition.

Work	Attenuation (dB/km)	LOS (metre)	Q-factor	BER	Bit Rate (Gbps)
Ref [11] (ASK)	20	100 m	3.86	5.03e−005	10
Ref [12]	20	800 m	21.08	-	2.5
Ref [13]	20	500 m	45.96	0	10
ASK DLF (proposed)	20	3500 m	56.5069	0	10
PSK DLF (proposed)	20	3500 m	57.0486	0	10

Table 3. Result analysis for rain and mist condition.

Work	Attenuation (dB/km)	LOS (metre)	Q-factor	BER	Bit Rate (Gbps)
Ref [11] (ASK)	30	100	3.86079	5.025e−005	2.5
Ref [12]	30	800	9.62	-	2.5
ASK DLF (proposed)	30	2500	31.4472	2.292e−217	10
PSK DLF (proposed)	30	2500	34.0397	2.855e−254	10

Table 4. Result analysis for snow condition.

Work	Attenuation (dB/km)	LOS (metre)	Q-factor	BER	Bit Rate (Gbps)
Ref [14]	40	-	30.2722	9.174e−202	2.5
ASK DLF (proposed)	40	1900	44.994	0	10
PSK DLF (proposed)	40	1900	46.139	0	10

Table 5. Result analysis for medium Fog condition.

Work	Attenuation (dB/km)	LOS (metre)	Q-factor	BER	Bit Rate (Gbps)
Ref [13]	70	500	2.934	0.00160863	10
Ref [14]	70	-	2.59	0.00153508	2.5
ASK DLF (proposed)	70	1200	16.1147	1.004e−058	10
PSK DLF (proposed)	70	1200	17.5354	3.841e−069	10

Proposed ASK delay line filter and PSK delay line filter under haze condition have 3500 m line of sight compared to previous published work and having a high quality factor of 56.5069 and 57.0486 respectively.

Proposed ASK delay line filter and PSK delay line filter under rain and mist condition have 2500 m line of sight compared to previous published work and having a high quality factor of 31.4472 and 34.0397 respectively.

Proposed ASK delay line filter and PSK delay line filter under snow condition have 1900 m line of sight compared to previous published work and having a high quality factor of 44.994 and 46.139 respectively.

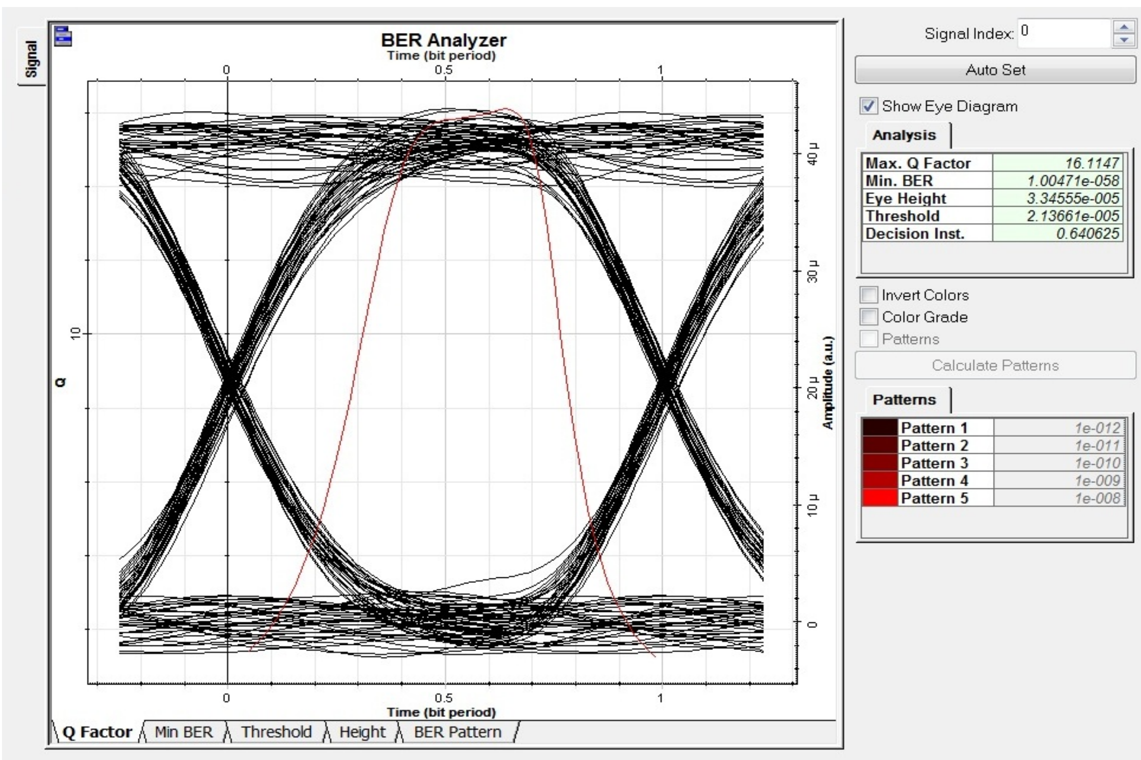
Proposed ASK delay line filter and PSK delay line filter under haze condition have 1200 m line of sight compared to previous published work and having a high quality factor of 16.1147 and 17.5354 respectively.

Eye diagram for various weather conditions of ASK DLF and PSK DLF is mentioned in Table 6 that include maximum quality factor, minimum BER and threshold.

4. Conclusion

A new approach for performance analysis of ASK and PSK modulation based FSO system using coupler-based Delay Line Filter under various weather conditions

Table 6. Eye diagram for various weather conditions.

Weather	ASK
Fog condition	 **Figure 5.** ASK DLF_1.2 KM_70 dB/km 10 Gbps BER.

Continued

Haze condition

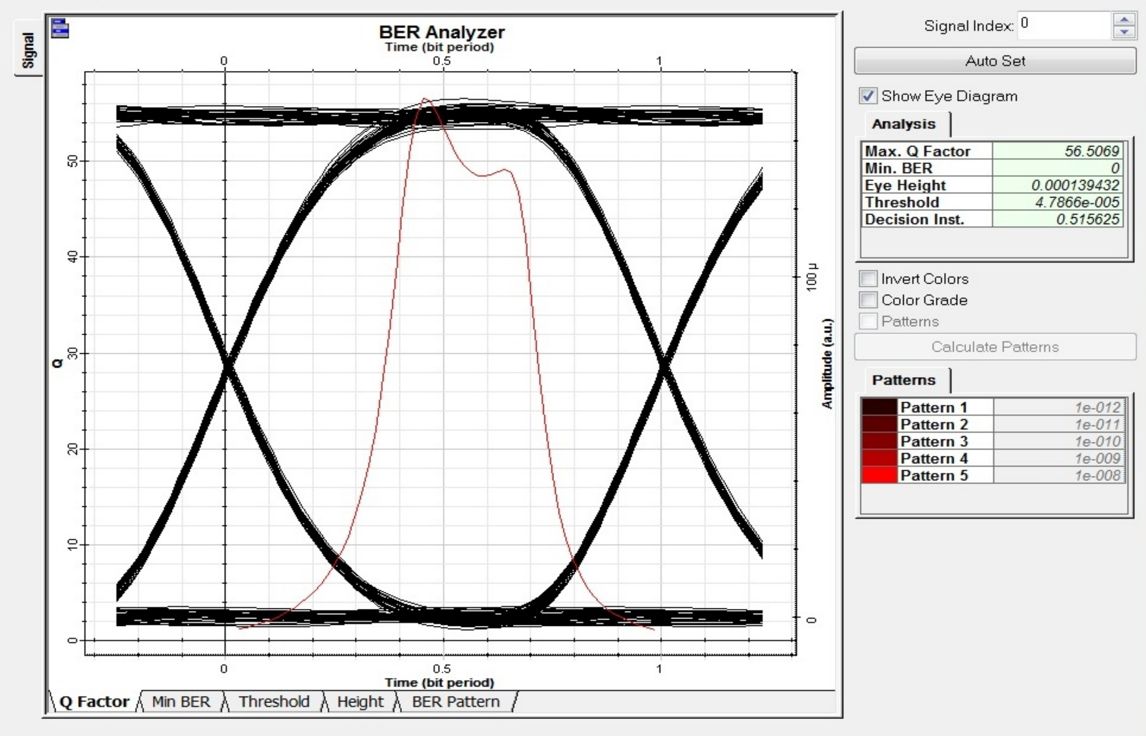


Figure 6. 10Gbps BER ASK DLF_3.5 KM_20 dB/km.

Rain and Mist condition

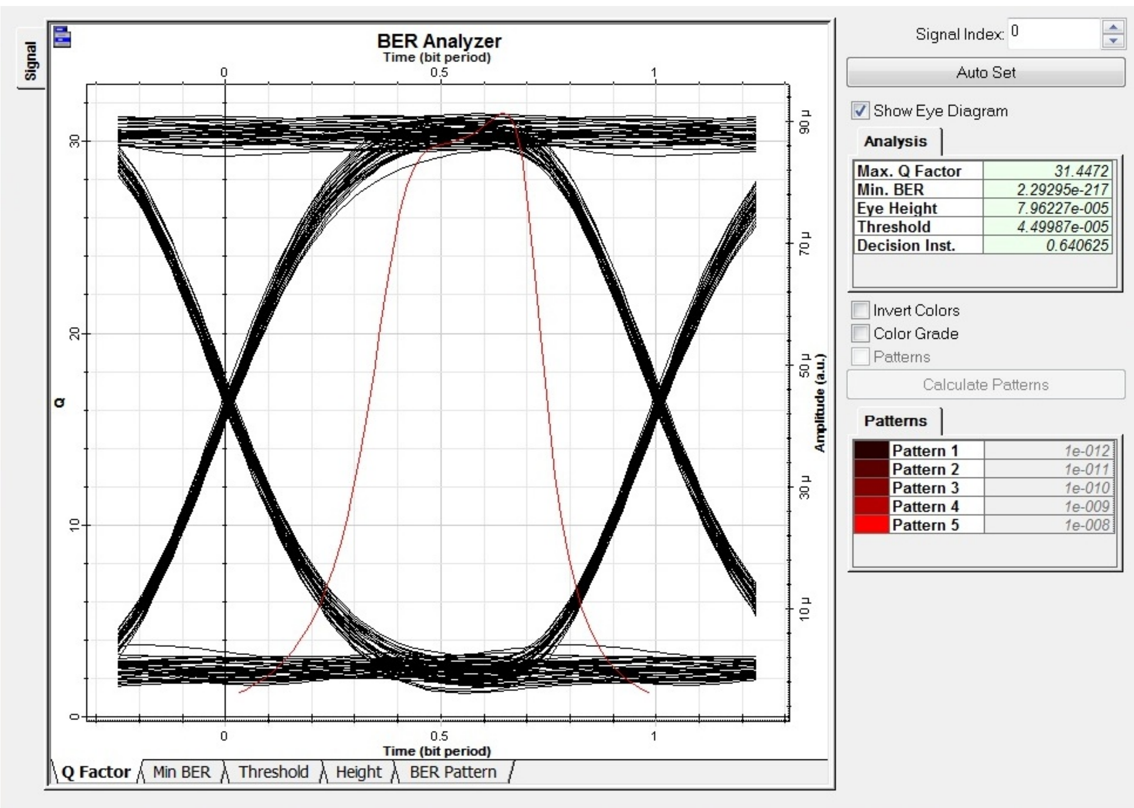


Figure 7. ASK DLF_2.5 KM_30 dB/km 10 Gbps BER.

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Snow condition

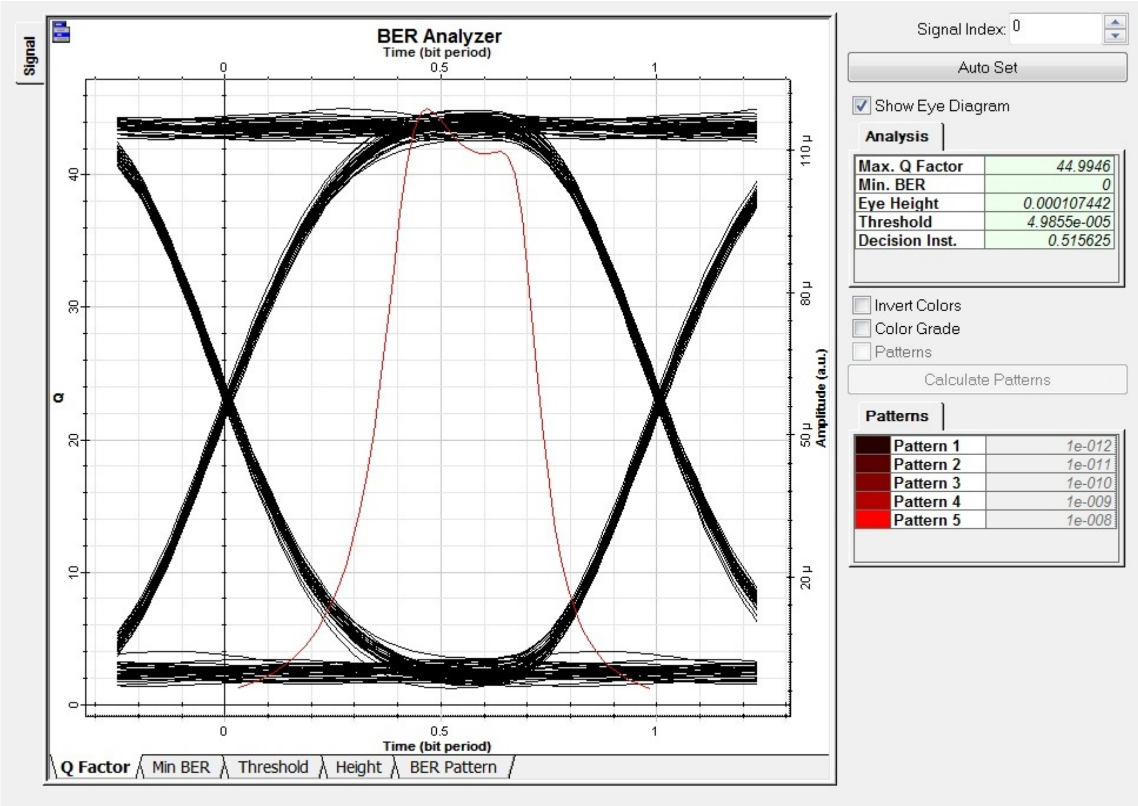

Figure 8. ASK DLF_1.9 KM_40 dB/km 10 Gbps BER.

Haze condition

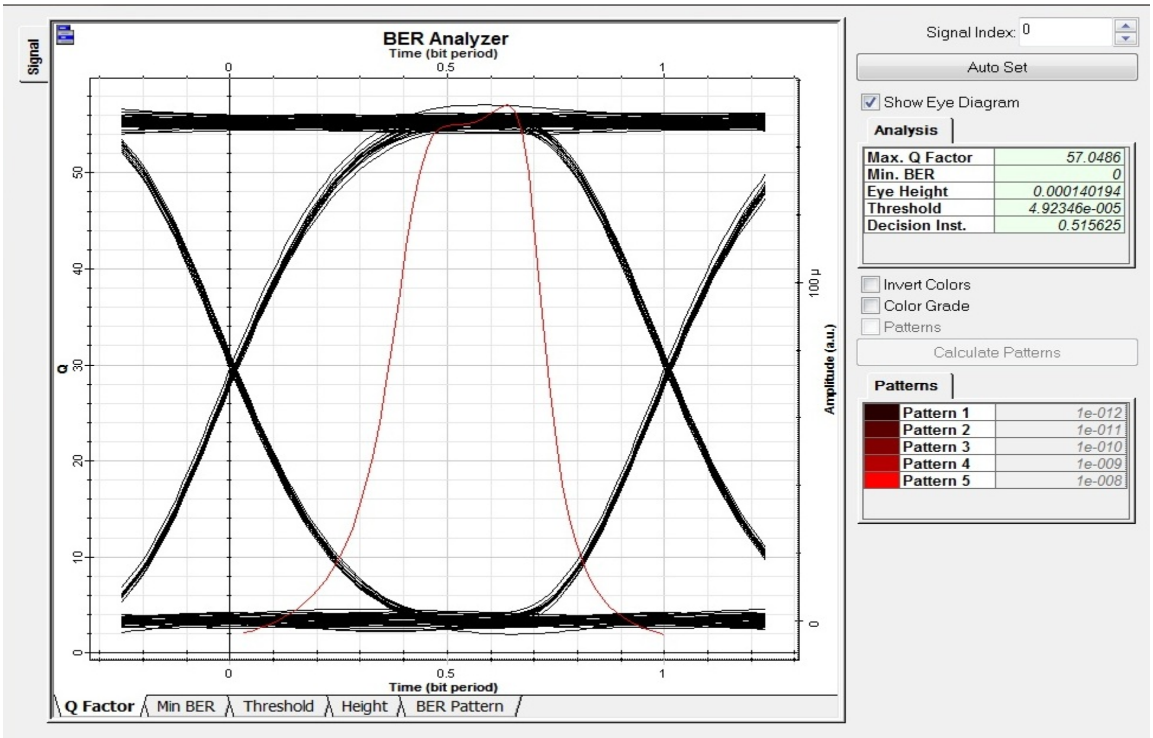

Figure 9. 10 Gbps BER PSK DLF_3.5 KM_20 dB/km.

Continued

Rain and Mist condition

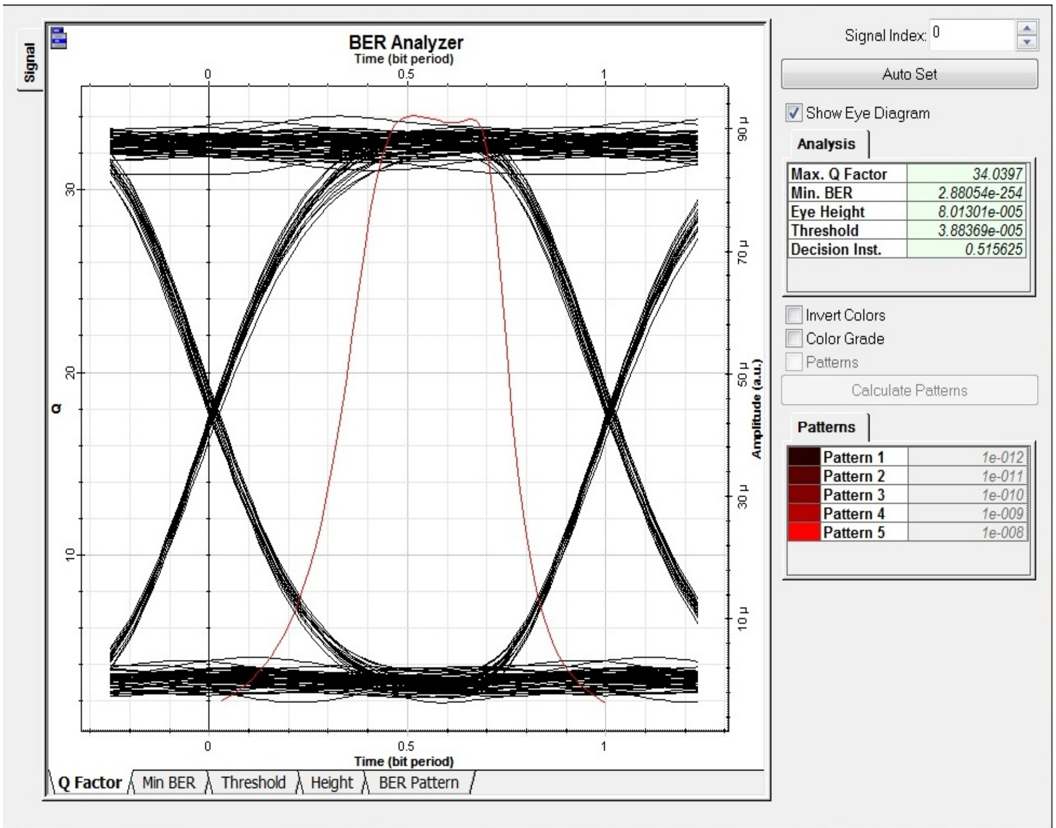

Figure 10. PSK DLF_2.5 KM_30 dB/km 10 Gbps BER.

Snow condition

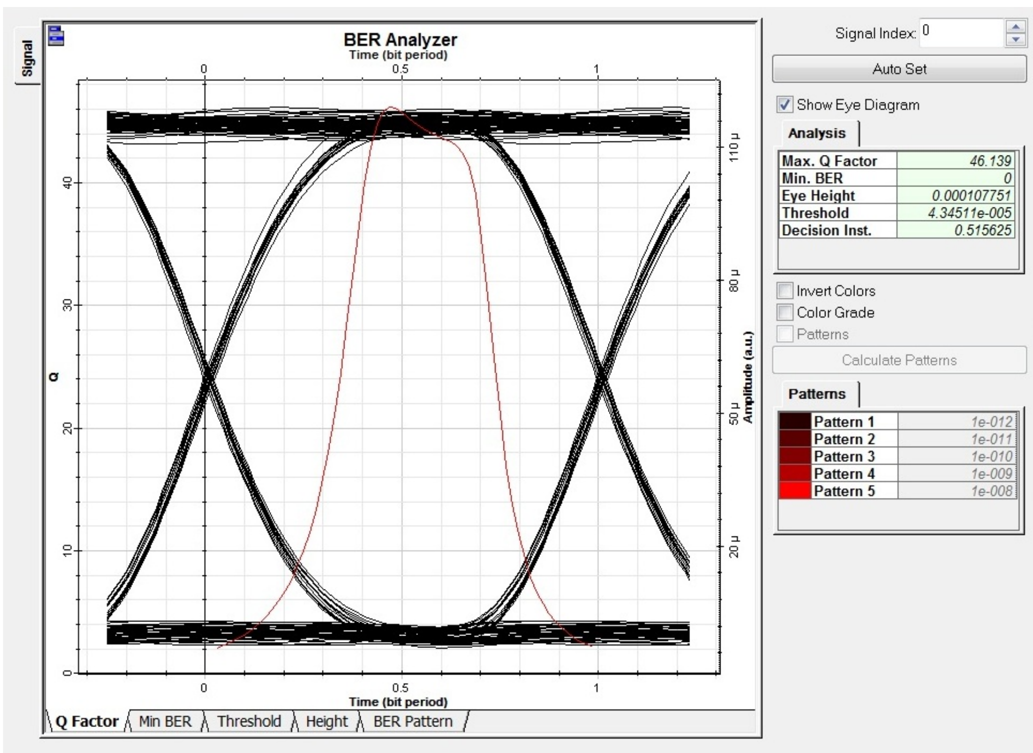

Figure 11. PSK DLF_1.9 KM_40 dB/km 10 Gbps BER.

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Fog condition

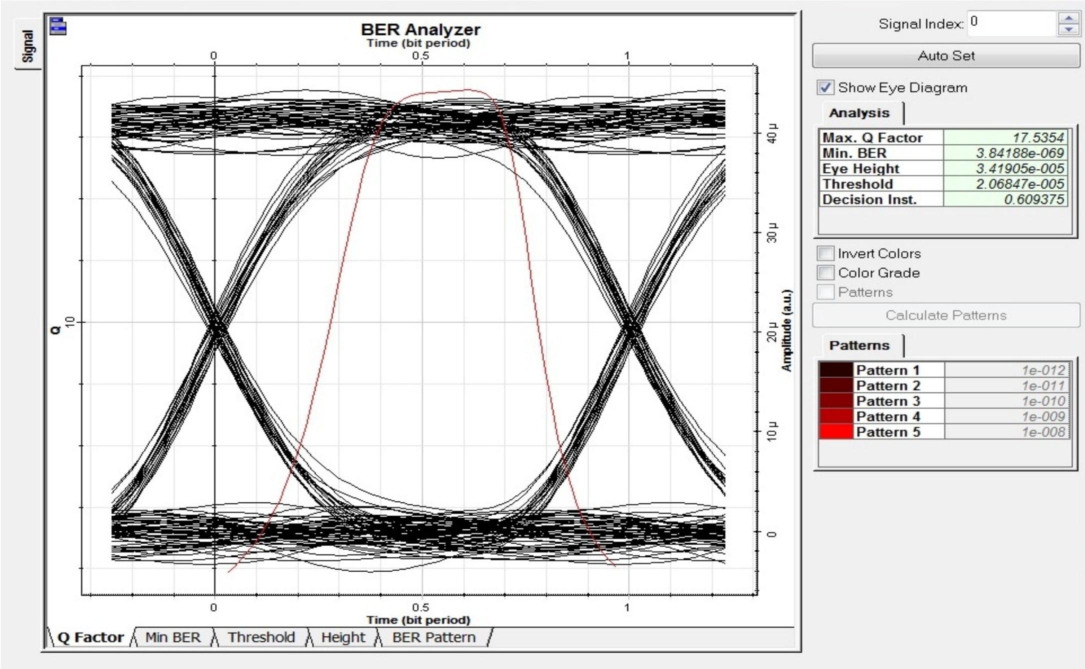

Figure 12. PSK DLF_1.2 KM_70 dB/km 10 Gbps BER.

has been presented having a feature of high Q-factor and BER is very close to zero.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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