Different Optical Filtration with DQPSK-NRZ Scheme Under Impact of Weather for 5G Optical Communication Systems

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Abstract—**5G communication is an emerging technology and it is also a popular area of research that seeks the attention of researchers to delve deeper into this field to enhance wireless communication methods. One of the widely used methods is the Optical wireless communication method. It is considered to be effective to transmit data from one place to another. However, certain aspects contribute to affecting the efficacy of the network. Thus this paper presents a novel approach for 5G communication in which Free space optics is utilized. The proposed model aims to improve the performance of the 5G optical communication model by designing DQPSK-NRZ based transmitter and receiver along with three different optical filters- Bessel, Trapezoidal, and Gaussian filters. The proposed DQPSK-NRZ scheme has achieved maximum Q-factor when is compared with the previous scheme. Further, the proposed work also considers different weather conditions (clear, rain, and haze) and determined the impact of weather on FSO. The simulation of the model is carried out in OptiSystem simulation software by Optiwave.**

Keywords: 5G Communication, Free Space Optics, Optical Filters, Weather Effects, etc.

I. Introduction

The next pace in mobile telecommunication standards is fifth-generation (5G) communication. New services having very high system capability, huge device access, ultra-low latency, ultra-high security, ultra-low consumption of energy, and tremendously high experience quality will be offered [1]. 5 G networking is expected to provide ultra-dense heterogeneous networks for which the amount of mobile data per area is 1000 times and the number of connected wireless devices is expected to be 100 times [1] [2].

In order to meet the specifications of 5G/6G and IoT networks, FSO is regarded as promising. Laser diodes (LD) and Photodiodes (PD) are typically used by the Free Space Optics (FSO) technology as the transmitter and the receiver, respectively. However, in FSO communication, a heterodyne optical detection receiver is utilized. Usually, it is operated by utilizing the IR as the medium of communication but it can also be operated by utilizing Visible light (VL) and Ultraviolet (UV). An FSO device can establish a very long distance as well as a high-data-rate communication link because of the narrow beams of concentrated light from an LD transmitter. In one of the conventional works [3], the detailed differences between optical wireless communication (OWC) technologies can be found.

With regard to FSO, in the 1960s the laser innovation gave the means for a range of applications for FSO[4]. The military and space work continued to provide the basis for commercial FSO [5]. In the 1990s, the civilian use of FSO connections increased, driven by growing data rates and high-quality communication requirements. Instead of fiber, FSO deployment is a cheaper and faster way to provide consumer bandwidth and can also be used in disaster situations [6]. Substantial research efforts to enhance the efficiency of the FSO system in adverse atmospheric conditions mean that, in the presence of turbulence, multi-gigabit speeds are possible.

In addition, FSO technology has integrated wireless networking characteristics and fiber optics. In both new and current wireless technology, the promise of high data rates and safe communication has proven its value. However, given that the signal is transmitted in free space, atmospheric turbulence and weather conditions are highly affected. Such conditions degrade both the signal-to-noise ratio and the signal quality by adding noise to the ambient light beam at the end of the receiver. For this, various filters were introduced.

II. Effect of Weather on FSO

Environmental conditions tend to have a greater influence on FSO despite having all the advantages over the optical fiber system and the microwave system and relative to other communication media. In terms of the availability and reliability of the FSO system,

 ISBN: 978-93-91355-11-1

local weather conditions play a supreme role [7][8]. It is influenced by weather conditions, also referred to as atmospheric turbulence, which degrades the link performance.

1. In signal quality degradation, certain parameters play their role. Visibility defines how far an open-air optical signal can go. Different elements that exist in the air will restrict visibility. These include rain, snow, fog, smog, and hot weather conditions[9].
2. Weak earthquakes, transmitter/receiver misalignment, and wind loads can lead to vibration of the beam and alignment issues known as impairment of pointing error[10],[11].
3. In the atmosphere, fog, snow, and rain trigger the dispersion of laser signals. A part of the light beam traveling from a source deflects away from the intended receiver through scattering.
4. The turbulence caused by random variations in the atmospheric refractive index is another atmospheric phenomenon under simple weather conditions. As a consequence, variations in the random period and irradiance (scintillation) of the optical signals are observed at the receiver [12].

Therefore, these became the major issue as it degrades the performance significantly.

III. Literature Survey

In this section, the review of various analyses carried out by different researches to enhance the performance efficiency of OWC-FSO systems is presented:

In paper [13], the author suggested a novel concatenated coded modulation based on the generalized frequency division multiplex (GFDM) system composed of adaptive turbo code with trellis-coded modulation (ATTCM). The proposed system has low complexity and offers high efficiency in the spectrum and substantial benefits in coding. The novel concatenated coding modulation signal (ATTCM 32QAM) has been shown to have a coding gain of 2.3 dB over the TCM32QAM signal at a bit error rate of 1e-3.

For future wireless networks, 5G networks were projected to reach gigabit-level throughput. However, handling 5G wireless backhaul traffic appropriately is a major challenge. Thus, the authors in [14] examined wireless backhaul traffic in two traditional network architectures that incorporate technology for small cell and millimeter-wave communication.

The research in [15] presented a study on the efficiency of the communication system of a hybrid 5 G RF / FSO. Using Maximal Ratio Combining (MRC) technology, all incoming signals were combined on the receiver side. Based on that, the authors presented the precise closed-form expression of the Average Symbol Error Rate (ASER) of the RF / FSO method considered in terms of the bivariate Fox'sH-Function for different modulation approaches.

In the article [16], indifferent 5G scenarios, the authors discussed index modulation and its general and particular representations, changes, and possible implementations. The aim was to reveal whether index modulation can strive for more output gains with less occupation of medium resources, and how.

The paper [17] uses different modulation approaches, NRZ, RZ, and CSRZ, to evaluate the efficiency of the 4 * 4 MIMO FSO systems. The results represent that, compared to NRZ and CSRZ, the RZ modulation RZ was superior to NRZ and CSRZ for low attenuation and limited connection, while RZ and NRZ were comparable for higher attenuation and greater connection. RZ performs better than NRZ and CSRZ in all aspects.

The Optical Wireless Communication (OWC) channels for various optical filters were analyzed and compared with their previous model in the paper [18]. Performance evaluation was carried out using various optical filters, namely Bessel optical filters, Trapezoidal, Gaussian, and Fabry Perot filters. Compared to the previous model, the findings provided a maximum consistency factor in terms of both optical range and beam divergence. Compared to different optical filters, it was found that the highest quality factor can be achieved using the Gaussian optical filter. Thus, to reconstruct the optical data, different types of optical filters have been used and also, the transmitter part of the model includes an NRZ pulse generator for the encoding technique. This work was regarded as the most efficient one as it has effective results. However, the transmitter part of the FSO model includes the NRZ technique for encoding that consists of some drawbacks that can make the system inefficient.

IV. Present Work

Various previous works are reviewed in the above section and it is analyzed that one of the efficient techniques for efficient 5G optical communication systems used different optical filters to reconstruct optical data. The transmitter part of the model includes an NRZ pulse generator for the encoding technique. However, the NRZ technique consists of some drawbacks such as:

1. The presence of low-frequency components may cause signal droop.
2. No clock is present.
3. Loss of synchronization is likely to occur (especially for long strings of 1s and 0s).

These drawbacks can degrade the performance of the system. Therefore, it is required to upgrade the previous approach used on the transmitter side to achieve a more efficient and reliable system.

Therefore, in the proposed work, the transmitter part of the model is upgraded by introducing a hybrid

ISBN: 978-93-91355-11-1

encoding scheme in a 5G communication system. In this hybrid technique, the DQPSK technique is used with the NRZ encoding technique. This can help to make the system more efficient and reliable to overcome all the above-stated drawbacks.

A. Differential QPSK (DQPSK)

Differential QPSK (DQPSK) is an inconsistent recipient (i.e. recipients who do not synchronize the demodulation oscillator with the modulation oscillator) compatible variant. In comparison to the previous symbol, the differential QPSK encodes information through a certain phase shift. The process in DQPSK would be 0°, 90°, 90°, 180° and 180° while using the criteria, i.e. 45°, 135°, 225°, and 315° in the QPSK technique. Therefore, choosing a relative phase over the absolute phase would have little effect on DQPSK, as this will retain both transmitter and receiver synchronization. Whereas both symbols would be symmetrically affected in the fixed offset process, this could further be avoided in the subtraction system. Therefore, as with other receiving transmission methods, DQPSK proved to be a good technique. Eventually, if a phase failure is introduced by the rate of a frequency offset, the differential phase from one symbol to the next will remain sufficiently precise. Compared to carrier recovery, this method of detecting the differential phase does not increase the difficulty, especially the conversion of the digital database from the analog into the software.

The benefits of DQPSK modulation include enormous spectral efficiency and high WDM device performance. This implies greater dispersion tolerance and tremendous bandwidth efficiency. All these benefits encourage the proposed model to combine this methodology with the NRZ method so that an effective system can be created.

Other than this, it is analyzed from the literature that in optical communication different weather conditions impact the overall performance of the system, so it is important to analyze the impact of weather on the designed system so it can work effectively in all possible conditions which were not done in previous work.

Thus, in the proposed work, the system is analyzed for three separate weather conditions, named clear, haze, and rain. Thus, the influence of these weather conditions on the proposed model is measured and the efficacy of the proposed model is determined by this.

B. System Architecture

This section defines the proposed system's architecture in which the traditional NRZ and MZM-based transmitter is replaced with a combined DQPSK and NRZ based transmitter. Later the data is forwarded to the optical amplifier to transmit through a free space channel. As at the transmitter end, the transmission module is updated, in addition to this at the receiver end after passing through the receiver end amplifier, different types of optical filters have been used to reconstruct the optical data. The significance of the optical filter on the receiver side is that it provides signal synchronization between the transmitted and received signals. The filtered signal is detected using the photodetector with DQPSK and NRZ decoder-based receiver before giving it to the Bit Error Rate (BER) analyzer. Optical spectrum analyzers can be used if needed, which provides the facility to analyze the optical spectrum.

An optical power meter is also used which represents the power received in Watts, mWatts, and dBm. BER analyzer automatically calculates the BER value, Q factor, displays an eye diagram and threshold.

The simulation is performed in optisystem software with a configuration setup as shown below in table 1. Also in proposed scheme 3 weather conditions are considered for analysis the attenuation values considered for clear, rainy, and hazy conditions[19][20][21][22] are also mentioned in table 1.

Table 1. List of Simulation Parameters

Sr. No.	Parameters	Values
1	Optical range (R)	100-1000 m
2	Beam divergence	2 mrad
3	Tx. aperture diameter	10 cm
4	Rx. aperture diameter	10 cm
5	Input power	0 dBm
6	Rainy weather attenuation	19.28 dB/Km
7	Hazy weather attenuation	2.37 dB/Km
8	Clear weather attenuation	0.233 dB/Km

V. Results and Discussion

This section represents the simulation models that are designed during the simulation is discussed along with the performance results of it with different filters and different weather conditions. The results show the comparative system performances of previous and proposed modified models such as the variation of Q-factor concerning channel range, BER, and eye diagram.

 ISBN: 978-93-91355-11-1

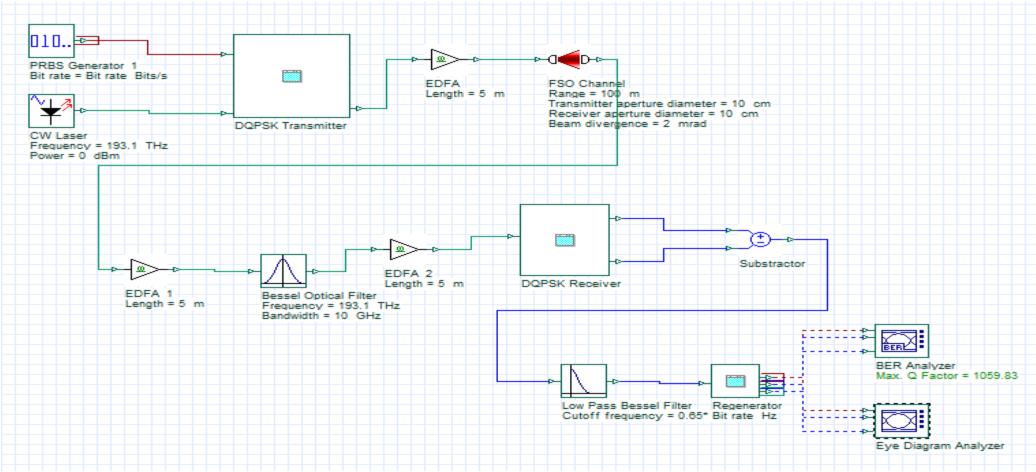
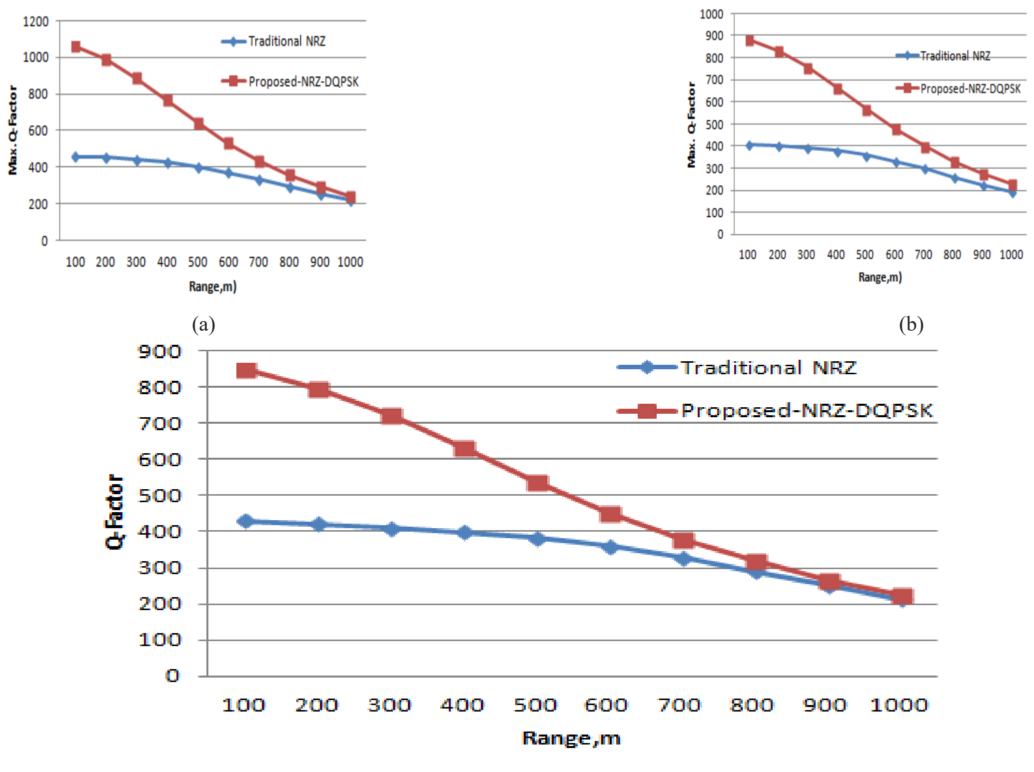


Fig. 1: Optisystem Simulation Model for TX/1 RX FSO System Using Bessel Optical Filter



(c)

Fig. 2: Comparison Graphs for Q-Factor for 3 Different Filter: (a) Bessel Optical filter, (b) Trapezoidal Optical filter, (c) Gaussian optical Filter

Fig. 1 represents the proposed model for the FSO system using the Bessel filter at the receiver end. In this model, the input signal is generated by using a CW laser of frequency 193.1 Thz, which is further connected to the proposed DQPSK-NRZ block designed in the proposed scheme which is further amplified to transmit the signal over the FSO link. In this scheme, pre and post-amplification are used for maintaining the signal strength at the receiver end. After receiving an amplified signal at the receiver end DQPSK-NRZ receiver is connected which further provides a signal to the Bessel optical filter to reduce the impact of noise. The performance is analyzed in terms of the Q-factor.

The proposed scheme is also analyzed with two more filters other than Bessel optical filter these filters are named Trapezoidal and Gaussian optical filter. Finally, an analysis is performed with 3 different optical filters to understand the impact on the received signal also to validate the results comparison is also performed with NRZ-MZM conventional technique. The achieved results are discussed in Fig 2. In Fig 2, a comparison of the proposed scheme and existing model with three different filters namely Bessel, Trapezoidal, and Gaussian optical filters, are given. The graphs present the relation between the Q-factor and the range on the y-axis and x-axis respectively. For Bessel Optical filter (Fig 2(a)), maximum Q-factor achieved for the proposed model is 1059.83 at 100 m, which is almost double that of existing technology that is having the Q factor of 457.35. From the trend of the graphs, it is analyzed that if the range is increased the Q factor going to be decreased. At nearly 1000m the Q factor of Traditional NRZ and the proposed scheme is 218 and 240 respectively, which become almost similar but still, the proposed scheme has a higher Q factor. Similarly, for the other two filters, it is observed that the Q factor is high at the initial stages. In the case of the Trapezoidal filter, the proposed scheme is achieving a Q factor of 882.05 at 100m and a minimum of 230.24 at 1000m, whereas in the traditional scheme it is 405 at 100m and 192.02 at 1000m. Finally, in the case of the Gaussian filter, the maximum Q factor achieved by traditional and proposed schemes are 429.12 and 848 respectively, whereas the minimum Q factor achieved is 213 and 224. It is perceived that the highest Q factor for Trapezoidal filter and Gaussian filter accounted between 800 and 900 which higher than that of the existing technique. Overall, it is observed that filter based model gives high effectiveness in terms of Q-factor.

Table 2 represents the Q-factor achieved by using 3 different filters at the receiver end with a traditional NRZ based transmission module and proposed DQPSK-NRZ scheme. In this, the communication length is varied from 100 m to 1000 m. All 3 comparison represented in the tables shows that the proposed scheme is giving effective results even after changing the communication distance. To explain this let us take an instance for comparison at 1000 m length, for NRZ based Bessel filter the achieved Q factor is 218.109 and for the proposed scheme, it is 240.34, for Trapezoidal filter traditional model is having Q-factor 192.02 and the proposed is having 230.24 and also for Gaussian filter traditional and proposed scheme having Q-factor as 213.76 and 224.23 respectively. The Q-factor is higher in all three cases shows the effectiveness of the proposed scheme.

A. Impact of Different Weather Conditions

As the proposed system uses light to travel in the atmosphere instead of fiber, However rain and haze becomes the main reason of attenuation by deteriorating the signal. Therefore the analysis is performed in the proposed system with 3 different conditions Clear weather, Rainy weather, Hazy weather. As every weather condition is having a different impact on the signal, that impact is considered in terms of attenuation (dB/Km), The considered attenuation factors for these conditions are mentioned above in table 1given in section IV. After the simulation of the proposed model with 3 different optical filters, the analysis is performed for all 3 conditions. the results are analyzed in terms of Q-factor by varying the link length from 100-1000 m.

Table 3 shows the Q-Factor values of the proposed model in clear, Haze, and Rain conditions. the achieved values are as for Bessel filter-based proposed model the Q-factor achieved at 100 m distance is 1059.83 for clear weather, 1009.25 for haze condition, and 1003.16 for rainy weather. Similarly, the comparison is done for the proposed scheme with Trapezoidal and Gaussian filters.

VI. Conclusion

5G wireless communication is a novel field of research that offers a significant number of factors to enhance the performance of communication. This paper proposed a novel technique by introducing optical filters with Differential QPSK with NRZ transmission

Table 2: Comparison for Q-Factor by Varying Link Length

Length (m)	NRZ Scheme with Bessel Filter	Proposed Scheme with Bessel Filter	NRZ Scheme with Trapezoidal Filter	Proposed Scheme with Trapezoidal Filter	NRZ Scheme with Gaussian Filter	Proposed Scheme with Gaussian Filter
100	457.35	1059.83	405.185	882.05	429.12	848.2
200	452.12	989.06	401.08	831.86	421.36	797.61
300	442.06	886.52	393.06	757.1	409.05	722.95
400	425.56	765.4	379.47	665.64	399.36	632.15
500	401.66	643.17	359	570.28	383.16	538.81
600	370.53	531.69	331.45	479.96	359.06	452.2
700	333.79	436.02	298.16	399.96	327.27	380.89
800	294.218	356.69	261.88	332.12	290.087	320.6
900	254.85	292.18	225.68	276.27	251.11	268.28
1000	218.109	240.34	192.02	230.24	213.76	224.23

ISBN: 978-93-91355-11-1

Table 3: Performance Analysis of Proposed Scheme Under Different Weather Conditions

Length (m)	Proposed Scheme with Bessel Optical Filter			Proposed Scheme with Trapezoidal Filter			Proposed Scheme with Gaussian Optical Filter		
	Clear	Haze	Rain	Clear	Haze	Rain	Clear	Haze	Rain
100	1059.8	1009.2	1003.1	882.0	880.6	874.4	848.2	846.7	840.4
200	989.0	949.7	914.1	831.8	824.4	788.8	797.6	790.2	754.5
300	886.5	855.6	759.8	757.1	737.5	643.9	722.9	703.4	610.4
400	765.4	737.5	577.2	665.6	631.0	479.2	632.1	597.5	451.4
500	643.1	613.8	412.1	570.2	521.7	337.0	538.8	491.8	325.1
600	531.6	498.4	291.1	479.9	422.4	232.8	452.2	400	226.7
700	436.0	399.1	203.8	399.9	338.3	160.4	380.8	326.3	156.9
800	356.6	321.9	144.3	332.1	270.8	111.8	320.6	263.1	109.7
900	292.1	259.1	104.2	276.2	217	79.2	268.2	211.4	78.0
1000	240.3	208.7	76.9	230.2	174.4	56.9	224.2	170.4	56.2

and reception technique. This technique is designed to provide a high-performance 5G communication system for wireless optical transmission. The simulation of the model is performed and the results are compared with the existing model. The simulation results demonstrated that the proposed DQPSK-NRZ scheme is achieving maximum quality factor with different link lengths in all combinations of optical filters. Moreover, the simulation is also performed for three weather conditions namely clear weather, rain, and haze. The results demonstrate that the effect of rain is the most for the FSO based communication concerning hazy or clear whether which can be an area of improvement in future. Simulation is carried out in OptiSystem software. The key outcomes of the research are that the proposed scheme is effective for optical communication especially with the use of Bessel filtration. Even in comparison with the traditional scheme, the proposed scheme is giving better results with other filters also. But still, in the case of Bessel filtration, the maximum Q factor achieved is higher approximately 1060. Other than this, while evaluating the current system under different weather conditions, the simulation results demonstrated that the proposed scheme is effective to handle such conditions in a low communication range, whereas if the communication range is increased the impact of weather conditions degraded the Q factor and performance of the system. The overall performance of the proposed model results very effectively with high quality and less error. Future work can be focused on handling the impact of weather conditions. Other than this, designing dynamic filters can be one of the major contributions to 5G optical communication systems.

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 ISBN: 978-93-91355-11-1