A 40 Gbps Ro-FSO transmission system for 5 G applications

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Never-ending demand for higher data rate has led the research to focus on new kind of networks (5G) which can support increasing number of users. To handle such traffic, integration use of millimetre (mm) wave is proposed with free space optical networks. This work focuses on transportation of 40 GHz radio signal over free space optical link. Four independent channels are used with a data rate of 10 Gbps and 40 GHz radio signal are transported over 400 m free space link by employing On-Off Keying (OOK). Analysis of the received output signal is performed using BER and eye diagrams. Furthermore, comparison of Non- Return to Zero (NRZ) and Return to Zero (RZ) modulation schemes are also investigated.

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1. Introduction

Global race to harvest potential LTE (4 G) technology successor has begun to address escalating needs of data rates. Key requirements from 5G networks are improved delay in micro seconds, data rates over 10 Gbps which can support 10, 000 times users than 4G and use of assorted networks [1]. The mm-wave band in (20-40 GHz) [2], is proposed to address these many goals. As this frequency band faces many concerns such as attenuation of ~3 dB/m, when transmitted over wired metallic cable system which eventually restrict the coverage zone [3]. For handling these many issues, new model of heterogeneous network was introduced named as Radio over Fiber (RoF). Thus it becomes easier to harness data carrying capacity of mm waves as well as diminish the distortions which were present in wired metallic cables [4]. With additional challenges of laying of fiber due to incessant development of cities and infrastructure and therefore inefficient system on cost basis, RoF is replaced by optical wireless channels named as Radio over Free Space Optics (Ro-FSO) in opaque city areas [5].

Free Space Optics (FSO) can make use of atmosphere as means for propagation and as there is no regulation in comparison to traditional RF systems, FSO helps in cost cutting of fiber laying in scarcely occupied regions [6, 7]. Notwithstanding benefits presented by the FSO systems, limitations such as scintillations and turbulences due to variations of refractive index of atmosphere presents challenges which requires to be considered for improving the Signal to Noise Ratio (SNR) [8]. Such Ro-FSO integration provides a ubiquitous strategy to harvest properties of RF network with elevated traffic handling ability and advisable model of communication [9]. Over the years, various multiplexing techniques have been introduced to improve system capacity. Wavelength Division Multiplexing (WDM) is one such technique that is extensively utilized in optical networks [7, 10-24].

In 2018 [25], researchers anticipated a Ro-FSO scheme by Phase Shift Keying - Mode Division Multiplexing (PSK-MDM) where they effectively communicated two channels with 20 Gbps-40 GHz data over 50 km. Another author in 2018 [3] describes usage of 24-26 GHz band for 64 QAM over a distance of 100 meter free space optics connection through steady turbulences and 500 meter to 1,000 meter through weak turbulences. Another study in 2018 [26], proposed a Ro-FSO scheme which utilizes Alternative Mark Inversion (AMI) encoding scheme for mode division multiplexing network with 2 autonomous channel each containing 2.5 Gbps data rate and 10 GHz of RF signal. In 2019 [27], researcher proposed Ro-FSO system which employs 2 channels each containing data of 2.5 Gbps - 60 GHz over a distance of 5000 meters. In 2019 [28] researcher analysed different filtration schemes for analysing 5G signal.

2. System description

Fig. 1 shows the Ro-FSO scheme architecture model in OptiSystem TM Software. The intended systems consist of four (4) independent channels, all carrying 10 Gbps NRZ data with 40 GHz RF signals. As shown in Fig. 1, 10 Gbps of data is encoded by NRZ/RZ and then up converted to 40 GHz radio signal. Fig. 2 shows the up-conversion of signal at 40 GHz. This radio signal is modulated over optical link by using optical modulator, which is derived by continuous wavelength laser. First channel is operated on 1545 nm, second channel is operated on 1546 nm whereas third and fourth are operated on 1547 nm and 1548 nm respectively. The output from all the modulators is combined together and transmitted over 500 m of FSO link. The signal is de-multiplexed on the receiver side by using de-multiplexer. Avalanche Photo Diode (APD) is used to detect the optical signal and then down-converted to original encoded signal by adding 40 GHz radio signal followed by low pass filter. Bit Error Rate (BER) tester is used to measure the BER. The other parameters of simulation set up are mentioned in Table 1.

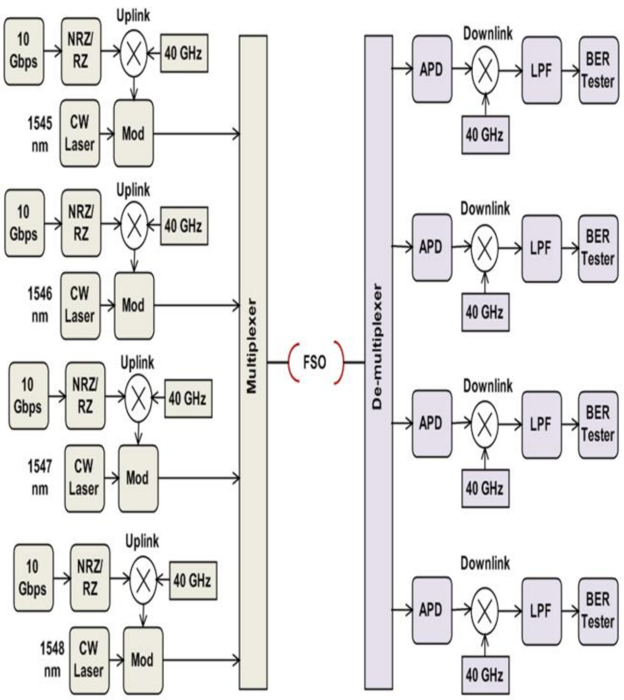

*Fig. 1. Proposed 4*10 Gbps-40 GHz Radio over Free Space Optics System*

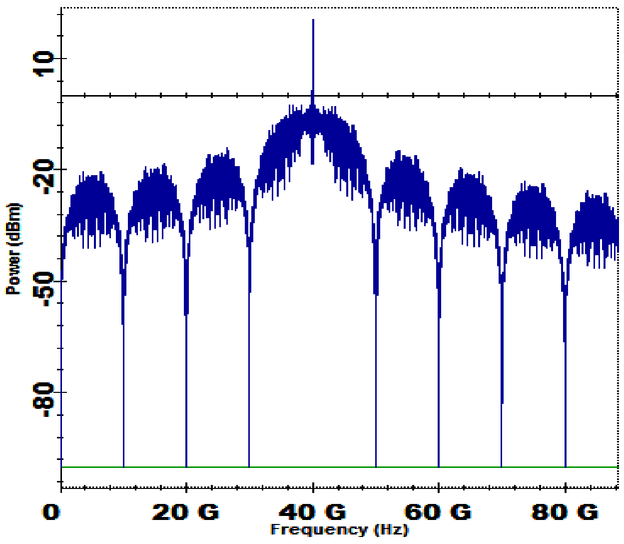

Fig. 2. RF Spectrum Analyser (color online)

Table 1. Parameters of Proposed System

Module Name	Parameters
Input Power of Laser	0 dBm
Line width of Laser	10 MHz
Laser Wavelength	1545 nm
RF Carrier	40 GHz
APD Sensitivity	1 A/W
Dark current of Photo diode	10 nA
Cut off frequency of LPF	3.75 e + 009 Hz

3. Results and discussion

The results from the simulation setup of Ro-FSO systems are presented and discussed in this section. The performance of various channel is discussed for different modulation formats in free space. Fig. 3 discuss the effects on BER with respect to varying free space distance on each channel having different wavelengths.

Fig. 3 shows comparison of NRZ and RZ encoded channels with respect to BER vs Range graphs. For NRZ, bit error rate for channel 1 is observed as 1.03×10^{-10}, 5.94×10^{-09}, 1.35×10^{-07}, 1.57×10^{-06} and 1.10×10^{-05} at 300, 325, 350, 375 and 400 metres of FSO link respectively. Similarly, for RZ bit error rate for channel 1 is observed as 5.24×10^{-08}, 9.03×10^{-07}, 8.47×10^{-06}, 4.79×10^{-05} and 1.92×10^{-04} at 300, 325, 350, 375 and 400 metres of FSO link respectively. This clearly indicates better performance of NRZ coding over the RZ coding in terms of minimum acceptable BER.

For NRZ, bit error rate for channel 2 is observed as 3.17×10^{-09}, 3.71×10^{-08}, 4.01×10^{-07}, 3.05×10^{-06} and 2.13×10^{-05} at 300, 325, 350, 375 and 400 metres respectively. Similarly for RZ bit error rate for channel 2 is observed as 2.14×10^{-07}, 2.68×10^{-06}, 1.98×10^{-05}, 8.60×10^{-05} and 2.76×10^{-04} at 300, 325, 350, 375 and 400 metres of FSO link respectively. Again, the results show better performance of NRZ over RZ coding with respect to minimum BER.

For NRZ bit error rate for channel 3 is observed as 4.68×10^{-08}, 5.17×10^{-07}, 4.70×10^{-06}, 2.70×10^{-05} and 1.07×10^{-04} at 300, 325, 350, 375 and 400 metres respectively. Similarly for RZ bit error rate for channel 3 is observed as 3.16×10^{-06}, 1.27×10^{-05}, 5.21×10^{-05}, 2.77×10^{-04} and 8.92×10^{-04} at 300, 325, 350, 375 and 400 metres of FSO link respectively. Hence NRZ again outperforms the RZ coding format.

For NRZ bit error rate for channel 4 is observed as 4.38×10^{-09}, 1.11×10^{-07}, 9.58×10^{-07}, 5.13×10^{-06} and 3.63×10^{-05} at 300, 325, 350, 375 and 400 metres respectively. Similarly, for RZ bit error rate for channel 4 is observed as 3.22×10^{-07}, 2.35×10^{-06}, 1.88×10^{-05}, 8.99×10^{-04} and 2.57×10^{-04} at 300, 325, 350, 375 and 400 metres of FSO link respectively. This shows that NRZ performs better than RZ encoding scheme. From the result presented in Fig. 3 and discussed here, it can be concluded that in Free Space environment, NRZ coding performs better with varying distance as compared to RZ coding.

Fig. 4 shows eye diagram at a distance of 400 meter for channel 1 and channel 4 for NRZ and RZ formats. For all the four channels, the unblemished opening of the eye at 400 meter indicates successful data transmission with acceptable BER.

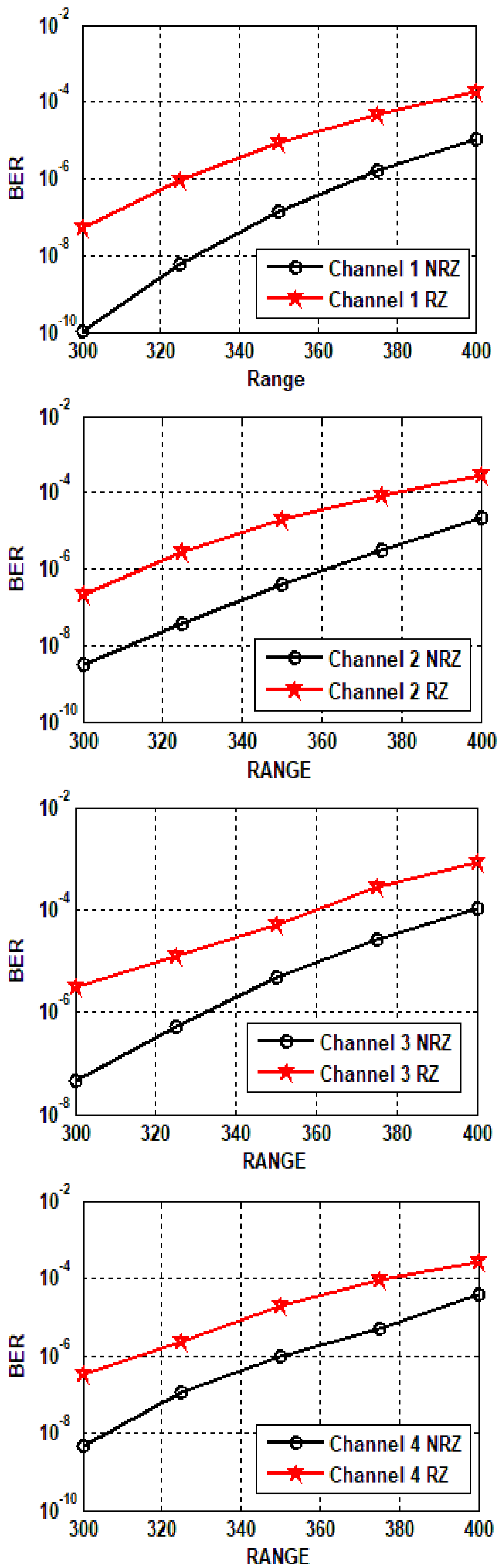

Fig. 3. Comparative study of NRZ and RZ BER vs Range for Channel 1 to Channel 4 (color online)

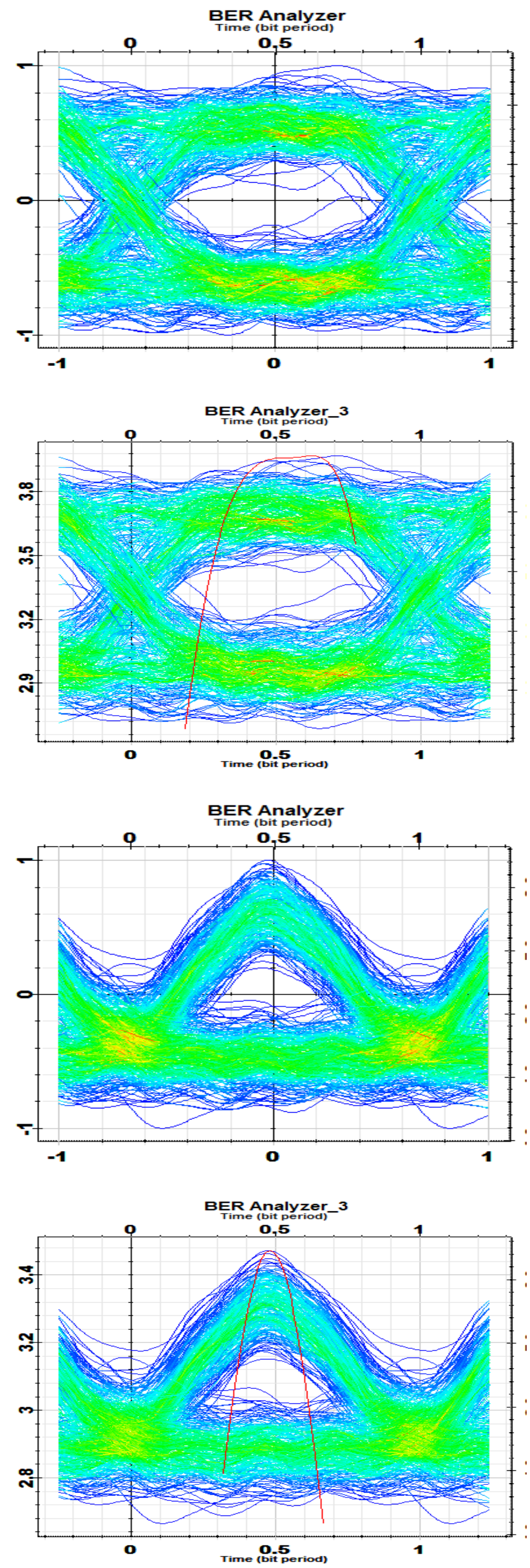

Fig. 4. Eye Diagram; Channel 1 and Channel 4 NRZ and Channel 1 and Channel 4 RZ (color online)

4. Conclusion

The performance of mm waves with FSO systems have proved to be more proficient with respect to enriched data carrying capability. High speed WDM Radio over - Free Space Optics (Ro-FSO) system for transmitting millimeter (mm) waves for 5G networks is designed in this work. Four channels transmitted more than 400 m of free space channel, all carrying 10 Gbps of data with 40 GHz of RF signal. The results show that NRZ performs better than RZ encoding scheme for the proposed Radio over - Free Space Optics (Ro-FSO) system. The simulative results show that all channels are successfully transmitted. Further it is observed that NRZ encoded signals have better BER than RZ encoded signals.

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