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Performance Estimation Of DDMZM Operation In RoFSO Network

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***Abstract**:*
In this manuscripta dual drive Mach Zehnder Modulator is deployed at the transmitter end of a standalone Free Space Optics network. The modulator is driven at both minimum transmission point & maximum transmission point to ascertain the optimum system performance. The simulative investigation is carried out at with signal of 10 GHz at data rate of 1 Gbps having Laser power of 30 dBm over a distance of 5 km. The study is done considering clear sky, light rain and fog as the atmospheric conditions for free space transmission. It is revealed that, the proposed network better quality transmission at minimum transmission point against maximum transmission point under clear weather, light rain and fog conditions. Further, it is also reported that at distance of 3 km, the dual drive Mach Zehnder Modulator successfully transmits good quality RF signal of 15 GHz at minimum transmission point and 10 GHz at maximum transmission point.
Keywords:Free Space Optics (FSO), Dual Drive Mach Zehnder Modulator (DDMZM),Minimum transmission point (MITP), Maximum Transmission Point (MATP).*

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I. Introduction:

In the recent times, the high-speed data communication has become prime requirement of the subscribers for domestic, commercial & scientific applications. The last mile connectivity is one of the essential traits of an excellent communication network. Free Space Optics (FSO) is such a technology which offers last mile connectivity to subscribers, especially in difficult terrains like hills, deserts etc. It is a line of sight (LOS) technology which transfers the data through free space where optical beam is generated via highly coherent laser light[1]. It is one of the promisingtechnologyin which it is also possible to transmit information usingRadio Frequency (RF) signals over FSO links.FSO system is amongst the most suitable technologywhich ensures digital inclusion due to its eminent features such as unlicensed frequency spectrum, enormous bandwidth, resistance to electromagnetic interference, trouble-free deployment in difficult terrains[2].Along withmultiple advantages offered by FSO technology, the transmitted signal gets degraded over larger distances due to atmospheric losses like absorption and scattering in accordance with the concentration of suspended particles heavily available in polluted and humid areas[3]. These environmental conditions impact the system performance usually leading to poor quality of service. Various kinds of mechanisms have been designed & adopted to counter the causes of impairments in FSO networks. Multiple input multiple output (MIMO) is one of the widely implied technique to counter atmospheric uncertainties[4]. In order to enhance the quality of received signal, implication of multiple beam technique is employed which can increase the quality of received signal significantly[5]. Hybrid wavelength and mode division multiplexing (WDM-MDM) technology is employed and achieved significantly high transmission rate[6]. A seamless optical and radio transmission using simple and robust Radio over Fiber and FSO network is practically employed and the received signal is investigated in different atmospheric conditions[7]. A significant increase in the Radio over FSO link performance is demonstrated using the Decode and Forward relay nodes in series in the presence of atmospheric turbulence and pointing errors[8]. A point to point Radio over FSO link using Dense Wavelength Division Multiplexed (DWDM) Radio is presented where optical power is allocated among four DWDM optical sources in order to enhance the FSO distance[9].

The optical modulator plays crucial role in defining the system performance of the FSO networks. Generally, Mach Zehnder Modulator (MZM) is extensively used in optical networks. It is operated in different configurations like single drive and dual drive where single or more than one version of RF signal is applied to it along with an optical signal. Both configurations offer their own advantages & disadvantages. In optical networks, single drive MZM is utilized most of the time on the basis of low cost & simple operation. However, when high frequency signals like RF signals are to be transported, MZM is required to provide best performance for an improved & excellent quality of service. In such scenarios, Dual Drive MZM (DDMZM) is employed. The DD MZM when deployed in full duplex Radio over Fiber (RoF) system provides self interference cancellation feature in the RF band of 25 GHz[10]. Further, in RoF system, DDMZM suppresses 3rd order intermodulation distortions (IMD3) significantly by 22 dB[11]. The DDMZM has also been utilised to generate 60 GHz mm Wave inRoF/FSO integrated network to transmit Radio signals over FSO links[12]. A 40 Gbps FSO convergent link backed by RoF structure containing 50 km of fiber and modulated by DDMZM is demonstrated which restricts power penalty within 2.5 dB for 2.5 km range of FSO link[13-14].It is found from the literature that DDMZM is used in Optical fiber assisted FSO links only. So, in this article, DDMZM is deployed in dedicated &stand alone FSO networks to transmit high frequency RF signals. Apart from this, performance of DDMZM is investigated by operating it at both Minimum transmission point (MITP) and Maximum transmission point (MATP). The output of the proposed network is analyzed in terms of Q factor, Bit Error Rate (BER) & eye diagrams.

The article is drafted in five different sections including introduction and some background literature in the 1st part, simulation setup and design of proposed system is explained in 2nd part. The 3rd section illustrates detailed results & discussions where comparison with existing literature is also highlighted. The article is concluded in section 4 followed by references.

II. System Design& Simulation Setup:

The schematic of designed network is shown in figure 1. The pseudo random bit sequencer (PRBS) is deployed to generate the data which is fed to NRZ modulator to get the corresponding electrical signal. A radio frequency (RF) generator is utilized which generates signal of 10 GHz. The out from RF generator and NRZ modulator is multiplied to get the modulated output and a phase shifter of 180 degree is used to get two simultaneous output signals (phase shifted & normal). These two electrical signals are supplied to DPMZM along with the LASER signal to get the modulated optical signal.DPMZM is operated at two different biasing points i.e. MATP & MITP. For MATP, biasing voltage levels are kept at 4v & 0v and for MITP, biasing voltage levels are kept at 4v & 4v. The optical signal thus obtained from DPMZM is transmitted towards receiver via free space. An APD based photo detector is deployed at receiver which converts optical signal back to electrical signal. This electrical is then evaluated using BER tester, Q meter and eye diagram analyzer to ascertain the quality of the signal. The detailed simulative setup and major simulation parameters are shown in figure 2 & table 1 respectively.

Table 1: Simulation Parameters

Wavelength	193.1 THz (1552 nm)
Laser Power	30 dBm
Bit Rate	1 Gbps
RF signal	10 GHz
Distance	1-5 km
Transmitter Aperture Diameter (FSO)	5 cm
Receiver Aperture Diameter (FSO)	20 cm
Beam Divergence	1 mrad
Environmental Attenuation	Clear Weather= 0.33 dB/km Light Rain= 3 dB/km Fog= 7.74 dB/km

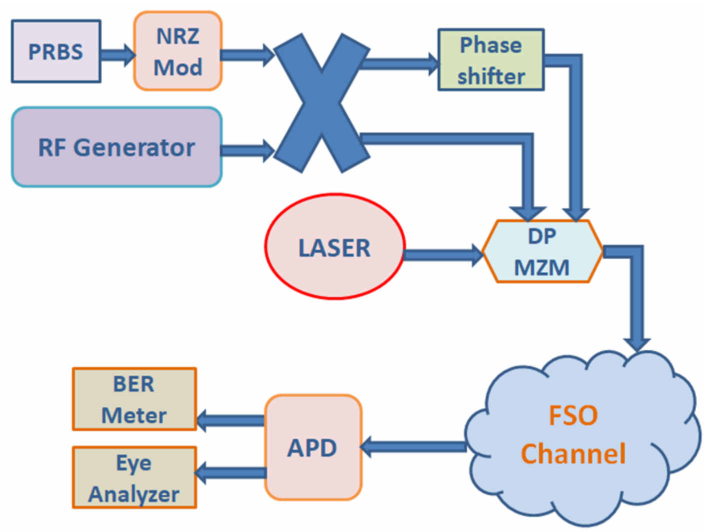

Fig 1: Schematic of designed FSO network

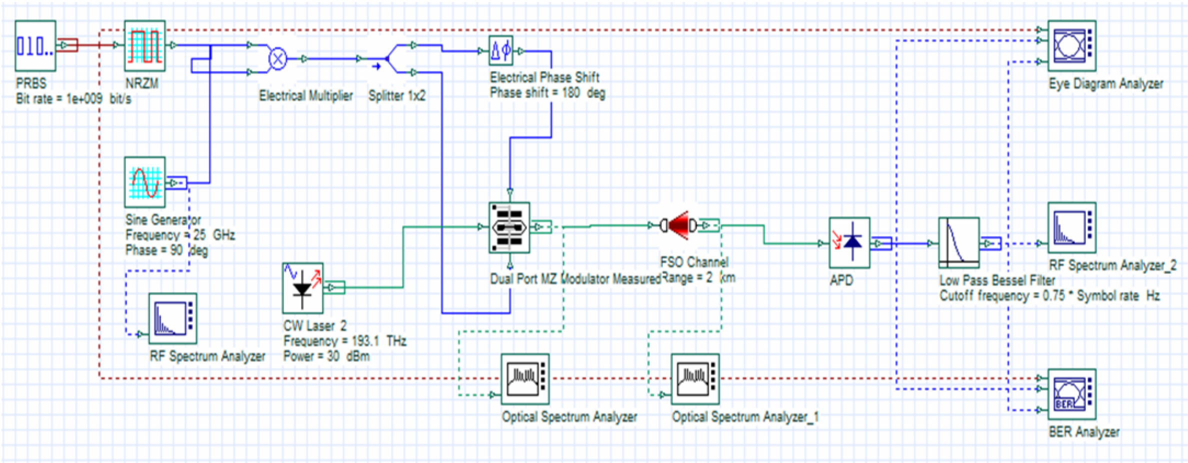

Fig 2: Simulative setup of designed FSO network

III. Results And Discussions

The simulativesetup developed in previous section is investigated on OptiSystem 18 version. The designed network is simulated to measure Q factor, BER against transmission distance and radio frequency. The following notations and standard acceptable values are used in the graphs to describe system performance:

MITP	Minimum transmission point
MATP	Maximum transmission point
Minimum acceptable BER/ Log_{10}(BER)	10^{-9}/-9
Minimum acceptable Q factor	6

The network is first studied under clear sky atmospheric condition. Figure 3 presents the measured values of Log (BER) against free space range. It is observed as the range is swept from 1 to 5 km, the BER increases. The signal quality obtained is good and in acceptable BER range for both MATP & MITP even at the range of 5 km. The BER obtained at 5 km is 10^{-46} & 10^{-33} for MITP & MATP respectively. The same behavior is obtained while measuring the Q factor under clear sky conditions which is depicted in figure 4. The Q factor is around 10 for MITP & MATP operation at the distance of 5 km.

The network performance under fog conditions is shown in figure 5 &6. It is reported that with the increasing distance, BER also increases. The quality transmission is achieved only upto distance of 2 km for MITP & MATP and quality deteriorates beyond this distance. However, the MITP mode provides better value of BER & Q factor against MATP before the distance of 2 km.

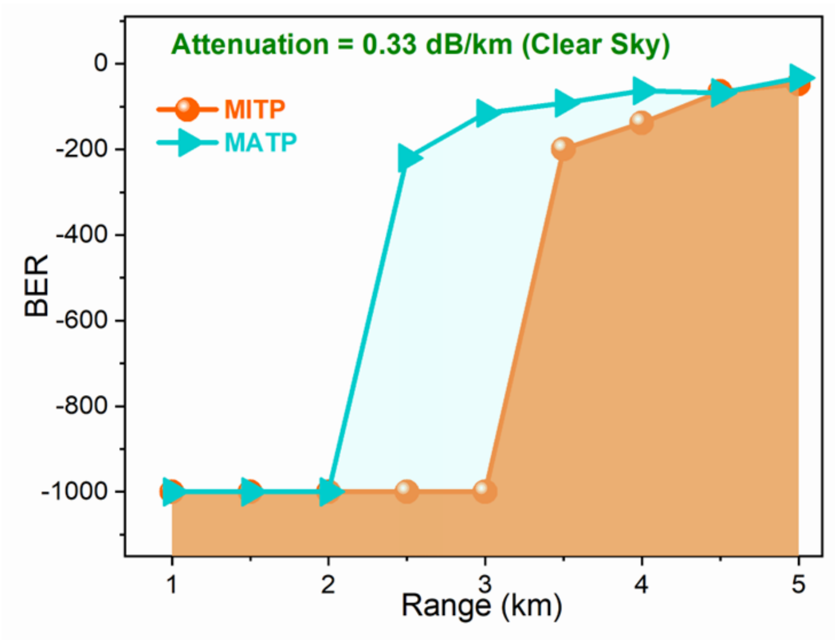

Fig 3: Range vs. BER for MATP & MITP under clear sky

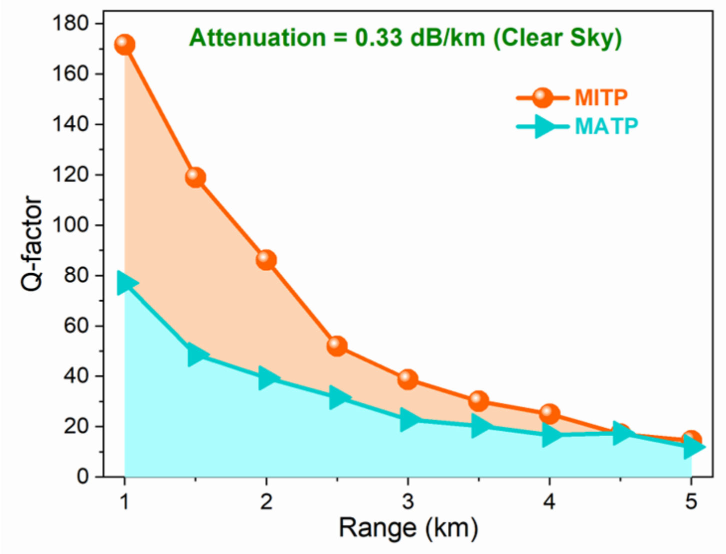

Fig 4: Range vs. Q factor for MATP & MITP under clear sky

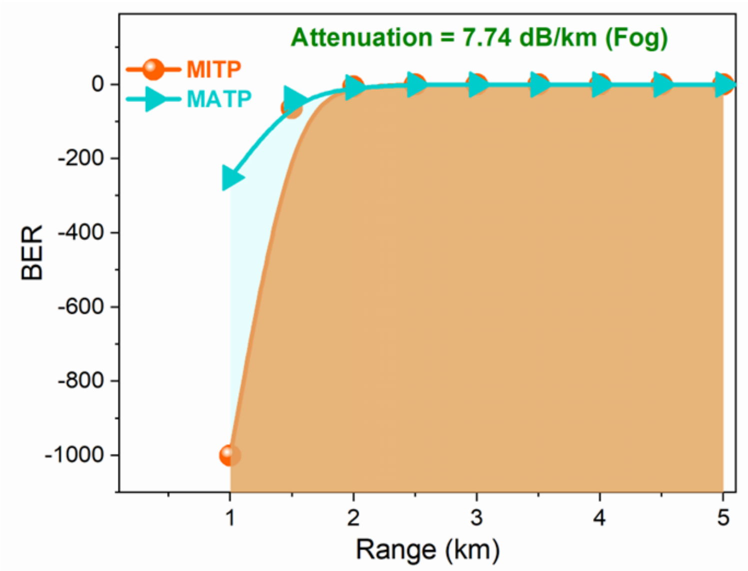

Fig 5: Range vs. BER for MATP & MITP under Fog

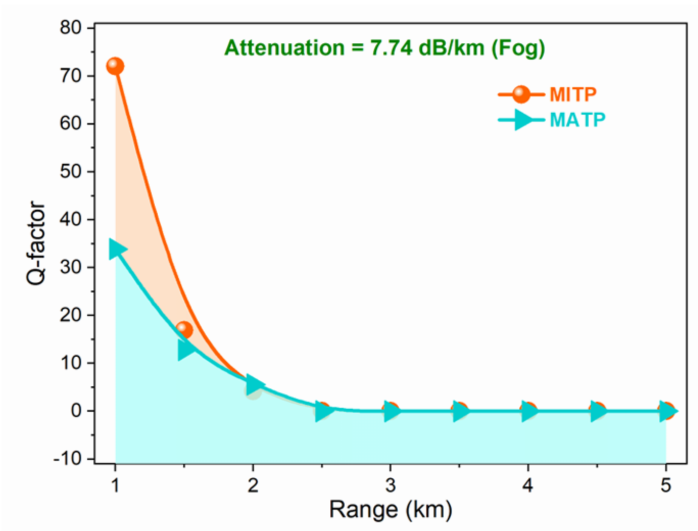

Fig 6: Range vs. Q factor for MATP & MITP under Fog

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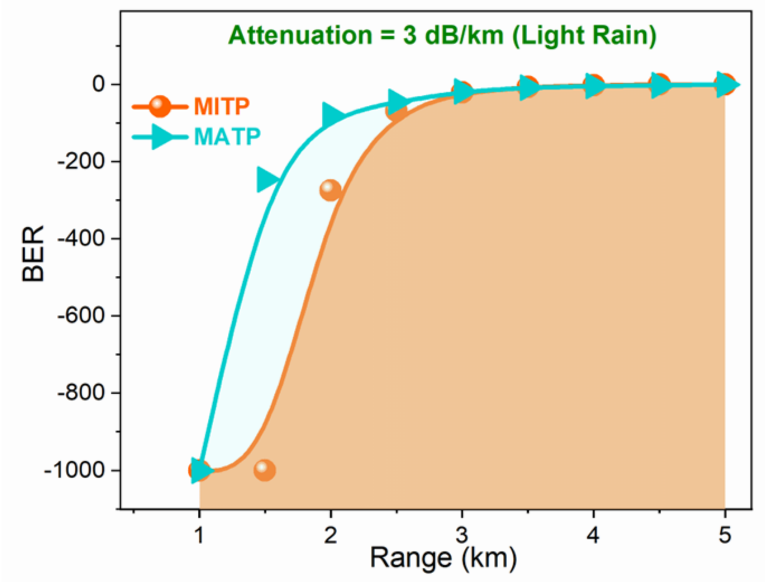


Fig 7: Range vs. BER for MATP & MITP under Light Rain

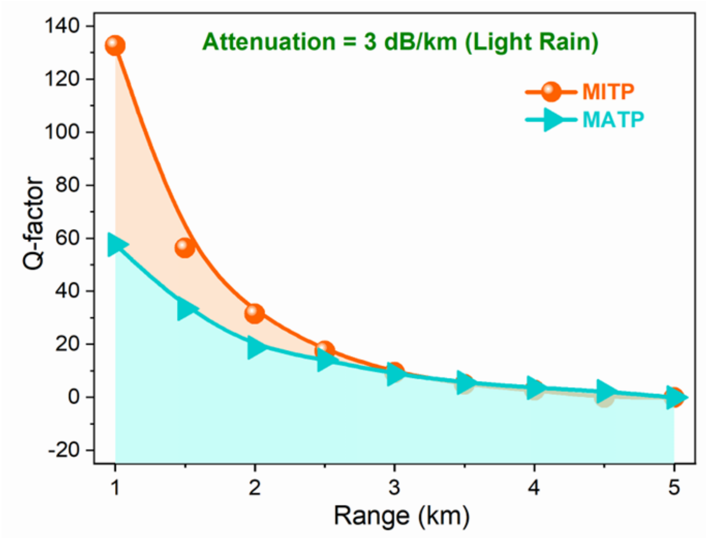


Fig 8: Range vs. Q factor for MATP & MITP under Light Rain

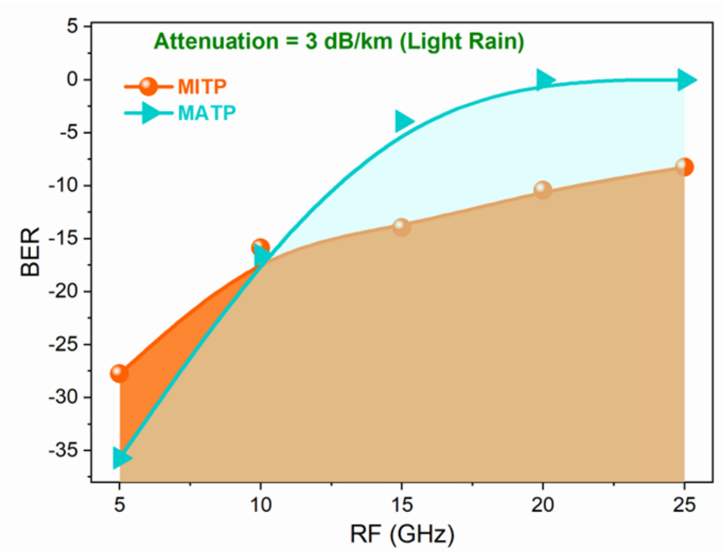


Fig 9: RF signal vs. BER for MATP & MITP under Light Rain

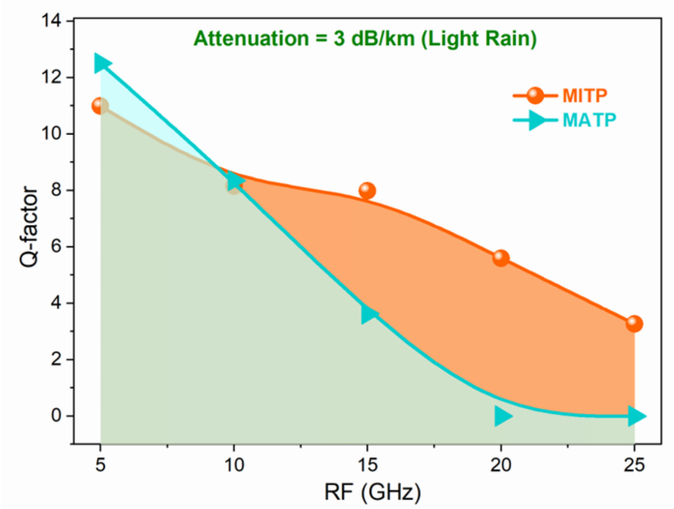
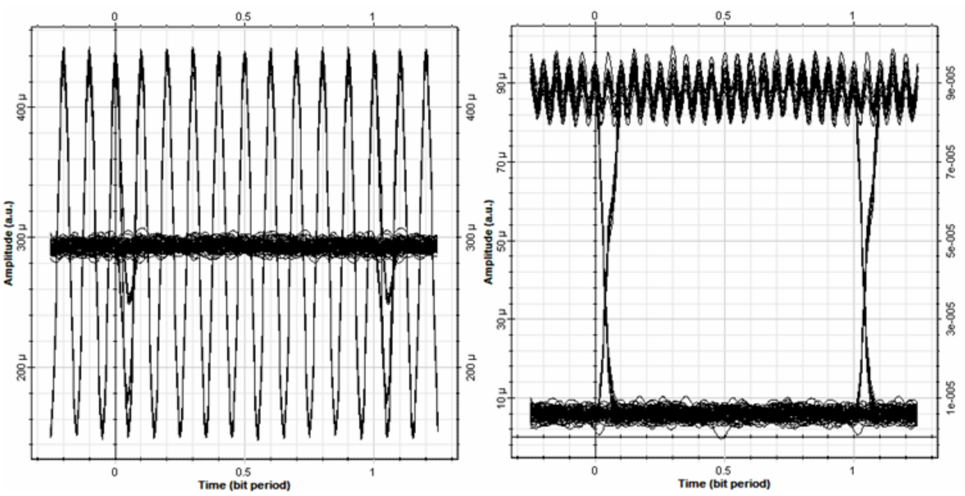


Fig 10: RF signal vs. Q factor for MATP & MITP under Light Rain

Figure 7& 8 show the system performance under light rain scenario in terms of BER & Q factor respectively. It can be seen that quality of received signal is acceptable only upto range of 3km. Again, the measured BER & Q factor prior 3 km are better for MITP operation compared to MATP operation.

Further, the system performance is studied on the ground of RF signal variation which is presented in figure 9 & 10 for BER & Q factor respectively. The study is carried out under light rain environmental conditions. It is observed that as the RF signal is varied from 5 to 25 GHz, signal quality degrades. From the graphs it can be seen that MITP offers minimum Q factor of 6 at the RF signal of 20 GHz while the same value of Q factor is obtained around 12.5 GHz for MATP operation. Hence MITP mode provides improved performance over MATP at higher range of RF signals.The eye diagrams obtained at a distance of 2 km with RF signal of 10 GHz under light rain environment are presented in figure 11. These are in agreement with initials results reported that show enhanced performance under MITP over MATP. The eye opening is wide & clear for MITP operation compared to MATP operation.



(a) **(b)**

Fig 11: Eye diagram at 2km for (a) MITP (b) MATP

The improved performance of MITP against MATP may be attributed to the fact that MITP mitigates even order optical sidebands, residual carriers, and enables efficient, high-frequency signal generation compared to MATP. In addition, MITP bias point limits nonlinearities and supports generation of discrete high-frequency signals without excessive distortions leading to signal transmission at high data rates for next generation optical networks.

Comparison with existing literature:

Following table presents a summary of previous major contributions regarding utilization of DDMZM for FSO networks. The DDMZM is utilized majorly for RoF networks or RoF/FSO integrated links. The proposed network examines DDMZM for dedicated FSO network only which reveals that DDMZM offers better performance at MITP especially at higher RF signals making it suitable to provide 5G data rate connectivity till last mile.

Table 2: Brief overview of major contributions with respect to proposed network

Sr. No.	Reference	Nature of Network	Outcome
1	"(Yunhao, 2015)"	Full duplex RoF system	Self interference cancellation feature in the RF band of 25 GHz.
2	"(Kumar & Tyagi, 2021)"	RoF system	Suppresses 3rd order intermodulation distortions (IMD3) significantly by 22 dB
3	"(Tripathi et.al, 2022)"	Integrated RoF/FSO network	DDMZM utilised to generate 60 GHz mm Wave to transmit Radio signals over FSO links
4	"(Atta, 2023)"	Integrated RoF/FSO network	Restricted power penalty within 2.5 dB for 2.5 km range of FSO link backed by RoF network.
5	***Proposed Network***	***Standalone FSO Network***	***DDMZM operation at MITP & MATP presented that reported enhanced performance in MITP mode at higher RF signal around 25 GHz for 5G applications.***

IV. Conclusion:

The DDMZM is extensively used in RoF based networks and RoF/FSO integrated networks for high frequency generation & transmission. In this paper, aDDMZM assisted dedicated standaloneFSO network is examined at MITP & MATP to transport RF signals from 10 GHz to 25 GHz. It is revealed that both MITP & MATP operation provide almost similar values of BER and Q factor when utilized for low range of RF signals over the distance of 5 km. However, MITP provides somewhat better values of BER & Q factor with different environmental conditions. Further, it is reported that when driven with high RF signals ranging upto 25 GHz, MITP operation acceptable BER of 10^{-9} till 20 GHz as compared to 12.5 GHz for MATP at a given distance of 3 km under light rain environment. Hence, it is concluded that DDMZM driven at MITP augments the FSO performance while transmitting higher RF signals for last mile connectivity.

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References

[1]. Garg, D. And Nain, A., Next Generation Optical Wireless Communication: A Comprehensive Review, Journal OfOptical Communications, Pp. 000010151520200254, 2021,DOI: Https://Doi.Org/10.1515/Joc-2020-0254.

[2]. Kazaura, K., Wakamori K., Matsumoto M., Higashino T., Tsukamoto K. And Komaki S., Rofso: A Universal Platform For Convergence Of Fiber And Free-Space Optical Communication Networks, IEEE Communications Magazine, Vol. 48(2), Pp. 130-137, 2010.

[3]. Kaur, K., Nain, A., Range Augmentation Of 16× 60 GhzWDM Rofso System In Foggy & Rainy Weather, Journal Of Optical Communication, 2023, DOI: Doi.Org/10.1515/Joc-2023-0316.

[4]. Kaur, K., Nain, A., Design OfAPrecise FSO Network Including Improved Modified Refractive Index Structure Profiling ForShimla City, India, Telecommunication AndRadio Engineering. Vol. 82(5), Pp. 59-71, 2023.

[5]. Kaur, K., Nain, A., An Improved Rofso Network Based OnMBMD Scheme Under Hazy Weather Conditions, Journal OfOptical Communications. Vol. 52(3), Pp. 630-644, 2022.

[6]. Saleh, MA., Abass, AK., Ali, MH., Enhancing Performance Of WDM-Rofso Communication System Utilizing Dual Channel Technique For 5G Applications, Optical AndQuantum Electronics, Vol. 54(8), Pp. 497-508, 2022.

[7]. Singh, M., Pottoo, SN., Suvidhi, Soi V., Grover, A., Ali, MH., A High-Speed Radio Over Free Space Optics Transmission Link Under Dust Environment Conditions Employing Hybrid Wavelength-And Mode-Division Multiplexing, Wireless Networks, Vol. 27(7), Pp. 4875-4888, 2021.

[8]. Naila, C. B., Wakamori, K., Matsumoto, M., Bekkali, A. And Tsukamoto, K., Transmission Analysis Of Digital TV Signals Over ARadio-On-FSO Channel, IEEE Communications Magazine, Vol. 50(8), Pp. 1509-1518, 2012.

[9]. Varotsos, GK., Nistazaki, HE., Tombras, GS., OFDM RofsoLinks WithRelays Over Turbulence Channels AndNonzero Boresight Pointing Errors, JournalOfCommunication, Vol. 12(12), Pp. 644-660, 2016.

[10]. Higashino, T., Tsukamoto, K., Komaki, S., Kazaura, K., Wakamori, K. And Matsumoto, M., A Demonstrative Link Design OfROFSO And Its Optimum Performance — Indoor Short Range Experiment AndA New Model Of Optical Scintillation, 2009 ITU-T Kaleidoscope: Innovations ForDigital Inclusions, Mar Del Plata, Argentina, 978-1-4244-6051-9/11/, 2009.

[11]. Zhang, Y. Et.Al, Self-Interference Cancellation Using Dual-Drive Mach-Zehnder Modulator For In-Band Full Duplex Radio-Over-Fiber System, Optics Express, Vol. 23(26), Pp. 33205-33213, 2015.

[12]. Kumar, P., Tyagi, N., Performance Evaluation OfDual Drive Dual Parallel Mach Zehnder Modulator Based Radio Over Fiber Link ForWireless Networks, International Conference OnSignal Processing AndCommunication, 978-1-6654-2739-5, DOI: 10.1109/ICSC53193.2021.9673209, Pp. 100-105, 2021.

[13]. Tripathi, A., Gupta, S., Mandloi, A. &Soni, G., Optically Assisted Mm-Wave-Based Multi-Gbps Rofso Transmission Link Under Channel Fading Models, Journal OfModern Optics, DOI: 10.1080/09500340.2022.2041754, Pp. 1-8, 2022.

[14]. Atta, R., Sarkar, N., Dutta, B. &Patra, A., A 40-Gbps Fiber-FSO Convergent Transmission System Employing OFCL-Based WDM And External Modulation Technique Results In Optics, Vol. 11, DOI: Doi.Org/10.1016/J.Rio.2023.100421, Pp. 1-5, 2023.