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HYBRID MODE-WAVELENGTH DIVISION MULTIPLEXING BASED OFDM-RO-FSO LINK

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ABSTRACT. Modeling and simulative numerical investigation of a high-speed radio-over-free space optics (Ro-FSO) link incorporating orthogonal frequency division multiplexing (OFDM) technique has been proposed in this work. Hybrid wavelength division multiplexing (WDM) and mode division multiplexing (MDM) have been used to enhance the information transmission capacity of the proposed link. Further the transmission range is being improved using Square root module (SRm). The recital exploration of the anticipated link is investigated under heavy fog weather. Four wavelength channels with 1 nm channel spacing (850nm, 851nm, 852nm, and 853nm) with each channel using four distinct spatial laser modes each carrying 20 Gbit/s-40 GHz data are successfully transported at a transmission range of 3500 m using the proposed Ro-FSO link.

1. INTRODUCTION

Optical networks are considered as the backbone for modern data transmission systems [1]. Radio-over-free space optics is competent enough to transmit multiple RF information signals by using an optically modulated carrier signal without the requirement of spectrum licensing and expensive laying of optical

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fiber cables. Ro-FSO is a cost-efficient technology which is capable of transporting high-speed information and is deployed for a variety of applications including military applications, deep-space transmission links, and inter-vehicular links [2]. Ro-FSO links provide high-bandwidth information transmission links with secure transmission and immunity to RF and electromagnetic interference. Ro-FSO links can be deployed easily and quickly and are capable of providing last mile access in remote areas [3]. Orthogonal frequency division multiplexing (OFDM) uses multiple sub carriers that carry high speed information. The orthogonality of the sub-carriers minimizes inter-carrier interference, alleviates multipath fading effects, provides high-speed links and improves the power efficiency of the system. Wavelength division multiplexing (WDM) in Ro-FSO links has been reported by researchers to maximize the information transmission rate of the system. Apart from WDM, (MDM) technique uses different Eigenmodes of a laser produced by optical signal processing techniques and spatial modulators (SLM's) to transfer high-capacity information. While much work has been reported on the performance of MDM based Ro-FSO links [1–6], this work proposes designing and performance investigation of a high-speed OFDM-Ro-FSO link incorporating WDM of four distinct wavelength channels with each channel using four distinct spatial laser modes each carrying 20Gbit/s-40GHz information, thus making a total of 16 channels with a net capacity of 320Gbit/s-640GHz. Also, an improved detection technique has been deployed at the receiving unit to enhance the transmission range. The performance of the proposed link is investigated under heavy fog weather. The main motivation behind this work is to design a long-reach high-capacity Ro-FSO transmission link to reliably transmit information under the effect of adverse weather conditions. Section 2 presents the schematic design of the proposed OFDM-Ro-FSO link. The simulative investigation outcomes are described in Section 3. Section 4 concludes the proposed work.

2. Simulation design and parameters

The proposed high-speed Ro-FSO transmission link using hybrid WDM-MDM-OFDM technique is elucidated in Figure 1.

Four channels (850 nm - 853 nm) with 1 nm channel spacing are transmitted in the proposed link as shown in Figure 1. Each channel has four sub-channels

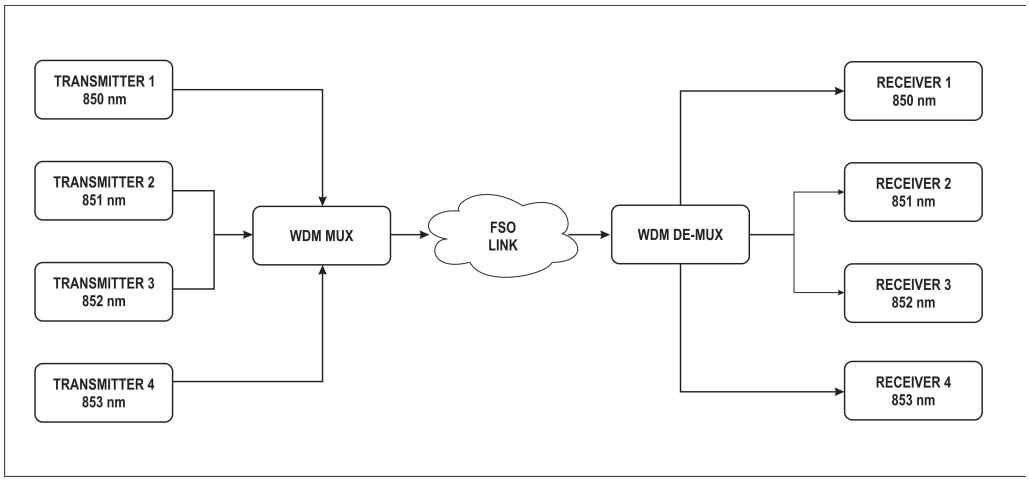

FIGURE 1. Proposed hybrid WDM-MDM-OFDM based Ro-FSO transmission link

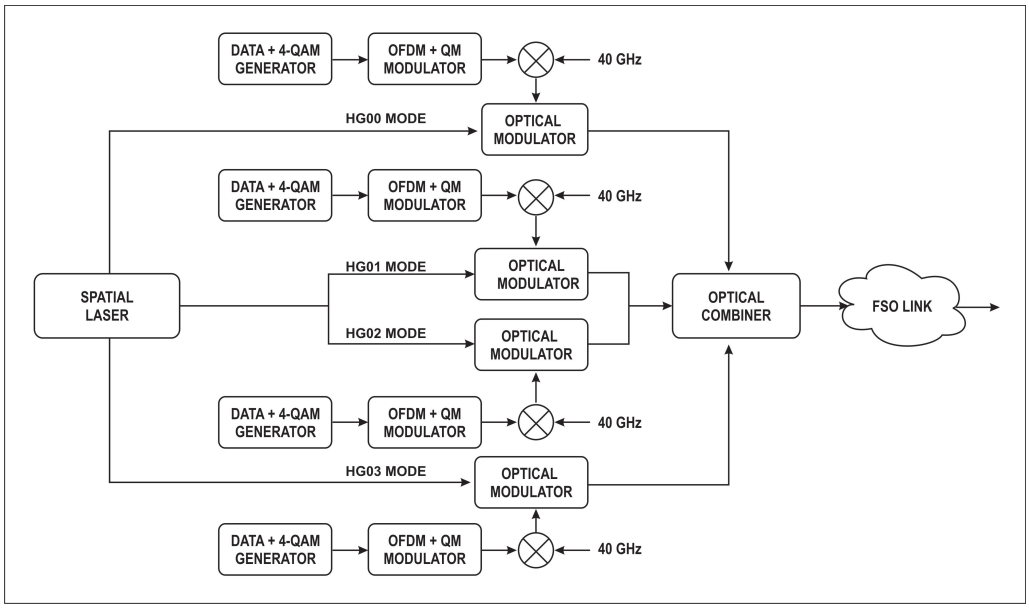

FIGURE 2. Schematic of the transmitter section of each sub-channel in the proposed link

where each sub-channel is transmitted using a distinct Hermite Gaussian (HG) mode. In the proposed work, a spatial laser with 10 dBm transmission power is used to generate distinct spatial modes. In each sub-channel, a 4-quadrature amplitude modulator (QAM) is used to generate 20 Gbit/s information, which is then OFDM modulated over 512 orthogonal sub-carriers having 32 cyclic prefix

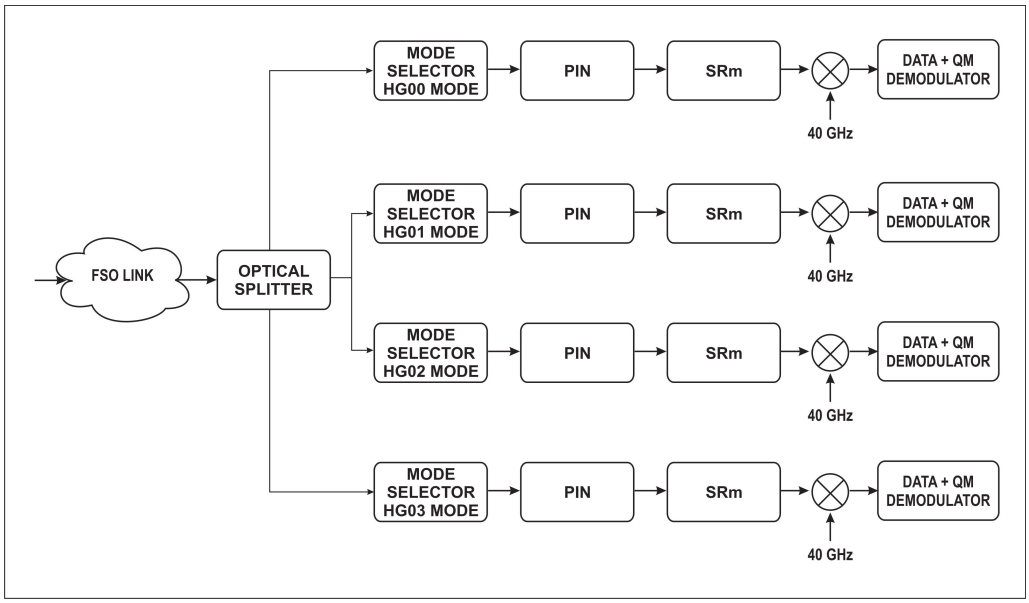

FIGURE 3. Schematic of the receiver section of each sub-channel in the proposed link

value. Further, the OFDM modulated signal is then IQ modulated at 7.5 GHz by a quadrature modulator (QM). A 40 GHz radio signal is added to this signal using a mixer. Each of the 20Gbit/s-40GHz signals is optically modulated using a LiNbO3 mach zehnder modulator derived by a 10 dBm spatial laser. These signals are then multiplexed using a WDM multiplexer (MUX) and then transmitted over free space as shown in Figure 2. Simulation parameters are taken as per practical FSO link as mentioned in [1–6]. The received optical signal is separated using a De-multiplexer (DEMUX). Distinct modes are separated using a mode selector. The signal from the output of the mode selector is then converted into an electric signal using a photo-diode. An OFDM demodulator and a QM decoder are used to retrieve the original information signal transmitted as shown in Figure 3.

3. SIMULATIVE INVESTIGATION OUTCOMES OF THE PROPOSED LINK

The simulation of the proposed link with and without SRm to emphasize the merits of using SRm has been demonstrated in this section. Figure 4 and Figure 5 show the SNR and received power plots for channel 1 (850 nm and HG00 mode) measured at the receiver terminal with respect to increasing transmission

range under heavy fog weather. The results demonstrate an improvement of 41 dB in SNR and received power at 2000 m transmission range by using SRm in the proposed link which validates the use of SRm to extend the transmission range under adverse environment surroundings.

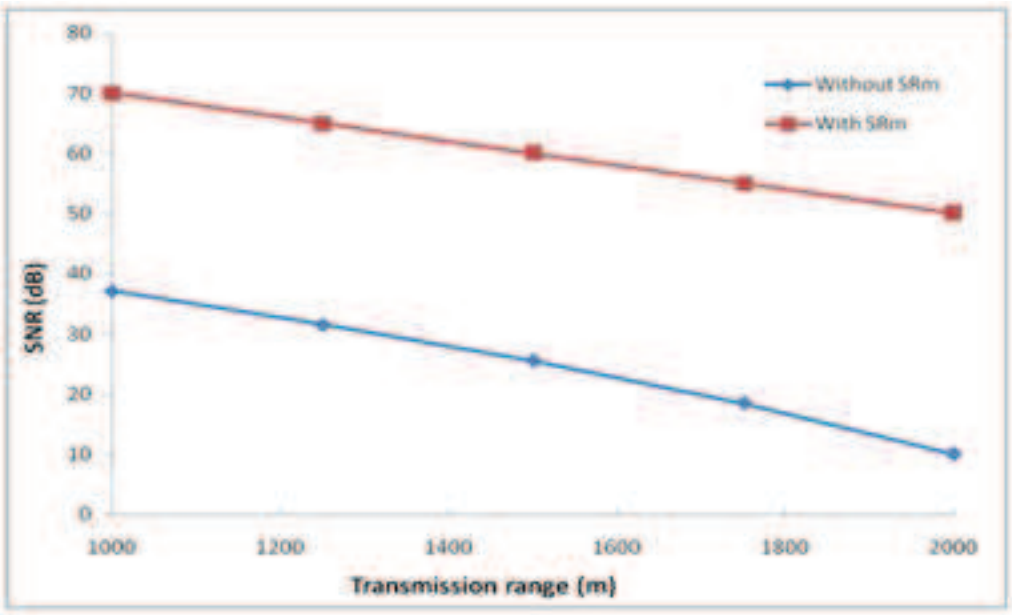

FIGURE 4. Measured SNR vs Transmission range with and without SRm

The result in Figure 6 exhibits that the SNR of the information signal intercepted at the receiving unit is calculated as 21.46 dB for HG00 mode, 18.66 dB for HG01 mode, 14.17 dB for HG02 mode, and 9.58 dB for HG03 mode at 3500 m transmission range. Alternatively, the received power of the intercepted information signal at the receiving unit is calculated as -66.33 dBm for HG00 mode, -69.03 dBm for HG01 mode, -73.02 dBm for HG02 mode, and -76.47 dBm for HG03 mode at 3500 m transmission range is shown in Figure 7. The results presented in Figure 6 and Figure 7 demonstrate faithful transportation of the information at 3500 m transmission range over heavy fog weather using the proposed link.

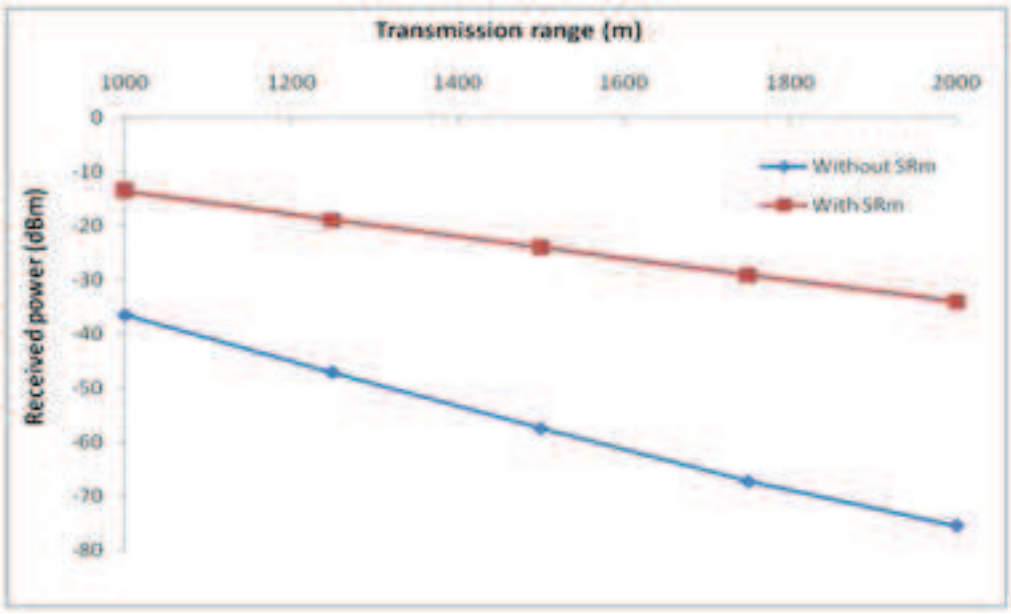

FIGURE 5. Measured Received Power vs Transmission range with and without SRm

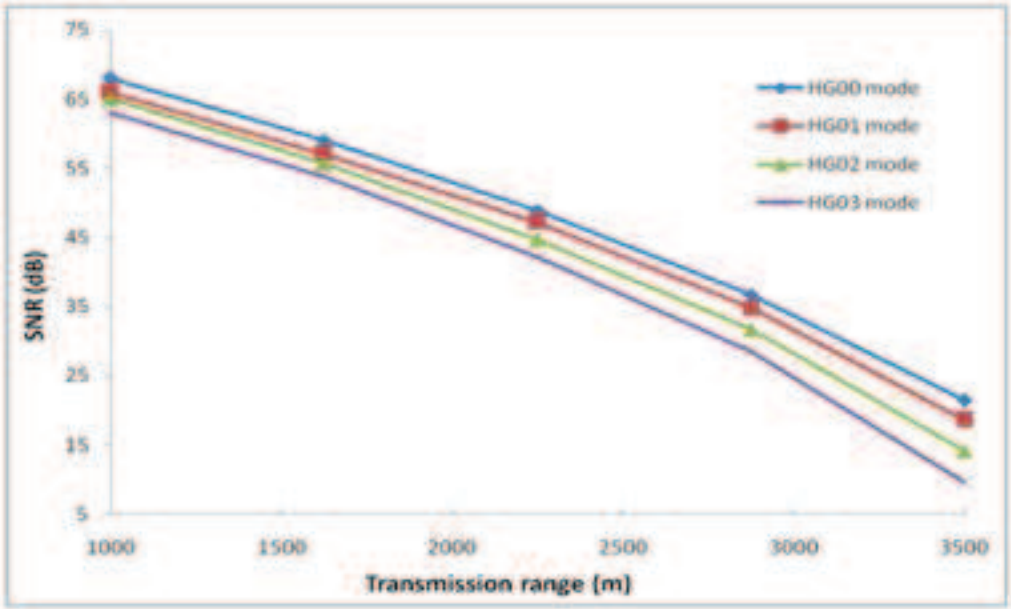

FIGURE 6. Calculated SNR vs Transmission range

4. CONCLUSION

This work proposes the designing of a 4X4X20 Gbit/s-40 GHz WDM-MDM based OFDM-Ro-FSO transmission link in which each channel carrying 20 Gbit/s-40 GHz data is transmitted using distinct Hermite Gaussian mode. The system

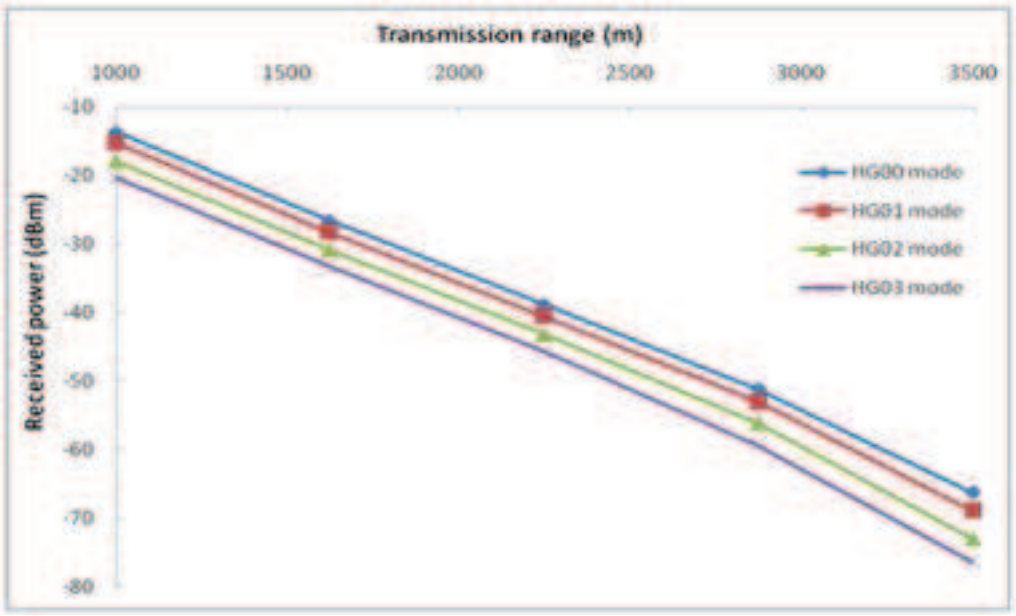

FIGURE 7. Calculated Received Power vs Transmission range

performance is investigated under heavy fog weather by using SRm. The Simulation results of the anticipated link demonstrate flourishing transportation of 320 Gbit/s-640 GHz information over 3500 m transmission range. The anticipated link can be used for transmitting high-powered signals reliably over long distance under the influence of adverse weather.

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