# Modelling of OFDM-ODSB-FSO Transmission System under different Weather Conditions

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***Abstract*—Due to multipath fading, FSO channel can vary considerably according to different weather conditions. A novel design of fading resistant ODSB-FSO system using a simulated test-bed employing OFDM scheme is reported in this work to compute the FSO range with acceptable SNR and BER with the highest stream rate of 5 Gbps under the impact of hazing, fog and clear weather conditions. Simulations indicate that the hybrid OFDM-ODSB-FSO transmission system promises considerably improved free space link compared to traditional FSO systems under different weather conditions.**

***Index Terms*—Orthogonal Frequency Division Multiplexing (OFDM), Optical Double Side Band (ODSB), Free Space Optics (FSO)**

## I. INTRODUCTION

FSO is one of the most promising candidates for future broadband communications, offering high transmission rates far beyond possible by RF technology. FSO has the combined features of wireless and fiber optics. Many of the aspects of FSO are related to fiber optics with an important difference of transmission medium which is air/free space rather than the glass of the fiber-cable. Being in the era of ever-present connectivity, the requirement of high speed networks had put the pressure on wireless communication networks to increase both the transmission capacity and the coverage area. The recent trends for ultramodern broadband, interactive and multimedia services over wireless media in both mobile and fixed cellular networks are to reduce cell size to accommodate more users together with to operate in the millimeter wave (mm-wave) frequency bands to avoid spectral congestion in the lower frequency bands [1]. FSO is a significant building block for wide area space networks, supporting mobile users, high speed data services for small satellite terminals and serving as a backbone network for high speed trunking [2]. However, FSO is exceptionally expensive preventing it from replacing the current wireless networks. By incorporating of coherent systems in links where coherent processing helps in reducing the system-cost [3]. FSO technology is implemented using a laser device which can be mounted on rooftops, corners of buildings or even inside offices and basically consist of an optical transceiver with a laser transmitter and receiver to provide full duplex capability. The architecture of FSO system can be point to point, mesh or point to multipoint. Low-power infrared beams, which does not harm the eyes, is the other mean by which FSO systems can transmit data through the air between transceivers, or link heads over distances of several hundred meters to a few kilometers, depending upon atmospheric conditions [4]. However, FSO channels offer more demanding state of affairs for signals than typical RF channels, making system accessibility a critical issue. So, it is important to take several FSO system parameters into consideration such as internal- and external-parameters. Most significant external-parameters are rain, dust, snow, and fog/smog that deteriorate the transmission path and shut down the network. The conditions become more severe with multipath fading. These environmental changes are inevitable and must be considered while designing a FSO system. In this work, a significant effort is made to probe the impact of these environment conditions by designing a high-speed and long-reach FSO system free from the impact of multipath fading by introducing OFDM scheme. Demonstrations of integrated OFDM-RoF systems have been reported in the previous research work [5-15], but hybrid OFDM-ODSB-FSO system has not been demonstrated and investigated extensively under the impact of different weather conditions. In this paper, we have demonstrated, first time, a hybrid OFDM-ODSB-FSO transmission system using to compute an FSO range with acceptable SNR and BER under the impact of Hazing, Fog and clear weather conditions. This paper is organized as follows; in section 2, we provide a brief introduction of the proposed hybrid OFDM-FSO transmission system, in section 3, we present and discuss the results obtained, and finally our conclusions and remarks are presented in section 4.

## II. MODEL DESCRIPTION

The FSO system is not much different from fiber optic communication where the difference relies in the propagation medium. In the OPTISYSTEMTM software, the FSO link is modeled under different weather conditions between an optical transmitter and optical receiver with 15cm aperture at each end. The transmitter and receiver gains are 0dB by assuming both the antennas ideal. Also, scintillation and mispointing losses are not considered in this simulative work. A CW laser diode of 1550nm of line-width of 10MHz with power of 0dBm is used in our proposed hybrid system. Due to multipath fading, FSO channel can vary considerably according to channel conditions and different weather conditions such as clear-, foggy- and hazy-channel conditions. The change in channel conditions can occur gradually as in the case of a clear, low fog, mild fog, heavy fog, low haze, mild haze and heavy haze conditions. In order to maximize channel

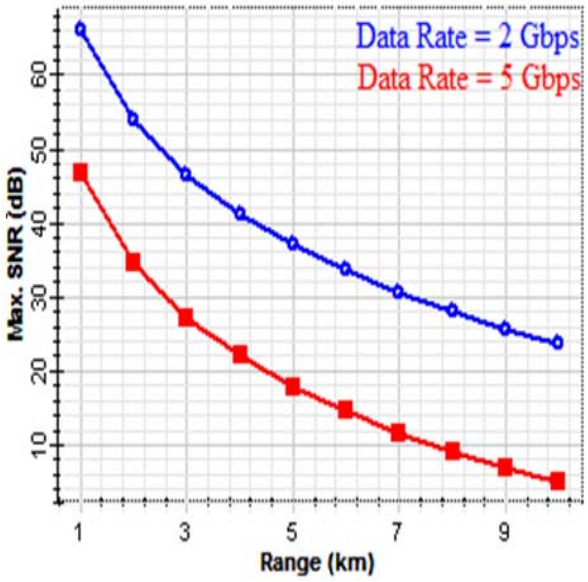
978-0-7695-4941-5/13 $26.00 © 2013 IEEE
DOI 10.1109/ACCT.2013.37

throughput and provide continuous communications, a modulation scheme that can adapt to various channel conditions needs to be employed. For channel conditions exhibiting delay spreads in the microseconds, transmission rates are limited to the order of megabits; while for nanosecond delay spreads, transmission rates in the gigabit regime can be achieved. In conditions where channel availability and bandwidth vary randomly, complex adaptive schemes that follow channel variations can be adopted to maximize throughput, however this entails an increase in system complexity and requires a fast and reliable feedback channel which might not be available. A more viable approach is to employ a modulation scheme in which the fading problem can be overcome creating a multi-carrier communication scenario. This is achieved by using OFDM technology. At transmitting end, a highest stream rate of 5 Gbps data is generated by using a 4 QAM sequence generator with 2 bit per symbol. This 5Gbps QAM data signals are then OFDM modulated by means of OFDM modulator using 512 subcarriers and FFT size of 1024 to generate OFDM analog data signals which, further, QAM modulated at 7.5GHz modulator frequency. This high rate OFDM analog data signals are then transmitted over FSO link by means of ODSB scheme via DEMZM modulator. At the base station, the RF signal is retrieved using PIN photo detector. The receiving end of the FSO system consists of a photo-detector and a low pass filter to recover high rate OFDM data successfully.

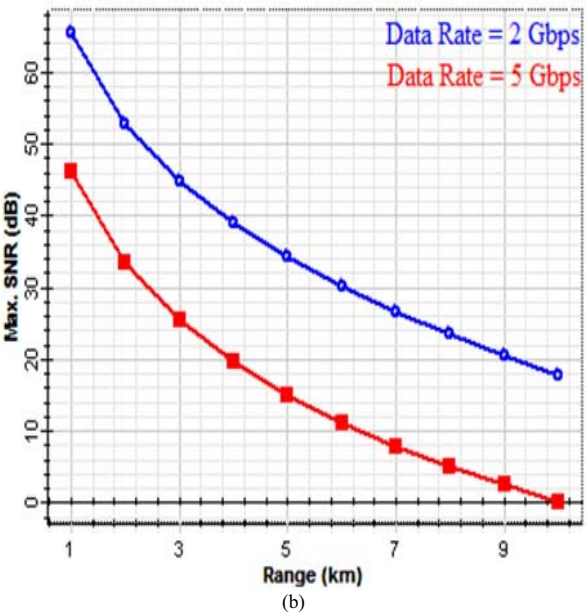
## III. RESULT & DISCUSSION

We have evaluated the system performance using a simulated test-bed, employing OFDM modulated signals transmitted through FSO link using ODSB scheme under different weather conditions with the highest stream rate of 5 Gbps. The threshold for acceptable operation was set at a bit error rate (BER) of 10-4 with an acceptable bound of 20 dB on the SNR. As shown in Fig. 1-4, OFDM-ODSB-FSO fails to operate beyond FSO link of 10 Km under clear weather conditions with attenuation of 0.155dB/Km at 2Gbps and is limited to FSO link of 4 Km at 5Gbps, as the channel induced inter-symbol interference bounds the acceptable BER to10-4. Under mild clear weather conditions with attenuation of 0.441dB/Km, the FSO link is limited to 9 Km at 2Gbps and to 3.8 Km at 5Gbps with acceptable BER to10-4.

The proposed system fails to achieve an acceptable performance for low haze condition beyond 1.25Km at 2 Gbps, while the 5 Gbps stream fails beyond FSO link of 750 meter. Similarly, the 2 Gbps and 5 Gbps stream are resilient to channels for mild haze condition with FSO link up to 750 meter and 500 meter respectively. In order to assure continued communications for heavy haze condition, the 2 Gbps and 5 Gbps stream are resilient to channels with FSO link up to 350 meter and 250 meter respectively. The proposed system is also investigated at different levels of Fog. It has been observed that the proposed hybrid FSO system fails to achieve an acceptable performance for low Fog condition beyond 1.40Km at 2 Gbps, while the 5 Gbps stream fails beyond FSO link of 900 meter. Similarly, the 2 Gbps and 5 Gbps streams are resilient to channels for mild and heavy fog conditions with FSO link up to 750 meter and 500 meter respectively in order to assure continued communications. Thus, continuity in communications is achieved throughout various channel conditions with acceptable BER by employing OFDM scheme at high transmission stream to realize ALWAYS ON COMMUNICATION for FSO communication system. Overall, a higher average bit rate is achieved, in addition to an increased level of data streams and prolonged FSO links by maintaining the simplicity of the system designing and design cost throughout the most channel condition.

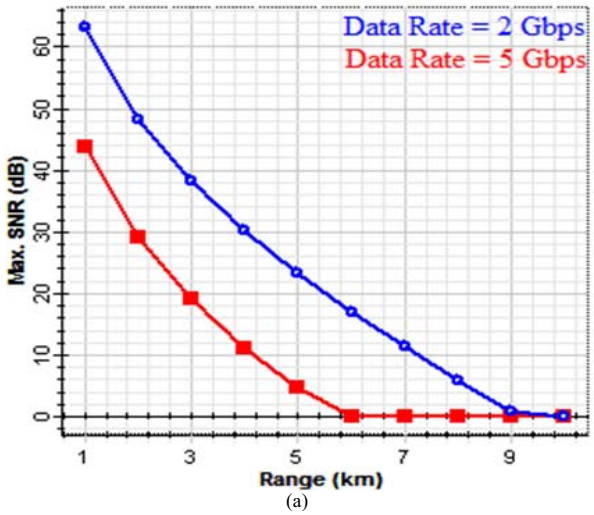


(a)

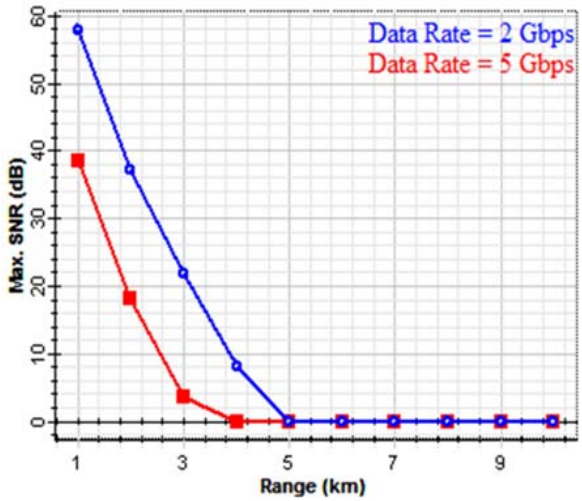


(b)

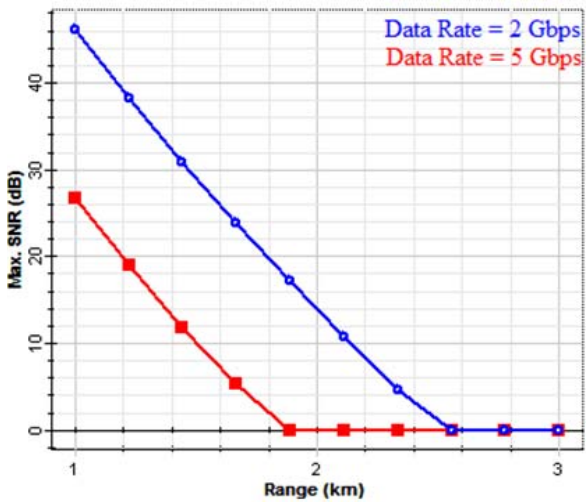
Fig.1 Evaluation of SNR of OFDM-ODSB-FSO system under clear weather conditions (a) 0.155 dB/km and (b) 0.441 dB/km




(a)

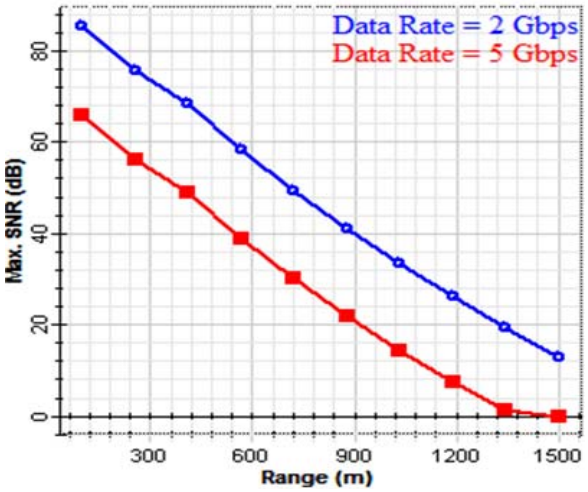



(b)

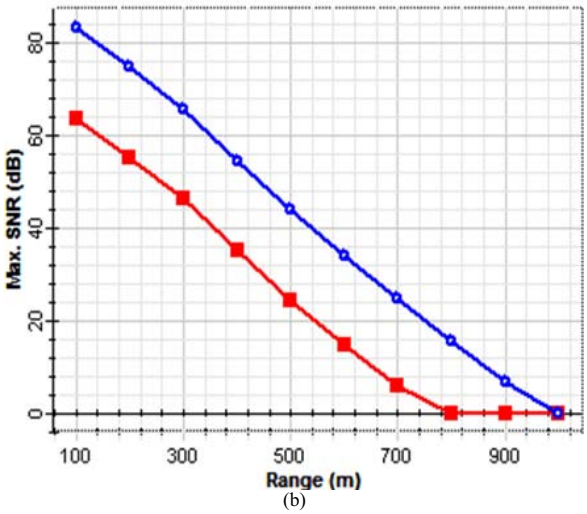



(c)

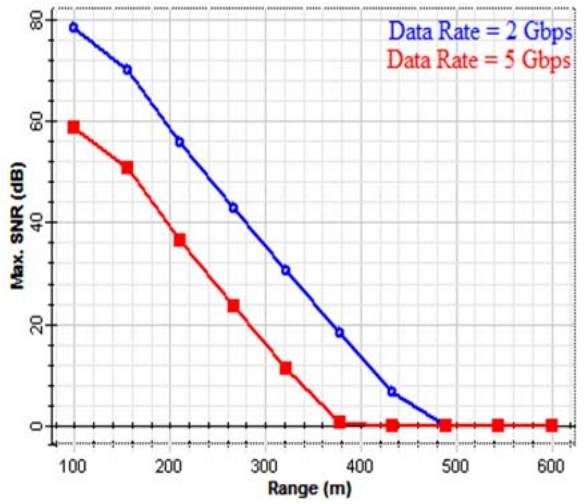
Fig.2 Evaluation of SNR of OFDM-ODSB-FSO system under different Haze conditions (a) Low Haze; 1.537 dB/km (b) Mild Haze; 4.285 dB/km (c) Heavy Haze; 10.115 dB/km




(a)

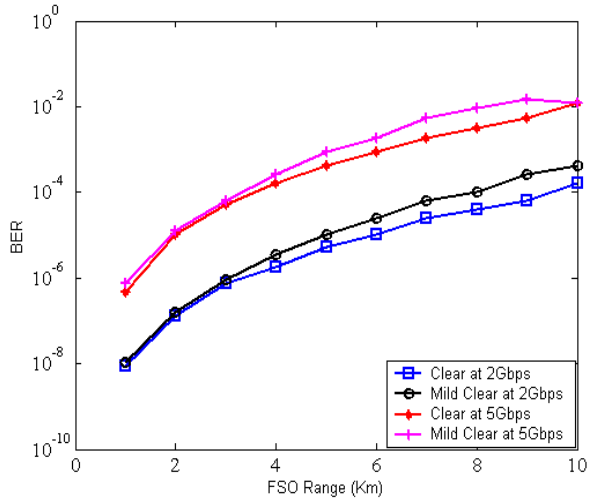



(b)

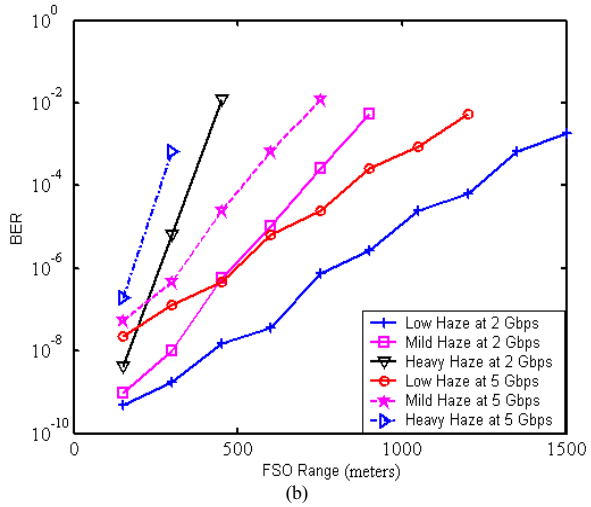



(c)

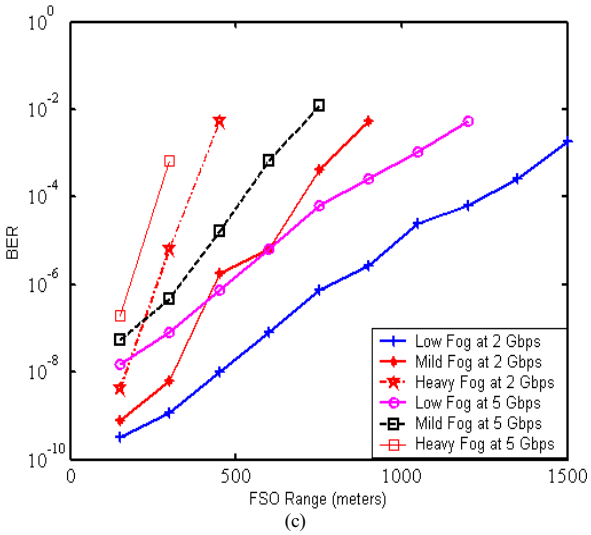
Fig.3 Evaluation of SNR of OFDM-ODSB-FSO system under different Fog conditions (a) Low Fog ; 15.55 dB/km (b) Mild Fog; 33.961 dB/km (c) Heavy Fog; 84.904dB/km




(a)




(b)




(c)

Fig.4 Evaluation of BER of hybrid OFDM-ODSB-FSO system under (a) Clear weather conditions (b) Haze, and (c) Fog

## IV. Conclusion

We introduced a multipath fading resistant FSO communication system architecture and investigated under different weather conditions through the use of OFDM multicarrier scheme. The proposed system offers increased resilience to channel conditions, as a gradual degradation in system performance with an increase in transmission rate under worst weather conditions like haze and fog. A higher average bit rate is achieved, in addition to an increased FSO link in a high speed hybrid OFDM-ODSB-FSO system.

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