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Research Article

DESIGN AND IMPLEMENTATION OF MIMO FREE SPACE OPTICALCOMMUNICATION SYSTEM FOR ENHANCED PERFORMANCE

Deepika. J[1] and Ramajeyam. R[2]
Department of Electronics and Communication Engineering, A.R.J College OfEngineering and Technology, Thiruvarur Dist, Mannargudi
**Author for Correspondence: ramajeyambalasubramaniyan@gmail.com*

ABSTRACT
Communication plays an integral role in enhanced performance. All conventional methods of communication including telephone, radio, and television could be down during disaster. Therefore, it is crucially important to have completely functional communication. In this project, the concept of Free Space Optical Communication (FSOC) is introduced, which is one of the most promising wireless communication techniques. FSOC enables us to offer extremely large capacity, high-immunity to interference, low latency, low-energy consumption, large data rate of transmission, reliable and secure communication. Besides all these, FSO faces challenges during transmission due to atmospheric turbulence like rain, fog, snow, cyclones, earthquake etc. Diversity technique is used in this project to mitigate the fading effects due to the above-mentioned effects. This project proposed a novel method of MIMO-FSO techniques to improve the transmission capacity. The capacity of MIMO-FSO networks is increased using Polarization Division Multiplexing (PDM). In this project, the most suitable modulation techniques among OOK, BPSK, OFDM is identified using simulation experiment. Xilinx ISE 9.1i and MATLAB R2011 are used for the simulation. The overall performance of the FSOC system is evaluated using Bit Error Rate (BER), Power level at the receiver under various turbulence conditions.

Keywords*: Atmospheric Turbulence, polarization division multiplexing (PDM), Multiple Input-Multiple Output (MIMO), On-Off Keying (OOK), Binary Phase Shift Keying (BPSK), Orthogonal Frequency Division Multiplexing (OFDM).*

INTRODUCTION
FREE SPACE OPTICAL COMMUNICATION
Free Space Optical Communication (FSOC) is a wireless Line of Sight (LOS) optical communication technology that uses light for the transmission of information through air or vacuum. In FSOC, data is transmitted by propagation of light in free space. FSOC having the same capabilities as that of fiber optics, but at a lower cost and very high speed. Free Space Optical Communication works on the principle of laser source driven technology which uses light sources at transmitter end and detector at receiver end to transmit and receive information, through the atmosphere. FSOC links have some distinct advantages over conventional Microwave, Radio Frequency and Optical Fiber Communication System by virtue of their veryhigh carrier frequencies that permit large capacity, enhanced high security, high data rate and so on respectively. FSOC systems are being considered for military systems application, because of their inherent benefits as normally most of the systems are rated for greater than one kilometer in three or more lasers operating in sequence parallel to mitigate distance related issues. The reliability of FSOC units has always been a problem for commercial telecommunications. Consistently, studies find too many dropped packets and signal errors over small ranges (400 to 500 meters). Military based studies consistently produce longer estimates for reliability, projecting the maximum range for terrestrial links is of the order of 2 to 3 km. All studies agree the stability and quality of the link is highly dependent on atmospheric factors such as rain, fog, dust and heat.

BASIC BUILDING BLOCKS OF FSOC

Block diagram as shown in Fig 1.1shows the essential parts of free space optical communication system. It has atransmitter, an atmospheric channel as medium and a receiver.

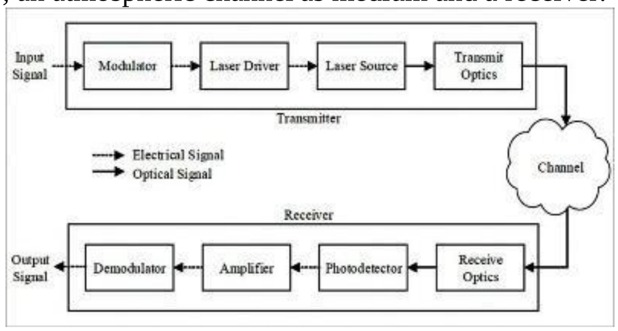

Fig. 1(a). Block Diagram of FSO System

Source generates the information that has to be communicated over the optical wireless system. The modulator, using different modulation techniques, modulates the data for transmission. The optical light source can be of two types- Light Emitting Diode (LED) or Laser Diode (LD). Laser is preferred because of the high pointedness and coherence that it's beam exhibits. The transmitter and receiver are configured to deliver and receive optical signals propagating in free space. Transmitter converts incoming electrical signal from driver circuit into optical form to be transmitted over the atmospheric channel. Atmospheric channel through which the optical beam passes encounters a lot of challenges. Thus the signal has to be properly modulated before transmission. Receiver side contains a photo detector which converts the received optical signal to electrical form.

FACTOR AFFECTING FSOC

As the medium for transmission in FSOC is free space, there are many challenges faced in implementing the free space optical system as shown in Fig 1.b They include atmospheric challenges due to changes in various weather conditions as well as many others. Atmospheric turbulence results in intensity fluctuations and degradation of the optical beam.

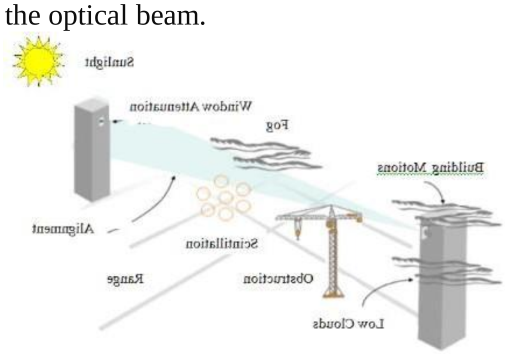

Fig .1(b). Challenges in Atmospheric Channel

For terrestrial applications, the principal limiting factors are:

- Fog (10 to ~100 dB/km attenuation)
- Rain
- Snow
- Atmospheric absorption
- Optical turbulence

- ✓ Beam wandering or beam dancing
- ✓ Beam scintillation
- ✓ Waveform aberration

The factors affecting the propagation of FSOC system is summarized below:

FOG: The highest attenuation in the transmitted signal is caused due to fog as it is mainly composed of small water droplets. The particles of fog are comparable to the wavelength of the optical beam. Its attenuation is from 40 to 70 dB/km for light fog and from 80 to 200 dB/km in heavy fog that is much higher when compared to the attenuation in clear weather which is in the range 0-2 dB/km. Table 1(a) shows the types of fogs and its attenuation in transmitted signal.

Table 1(a). Optical Attenuations Based on Visibility Range Estimate

DESCRIPTION	**RANGE**	**ATTENUATION (dB/km)**
Dense fog	40-70	250-143
Thick fog	70-250	143-40
Moderate fog	250-500	40-20
Light fog	500-1000	20-9.3

ATMOSPHERIC ABSORPTION: Energy in a laser beam is attenuated by both absorption and scattering effects due to natural atmospheric gases and aerosols. This can be greatly complicated by the addition of dust, smoke, precipitation and fog etc. Molecular absorption depends on the concentration of the absorbing gases, the ambient temperature and pressure, and the path length. Aerosol absorption depends on the particulate size distribution, number density, chemical composition, and path length.

RAIN: The attenuation and scattering of laser beams by rain, fog, and snow were calculated and measured at 0.63, 3.5, and 10.6. However, they found that the attenuation by rain decreases slowly from millimeter to visible wavelengths primarily because of strong forward scattering by raindrops in the visible region. While attenuation by fog can be much greater than that of rain.

SNOW : Snow refers to forms of ice crystals that precipitate from the atmosphere. The peak value of snow attenuations can vary depending upon the snowflake size and the snowfall rate. Generally the snowflake size is larger than the rain drop size which results in much deeper fades when compared with the corresponding fades dueto rain drops. Recent studies reported that a snowflake size can be as large as 20 mm and it can even completely block the optical signal if the beam width is smaller than the snowflake size.

CLOUDS: Cloud layer are main part of earth atmosphere. The formation of clouds is done by the condensation ordeposition of water asbove earth's surface. It can completely block the fraction of optical beam transmitted from earth to the space. The attenuation caused by clouds is difficult to calculate because of the diversity and in homogenity of the cloud particles.

NATURAL DISASTERS

FLOOD: Floods are one of the most common hazards in the United States. They occur when land that is normally dry experience an overflow of water. Several events cause flood, including hurricanes and tropical storms, failed dams or levees, flash foods that occur within a few minutes or hours of excessive rainfall.

EARTHQUAKES: An earthquake is the shifting of the Earth's plates, which results in a sudden shaking of the ground that can last for a few seconds to a few minutes. Within seconds, mild initial shaking can strengthen and become violent. Earthquakes happen without warning and can happen at any time of year. Certain states are more prone to higher frequency of earthquakes, particularly California, Hawaii, Nevada and Washington.
OPTICAL TURBULENCE: Refractive index fluctuations in the atmosphere lead to such propagation phenomena as beam spread, beam wander, and waveform aberration.
Beam wandering or beam dancing:
Beam wandering is defined as deviation of laser beam from its original path. The received beam focus moves in the image plane due to variation in the beam's angle of arrival as shown in Fig 1.c.

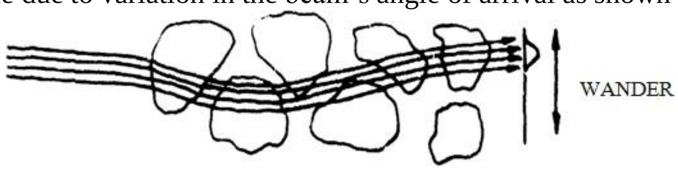

Fig. 1(c). Beam Wandering Due to Atmospheric Turbulence

Beam scintillate: Beam scintillation is defined as degradation of power or intensity of laser beam due to atmospheric turbulent parameters. Variation in the spatial power density at the receiver plane caused by small destructive interference within the optical beam.

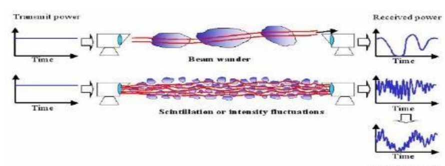

Fig. 1(d). Combined effect of beam wandering and scintillation

II. DESIGN OF PROPOSED MIMO-FSO SYSTEM

***MIMO-FSO SYSTEM*:** The performance of FSO system over Malaga fading channels has proved that effective fading mitigation techniques are required to satisfy the typical (BER) and capacity targets for FSO applications at the range of practical signal-to-noise ratios (SNRs). Wireless radio system use MIMO technique by deploying multiple aperture at the transmitter and the receiver, the FSO system performance can be significantly enhanced.
***MIMO*:** Multiple-Input and Multiple-Output (MIMO) is a method for multiplying the capacity of a radio link using multiple transmission and receiving antennas to exploit multipath propagation. The antennas at each end of the communications circuit are combined to minimize errors, optimize data speed and improve the capacity of radio transmissions by enabling data to travel over many signal paths at the same time.

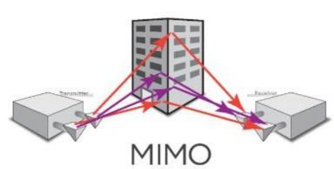

Fig: 2(a). General block diagram of MIMO

BLOCK DIAGRAM OF MIMO-FSOC USING PDM & DIVERSITY TECHNIQUES

Binary information are generated through PRBS using VHDL module which can fed random binary data to the laser transmitter and other is images which we want to send is loaded in Xilinx and transmitted via serial port. FPGA receive information and fed to the laser transmitter circuit. The laser transmitter circuit comprises the laser modulator and laser source. The modulation scheme (OOK, BPSK & OFDM) is employed to generate the modulated signal. The modulated signal is fed to the laser source which converts the electrical signals into optical signal. The optical signal is passed through the atmospheric channel. Receiver section contains photo detector, Equal Gain Combining (EGC), decision device, switching logic. The photo diode in photo detector is used to converts optical signal into electrical signal. There are two types of photodiode which is commonly used in optical communication. They are avalanche photo diode and pin photo diode. In equal gain combining diversity technique, N number of photo detectors in the receiver is realized. The electrical signals from N photo detector are unified and then demodulated. EGC (Equal Gain Combining) is used to combine the signals from multiple outputs ie. photodetector. A decision circuit, that measures the probable value of a signal element and makes an output signal decision based on the values of the input signal and a predetermined criteria. Finally, the switching function takes only the values '0' and '1'. The function of an electric switch is to regulate the current.

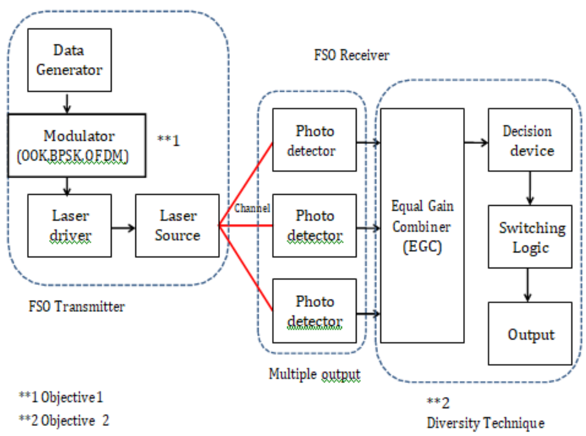

Fig.2(b). Block diagram of MIMO-FSOC

IV. FLOW CHART FOR PROPOSED SYSTEM

The flow chart of proposed various modulation technique (OOK, OFDM and BPSK) are given. Initialize all frequency and amplitude variables; switching function takes only these two variables ie. 0's and 1's. Input variable are 00,01and 10. Modulator select switch is used to select the input variable. If the mod_ sel switch ='00' then OOK(On-Off Keying) modulation is implemented. Based on OOK, the waveform is displayed. It's not satisfying this condition; the process goes for second condition. If the mod _ sel switch='01', then BPSK (Binary Phase Shift Keying) modulation is implemented. Based on BPSK, the waveform is displayed. If not satisfying second modulation, then the third condition '10' is process ie. OFDM modulation. It satisfies the input, then OFDM (Orthogonal Frequency Division Multiplexing) modulation is implemented and the output is displayed. The three condition are not satisfy, the loop will go back to the input clock and modulator select switch, then the process will execute again

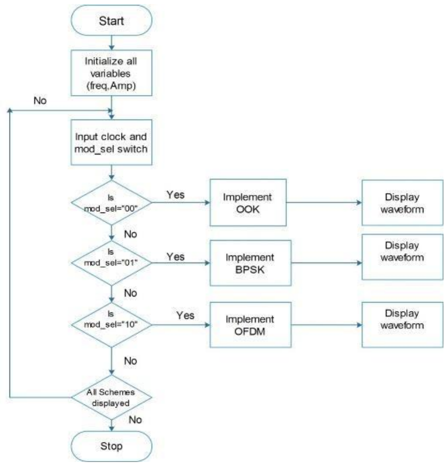

Fig. 4(a). Flowchart for proposed system

V. CONCLUSION

In this project, a novel method for disaster management using FSO with modulation scheme is proposed. This project implemented a method to improve the capacity of MIMO-FSO communication using diversity technique. In Existing system, FSO faces many challenges during transmitted data due to atmospheric turbulence. The proposed system overcomes the existing system by using suitable modulation techniques (OOK, OFDM and BPSK). Diversity technique is used to increase capacity and performance of the system. The application of the proposed system can be applicable on remote sensing area, military and etc., The system is analyzed for weather turbulence which can be applied for disaster management scenario. In future, the FPGA implementation of proposed system will be developed. Instead of (OOK, OFDM & BPSK) modulation we can used WDM-FSO based system are new approach to improve the system performance with high speed and longer distance. So, new technique can be designed by combination of these and by enhancing the system can be improved.

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