

# SPATIAL DIVERSITY TECHNIQUES IN MIMO WITH FREE SPACE OPTICAL COMMUNICATION

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## ABSTRACT

*In this paper we have described Multiple Input and Multiple Output (MIMO) with Free Space Optical (FSO) link using spatial diversity technique. Here we have used different combining techniques at the reception side to improve the overall system performance. Channel model used here is Gamma-Gamma model which can be used for high to low turbulence environment.*

**Keywords:** *Combining Techniques, MIMO, SISO.*

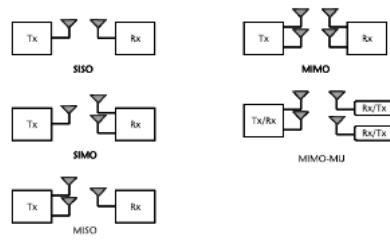
## I INTRODUCTION

In telecommunication, Free Space Optics [FSO] provides an optical communication technology which uses light energy to transmit the information from one point to another point. This technology is very useful where it is difficult to incorporate the optical fiber due to structure of the surface or due to maintenance. Like fiber, FSO uses lasers to transmit data, but through the open air instead of using closed fiber cable. FSO is capable of sending up to 1.25 Gbps of data, voice, and video communications simultaneously through the air [1]. Short Range line of sight optical links have the potential for providing high bandwidth access to larger wired network as well as they can be used to link intranets within the corporate campuses. FSO is attractive compared to RF due to several reasons. First, optical beams are very directive with beam width on the order of 10mrads so spatial isolation from other potential interferes is maintained. Secondly, there is no license is required for optical bandwidth. Third, it provides high level of security with data speed of upto 1.25 Gbps. Fourth its maintenance is low and can be installed behind the windows, so roof top is required [2]. Systems using Multiple Transmit and Multiple receive Antenna are known as Multiple Input and Multiple Output (MIMO) System. This wireless technique has greatly improved the capacity and range of wireless communication channel. MIMO systems constructively explores multipath propagation by using different transmission path to the receiver, which provides redundancy of data thus increases the reliability of transmission. This technique is also useful for increasing the transmitted data rate. MIMO system has attracted users significantly because it offers high speedreliable data range at the same power and bandwidth [3]. MIMO system can also be used for FSO system. As MIMO uses multiple transmit and receive antenna so at the transmitter several laser diode are used (as laser diodes convert electrical information into optical data stream) for transmitting the data and at the receiver several photo diodes are used to collect the transmitted information.

In this paper, we describe an optical wireless terrestrial link in which we have used the concept of MIMO with free space optical communication. Different combining schemes are used at the receiving side to evaluate the performance of link with 2x2 and 4x4 MIMO systems.

## II MIMO SYSTEM

MIMO system uses multiple transmitters and multiple receivers, which has been shown in Fig 1.



**Fig.1. Multiple Input and Multiple Output System in FSO**

### III CHANNEL MODEL

Optical Channel is affected by parameters like scattering and turbulence. Gamma-Gamma PDF closely models experimental results over low to high turbulence strengths and is most suitable for studying link performance parameters for slow fading conditions.

The irradiance of optical field is defined as the product of two random processes, i.e.  $I = I_x I_y$ , where  $I_x$  arises from large scale turbulent eddies and  $I_y$  from small-scale eddies. Specifically, gamma pdf is used to model both small-scale and large scale fluctuations, leading to the so-called gamma-gamma pdf, i.e. [4]

$$f(I) = \frac{2(\alpha\beta)^{\frac{(\alpha-\beta)/2}{\Gamma(\alpha)\Gamma(\beta)}} \left(\frac{\alpha+\beta}{2}\right)^{-1} K_{\alpha-\beta}(2\sqrt{\alpha\beta I})}{\Gamma(\alpha)\Gamma(\beta)} I > 0 \quad (1)$$

Where  $K_a(\cdot)$  is the modified Bessel function of the second kind of order  $a$ . Here,  $\alpha$  and  $\beta$  are the effective number of small-scale and large-scale eddies of the scattering environment. These parameters can be directly related to atmospheric conditions according to

$$\alpha = \left[ \exp \left[ \left( 0.40\beta^2 / (1 + 0.18d^2 + 0.56\beta^{\frac{12}{5}})^{7/6} \right) - 1 \right] \right]^{-1} \quad (2)$$

$$\beta = \left[ \exp \left[ \left( 0.51\beta^2 / (1 + 0.9d^2 + 0.62\beta^{\frac{12}{5}})^{5/6} \right) - 1 \right] \right]^{-1} \quad (3)$$

Where  $\beta = 0.5C_n^2 k^{7/6} L^{11/6}$  and  $d = \left(\frac{kD^2}{4L}\right)^{1/2}$ . Here  $k = 2\pi/\lambda$  is the optical wave number,  $\lambda$  is the wavelength and  $D$  is diameter of receiving collector aperture lens.  $C_n^2$  stands for index of refraction structure parameter and is altitude dependent. Several  $C_n^2$  profile models are available in the literature, but the most commonly used is the Hufangle-Valley model is described by

$$C_n^2(h) = 0.00594(V/27)^2(10^{-5}h)^{10} \exp(h/1000) + 2.7 \times 10^{-6} \exp(-h/1500) + A \exp(-h/1000) \quad (4)$$

Where  $h$  is altitude in meters (m),  $V$  is rms wind speed in meters per second (m/s) and  $A$  is the nominal value of  $C_n^2(0)$  at the ground in  $m^{-2/3}$  for the FSO links near the ground.  $C_n^2$  can be taken approximately  $1.7 \times 10^{-4} m^{-2/3}$  during daytime and  $8.4 \times 10^{-15} m^{-2/3}$  at night. In general  $C_n^2$  varies from  $10^{-13} m^{-2/3}$  for strong turbulence to  $10^{-17} m^{-2/3}$  for weak turbulence with  $10^{-15} m^{-2/3}$  often defined as typical average value.

## IV DIVERSITY COMBINING TECHNIQUES

There are various combining techniques used to combine the signal from multiple diversity branches available in literature such as Selection Combining (SC), Equal Gain Combining (EGC) and Maximal Ratio Combining (MRC) [5].

### 4.1 Selection Combining

In selection combining technique the best signal among all of the signals received from different nodes is selected at the receiver end. As each element, there is an independent sample of fading process, so that the signal with high SNR is chosen from all the branches at receiver end.

### 4.2 Equal Gain Combining

In equal gain combining the received signals are summed up coherently with equal weights at all the received diverse signals. This technique gives better performance in terms of BER as compared to selection combining technique.

### 4.3 Maximal Ratio Combining

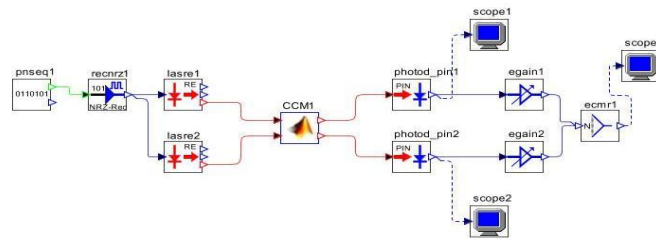
In maximal ratio combining each signal branch is multiplied by a weight factor that is proportional to the signal amplitude. Which means signal with high SNR will be multiplied by a weight i.e. it is amplified, while the signal with low SNR will be attenuated. In telecommunications, maximal ratio combining is a method of diversity combining in which the signal from each channel are added together and the gain of each channel is made proportional to the RMS value of signal and inversely proportional to the mean square noise level in that channel. Different proportionality constants are used for each channel. It is also known as ratio squared combining. Maximal ratio combining is the optimum combiner for independent AWGN channels. In this combining the signal from all the branches are weighted according to their individual SNRs and then summed.

## V. SYSTEM MODEL

MIMO-FSO link has been simulated in RsoftOptsim for different combining schemes as discussed above i.e. for SC, EGC and MRC. The signal to noise ratio (SNR) Vs bit error rate (BER) curves have been found each the combining schemes.

### 5.1 2x2 MIMO FSO Link-

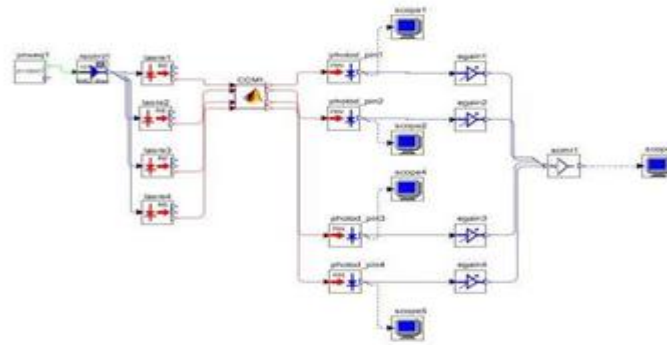
In Fig 2, we have used 2x2 MIMO link. There are two laser diodes and two PIN detectors and the channel is modeled as gamma gammapdf which has zero mean i.e.  $\mu = 0$  and variance  $\sigma^2 = N_0/2$ , which has simulated using Optsim- Matlabco simulation. Pseudo random sequence generator which generates the random data pattern at bit rate of 1 Gbps, rectangular electrical driver/NRZ driver which converts the data pattern into electrical form and the direct modulated laser source at 1550nm. Two laser diodes have been used at transmitter end to transmit the same data, which has been collected at two photodiodes via optical channel. The converted electrical signals have been assigned weights according to the combining techniques used and then a combiner is used to combine both the signals.



**Fig. 2.2x2 MIMO Simulation Model**

### 5.2 4x4 FSO MIMO Link

The link has been designed for 4X4 MIMO FSO system shown in figure 3. Here the channel matrix is of 4X4 and the length of the channel is 1 Km. The PRBS generator generates randomdata which is converted into electrical domain through NRZ electrical driver. The NRZ driver modulates the direct modulated laser source. The output from the laser source is passed through the channel which is modeled as lognormal having variance < 1. After the channel there is a detector which is PIN Diode. It converts the optical data into the electrical form. We can analyze the performance of the link by measuring the eye pattern and bit error rate.

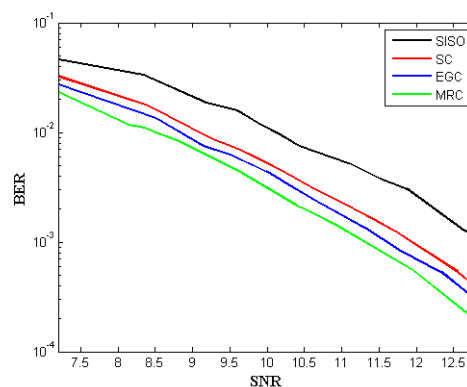


**Fig.3: 4x4 MIMO Simulation Model**

## VI SIMULATION AND RESULTS

### 6.1 2x2 MIMO FSO LINK

In Fig 4, BER performance comparison for SISO, SC, EGC and MRC for 2x2 FSO- MIMO system has been shown. Here, we can see that for BER of  $10^{-3}$  the SNR requirement is 13db, 12.5 dB, 11.5dB and 11dB for SISO, SC, EGC and MRC respectively. Hence we can observe that MRC provides the SNR improvement of 2dB over SISO system.



## Fig. 4. BER performance of SISO and different combining schemes for MIMO

### 6.2 4x4 FSO MIMO LINK

In Fig 5, BER performance comparison for SISO, SC, EGC and MRC for 4x4 FSO- MIMO system has been shown. Here, we can see that for BER of  $10^{-4}$  the SNR requirement is 14.5dB, 13 dB, 12.5dB and 11.5dB for SISO, SC, EGC and MRC respectively. Hence we can observe that MRC provides the SNR improvement of 3dB over SISO system.

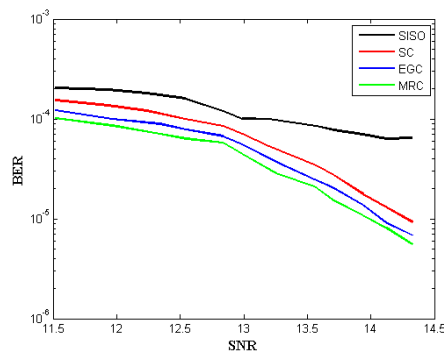


Fig 5. BER performance of SISO, SC, EGC and MRC for 4x4 MIMO system

## VII. CONCLUSION

At SNR of 12dB, we have the BER is around  $10^{-3}$  for the Equal Gain Combining case in 2X2 MIMO and  $10^{-4}$  for the Equal Gain Combining case for 4X4 MIMO FSO link. Hence we can conclude that the performance of 4X4 MIMO FSO link is better than 2X2 MIMO FSO link and MIMO-FSO system guarantees the performance over SISO system.

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