# Efficient QoS Provisioning for Free-Space MIMO Optical Links over Atmospheric Turbulence and Misalignment Fading Channels

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***Abstract:*** In cellular mobile communication the usage of MIMO FSO antenna system has shown the tremendous improvement in the quality of the signal. The MIMO system designed with the multiple transmitting & receiving antennas will help to increase the overall output gain as gain is proportional to the product of M transmitter and N receiver antennas'. In MIMO free space optical communication the transmission of the optical signal required the direct line of sight communication, where there should not be any obstacle in between the transmission of the original signal. But in practicality meeting the above condition is more difficult as many obstacles like bulding, mountain existing in between the transmission path of the signal. So in order to come up with the solution for this problem we have to place the antennas' on height as on the top of the taller building, on top of the mountain so that it will help to eliminate the obstacle in between the transmisition path and to meet the criteria of the line of sight communication.

***Keywords:*** Free-space optical communications, MIMO (multiple input multiple-output), atmospheric turbulence fading, misalignment fading, outage probability, diversity gain.

## I. INTRODUCTION

The free space optical communication implies the making use of free air, vacuum as transmission medium for the signal .the optical waves or electromagnetic wave travelled at the speed of light thro the channel. While travelling through the air signal may get damaged by reflection or due to the refraction where the signal may get change in terms of it angle or direction. due to this received signal may get scattered and lead to the loss of original signal .the signal to noise ratio of received signal get reduces .the MIMO system make use of increased no of transmitter and receiver antennas to eliminate the loss of signal .increased no of antennas will helps to lower the probability of outage but rate of change is unaffected. For the effective transmission of signal the channel capacity should be always larger than the rate of transmission. When channel capacity goes below the rate of transmission on rate the time channel is unable to carry the whole information and it leads thro outage of transmitted signal. With the help of MIMO antennas we somewhat try to reduce the channel outage.

## II. PROPOSED SYSTEM:

We can design the system by placing multiple antennas by keeping the specific distance between each two successive antennas. the performance is checked for both symmetric and unidirectional misalignment .the probability of outage is calculated by considering pulse amplitude modulation signal and to determine the diversity gain we can make use of the lognormal distribution It is shown that for misalignment condition the output is independent of product of transmitter and receiver antenna and depend on the variation parameter. Whereas on the other hand when antennas are properly placed that means there is will be no any misalignment the output is directionally proportional to product MN.

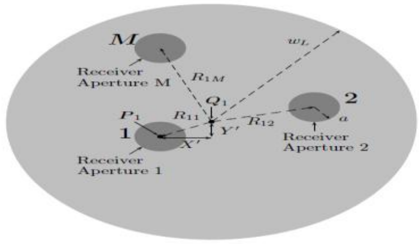

Fig. 1. Block diagram of the proposed system.

## III. STATISTICAL CHANNEL MODEL OF MIMO FSO SYSTEM

The geometric arrangement of the transmitter and receiver antenna leads to the misalignment fading. Will take the no of antennas are M=N. Initially we kept the spacing of d in between two successive transmitter antennas and same in between the receiver antennas the note that $d$ is assumed to be larger than the coherence length of atmospheric fading. We assume that initially each transmit laser is properly aligned to the corresponding receive aperture. We consider the Pm and Qm as coordinate vector of the beam footprint at the respective transmit and receive plane. The total beam footprint at receiver end with random displacement in X 'in direction x and Y' in direction y is

$$Qm = \begin{bmatrix} X' \\ Y' \end{bmatrix} + Pm$$

for the case of no misalignment *Pm=Qm.*

$$e^{G} = \sum_{n=1}^{N}\sum_{m=1}^{N} e^{X_{mn}} -^{U_{mn}}$$

where $G$ is a Gaussian random variable with mean $\mu_G$ and variance $\sigma_G^2$

$$H = A_0 e^{G-T} = A_0 e^{V}$$

where $V = G\text{-}T$ with probability density functions (pdf) given by

$$f_V(\mathrm{v}) = \int_0^{\infty} f_{V|T}(v|t)\, f_T(\mathrm{t})\, \mathrm{dt}$$

## IV. DIVERSITY GAIN OF MIMO FSO CHANNELS

This section three different misalignment scenarios will be analyzed depending on the random displacements $X'$ and $Y'$.

**Symmetric Misalignment in $X'$ and $Y'$ Directions**

The displacements $X'$ and $Y'$ have i.i.d Gaussian distributions with zero mean and variance $\sigma_s^2$. Defining $\gamma = w/(2\sigma_s)$ the pdf of $T = 2R^2/w^2$ is given by

$$f_T(t) = \gamma^2 e^{-\gamma^2 t}$$

and hence

$$f_V(\mathrm{v}) = \int_0^{\infty} f_{V|T}(v|t)\, f_T(\mathrm{t})\, \mathrm{dt}$$

$$= \int_0^{\infty} \frac{1}{\sqrt{2\pi\sigma_G}} \mathrm{e}^{-\frac{(\mathrm{v}-(\mu_G-\mathrm{t}))^2}{2\sigma_G^2}} . \gamma^2 e^{-\gamma^2 t}\, dt$$

where

$B_1 = \frac{\gamma^2}{2} e^{\gamma^4} \sigma_G^2 \big/ 2 - \gamma^2 \mu_G$, and $B_2 = \gamma^2 \sigma_G^2 - \mu_G$.

Substituting $s = v + B2$ the outage probability can be simplified to

$$P_{out}(R) = \frac{1}{2}\left[e^{\gamma^2\left(\eta+\gamma^2\sigma_G^2/2-\mu_G\right)} erfc\left(\frac{\eta+B_2}{\sqrt{2}\sigma_G}\right) + erfc\left(\frac{\gamma^2\sigma_G}{\sqrt{2}} - \frac{\eta+B_2}{\sqrt{2}\sigma_G}\right)\right]$$

Substituting the results in the asymptotic probability of outage $P_{out}^{Asy}$ given as

**Unidirectional Misalignment**

In this case $X' \sim (0, \sigma_S^2)$ and $Y' = 0$. The probability density functions of $T = 2X'^2/w^2$ is given by

$$f_T(t) = \frac{\gamma}{\sqrt{\pi t}} e^{-\gamma^2 t}$$

The outage probability is

$$P_{out}(R) = \int_{-\infty}^{\eta} f_V(v)\, dv,$$

$$= \int_{-\infty}^{\eta}\int_{0}^{\infty} f_{V|T}(v|t)\, f_T(t)\, \mathrm{dt\, dv}$$

The outage probability can be further approximated as

$$P_{out}(R_0) \approx 1 - \tfrac{1}{2} erfc\left(\tfrac{\eta-\mu_G}{\sqrt{2}\sigma_G}\right) + \textstyle\sum_{j=1}^{J} \tfrac{a_j}{2} e^{b_j}\, \gamma^2 \left(\eta + \tfrac{b_j\gamma^2\sigma_G^2}{2-\mu_G}\right) \mathrm{Erfc}\left(\tfrac{\eta-\mu G+b_j\gamma^2\sigma_G^2}{\sqrt{2}\sigma_G}\right)$$

for some integer $J \geq 1$. At high signal-to-noise ratio with erfc $(\eta) \approx 2$, the asymptotic outage probability is approximated as

$$P_{out}^{Asy}(R_0) \approx \sum_{j=1}^{J} a_j e^{b_j}\, \gamma^2 \left(\eta + b_j\gamma^2\sigma_G^2/2 - \mu_G\right)$$

**No Misalignment**

In, this scenario when there is no displacement co we can assume $X' = 0$ and $Y' = 0$, i.e., no misalignment, is also considered. The channel gain is given in terms the product of MN

$$H_0 = A_0 \sum_{n=1}^{N}\sum_{m=1}^{N} e^{X_{mn}} - U_{mn}$$

$U_{mn} = \frac{2}{w^2} \| P_m - P_n \|^2$ and $Go$ is Gaussian with mean and variance

$$\mu_0 = \mathbb{E}\{G_0\} = \log \frac{MN}{\sqrt{1 + \frac{1}{MN}\left(e^{\sigma^2 X} - 1\right)}}$$

and $\sigma^{2G_0} = \log\left(1 + \frac{1}{MN}\left(e^{\sigma^2 X} - 1\right)\right)$

The outage probability is given as

$$(R_0) = 1 - \frac{1}{2} erfc\left(\frac{\eta - \mu G_0}{\sqrt{2}\sigma G_0}\right)$$

$$\mu_0 = \mathbb{E}\{G_0\} = \log \frac{MN}{\sqrt{1 + \frac{1}{MN}\left(e^{\sigma^2 X} - 1\right)}}$$

and $\sigma^{2G_0} = \log\left(1 + \frac{1}{MN}\left(e^{\sigma^2 X} - 1\right)\right)$

The outage probability is given as

$$(R_0) = 1 - \frac{1}{2} erfc\left(\frac{\eta - \mu G_0}{\sqrt{2}\sigma G_0}\right)$$

## V. SIMULATION RESULTS

We consider Gaussian-beam of wavelength $\lambda$ = 1550 nm, beam waist $w_o$ = 2.1 cm, and radius of curvature $F_o$ = −11 m at the transmitter. the propagation distance oh l=1km .circular aperture of receiving antenna is =5cm the spacing between two transmitter antenna is to be d=20 cm typical misalignment transmitter.
variance of $\sigma^2_s$ = 0.1 m2 is considered and rate $R_0$ = 1 bits/channel-use is considered.

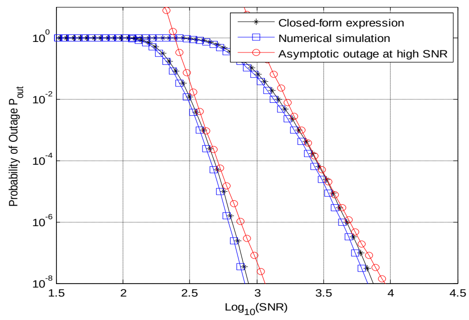


**Figure.1.** Probability of outage versus SNR for 2 × 2 and 4 × 4 MIMO FSO systems arranged as $\mathcal{P}$2×2 and $\mathcal{P}$4×4 respectively with symmetric misalignment fading,

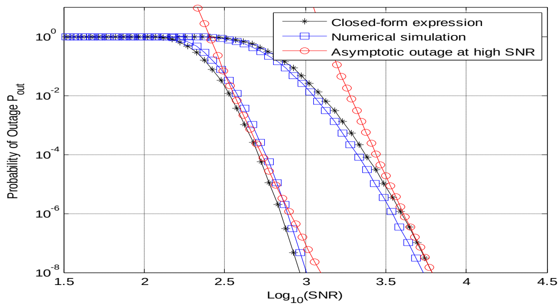


**Figure.** Probability of outage versus SNR for 2 × 2 and 4 × 4 MIMO FSO systems arranged as $\mathcal{P}$2×2 and $\mathcal{P}$4×4 respectively with unidirectional misalignment fading

## CONCLUSION

A MIMO system model is design to satisfy the system performance which is expressed in terms of diversity gain and outage probability. From the analysis of MIMO antenna system with different misalignment scenario we can proof that the output will get change as per the misalignment scenario. The graph for 2*2 AND 4*4 mimo is showing the respective value of probability of outage vs. diversity gain. For the both the antenna system diversity gain is unaffected by the variation parameter under no misalignment condition. As diversity gain increased its lead to decrease in probability of outage. Where as in symmetric misalignment condition the output get affected by the variation parameter. So we can conclude that to get the reliable output of system the ratio of probability outage has to be reduced and diversity gain has to be increased by making use of the MIMO antenna system with proper alignment of antennas.

## REFERENCES

[1] J. M. Kahn and J. R. Barry, "Wireless infrared communications," *Proc. IEEE,* vol. 85, pp. 265–298, Feb. 1997.
[2] D. Tse and P. Viswanath, *Fundamentals of Wireless Communication*, 1st edition. Cambridge University Press, 2005.
[3] M. Razavi and J. H. Shapiro, "Wireless optical communications via diversity reception and optical preamplification," *IEEE Trans. Wireless Commun.*, vol. 4, pp. 975–983, May 2005.

[4] X. Zhu and J. Kahn, "Free space optical communication through atmospheric turbulence channels," *IEEE Trans. Commun.*, vol. 50, pp.1293–1300, Aug. 2002.
[5] S. M. Navidpour, M. Uysal, and M. Kavehrad, "BER performance of free-space optical transmission with spatial diversity," *IEEE Trans.Wireless Commun.*, vol. 6, pp. 2813–2819, Aug. 2007.
[6] T. A. Tsiftsis, H. G. Sandalidis, G. K. Karagiannidis, and M. Uysal, "Optical wireless links with spatial diversity over strong atmospheric turbulence channels," *IEEE Trans. Wireless Commun.*, vol. 8, pp. 951– 957, Feb. 2009.
[7] N. Letzepis and A. G. i Fábregas, "Outage probability of the Gaussian MIMO free-space optical channel with PPM," *IEEE Trans. Commun.*, vol. 57, pp. 3682–3690, Dec. 2009.
[8] "Outage probability of the free-space optical channel with doubly stochastic scintilation," *IEEE Trans. Commun.*, vol. 57, pp. 2899–2902, Oct. 2009.
[9] S. M. Haas and J. H. Shapiro, "Capacity of wireless optical communications," *IEEE J. Sel. Areas Commun.*, vol. 21, pp. 1346–1356, Oct. 2003.
[10] S. G. Wilson, M. Brandt-Pearce, Q. Cao, and J. H. Leveque, "Free-space optical MIMO transmission with Q-ary PPM," *IEEE Trans. Commun.*, vol. 53, pp. 1402–1412, Aug. 2005.
[11] S. G. Wilson, M. Brandt-Pearce, Q. Cao, and M. Baedke, "Optical repetition MIMO transmission with multipulse PPM," *IEEE J. Sel. Areas Commun.*, vol. 23, pp. 1901–1910, Sep. 2005.
[12] G. A. Koepf, R. Peters, and R. G. Marshalek, "Analysis of brust error occurrence on optical intersatellite link (ISL) design," in *Proc. SPIE Opt. Tech. Commun. Satellite Applications*, Jan. 1986, vol. 616, pp. 129–136.