A study on Free Space Optical Communication for Bhubaneswar City

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Abstract— **In this work, feasibility studies of free space optical (FSO) communication for Bhubaneswar city is presented with the help of theoretical and simulation models. Visibility, rain, wind speed data over last 5years for Bhubaneswar is used to calculate the atmospheric losses i.e. scattering losses, turbulence, rain attenuation and geometric losses under bad and clear weather conditions. Optimal FSOC link range for Bhubaneswar city is calculated and analyzed under different weather conditions.**

Keywords—Free Space Optical Communication, Visibility, Scattering loss, Turbulence, Rain Attenuation, Link Margin.

I. INTRODUCTION

FSO is a promising, cost-effective, optical communication technology capable of supporting high bit-rate information transfer. Features like ease of installation, lightweight and small form factors makes FSO a very popular technology for research as well as for commercialization application [1-3]. FSO is capable of transmission up to Gbps of data, voice and video communications over the atmosphere for which spectrum licensing is not required. Similar to other form of communication, FSO systems also comprises of transmitters, channels (the atmosphere) and the receivers. Typical free space links are between 300m to 5km. FSO transmission lies in Terra Hertz (THz) spectrum of 800-1550nm wavelengths band. The optical power transmitted from the transmitter is affected by various factors before arriving at the receiver. Transmitted power of the emitted signal is highly attenuated by scattering and turbulence phenomena. The different losses over the air includes geometric and misalignment loss, atmospheric loss, rain and fog etc., [5].

II. TOTAL ATTENUATION CALCULATIONS FOR BHUBANESWAR

To determine the total attenuation for Bhubaneswar city wind speed data, altitude data along with last five year data of visibility and rain rate was obtained from the Indian Meteorological department.

A. Attenuation coefficient due to scattering

The visibilities data under the conditions of high visibility, average visibility and low visibility was collected for the last five years (2011-2016) for calculating scattering losses and is listed in in Table1.

TABLE 1– HIGH, AVERAGE AND LOW VISIBILITY

Year	High visibility(Km)	Average visibility(Km)	Low visibility(Km)
2011	3.41	2.41	1.83
2012	3.35	2.62	1.92
2013	3.44	2.75	1.99
2014	3.23	2.49	1.89
2015	3.62	2.81	2.05
2016	3.68	3.16	2.51
2011-2016	3.46	2.71	2.03

From the calculation it is found that, this city exhibits attenuation coefficient of 0.4518 dB/Km, 0.6197 dB/Km, 0.893 dB/Km for High, Average and Low visibility respectively. These attenuation coefficients can used to determine the scattering losses for this location for a given distances [2]

B. Refractive index structure parameter

Average wind speed (m/s) corresponding to an altitude value (m) for this location, were used to determine the refractive index structure parameter C_n^2 [3]. From the result in Table 2, this city has refractive index structure parameter of 1.11×10^{-14} at an altitude of 45m and wind speed of 3.10 m/s. Turbulence losses were determined by using refractive index structure parameter value as reported in Table 2 and [4].

TABLE 2 - WIND SPEED, ALTITUDE AND REFRACTIVE INDEX STRUCTURE PARAMETER

Location	Average wind speed(m/s)	Altitude(m)	Refractive index structure parameter ($m^{-2/3}$)
Bhubaneswar	3.10	45	1.11 x 10^{-14}

C. Attenuation coefficient due to rain

Rain fall over last five years (2011-2016) for this location has obtained to determine the rain attenuation coefficient [1] as reported in Table 3. The average rainfall rate was found to be 10.13cm/hr. using this value the rain attenuation coefficient was found to be 13dB/km.

TABLE 3 - AVERAGE RAIN

Year	Average rain(cm/hr)
2011	9.52
2012	10.2
2013	14.42
2014	11.27
2015	8
2016	7.34
2011-2016	10.13

III. SIMULATED RESULTS

A. Loss under bad weather condition

Fig. 1 shows the individual losses i.e., scattering loss due to lowest visibility of 4dB at 1000m and it is increases to 39dB at 10Km; loss due to rain of 15dB at 1000m becomes 51dB at 10Km; similarly turbulence due to wind speed of 11dB at 1000m and geometric loss has maximum value of 14dB at 10Km link distance. All losses are in 15dB up to 4000m after that it affect FSO link severely.

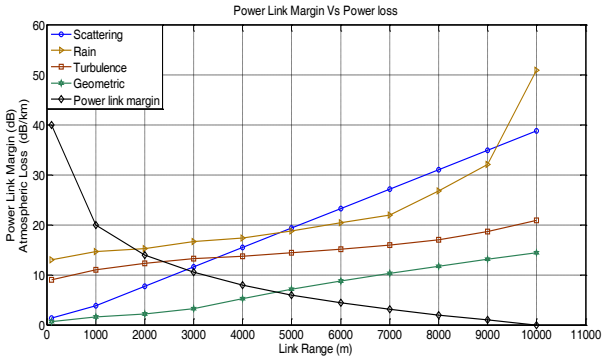

Fig. 1. Power Link Margin Vs Atmospheric loss (lowest visibility, Turbulence, Rain, Geometric loss)

B. Loss and FSOC link availability under moderately clear weather condition

Clear weather condition based on highest visibility, wind speed and without rain. Fig. 2 shows the scattering, turbulence and geometric loss under clear weather condition. Scattering loss of 2.5dB at 1000m and 19.5dB at 10km was observed.

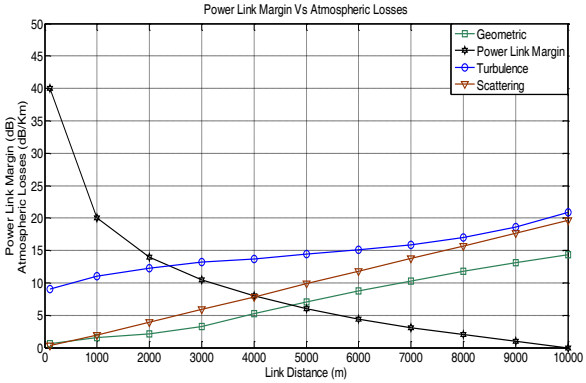

Fig. 2. Link Distance Vs Power Loss (Scattering loss for High visibility and Turbulence, geometric loss, no rain)

C. Total attenuation and FSO link availability under bad and clear weather condition

Total attenuation can be determined for both bad and clear weather condition by adding all the losses. From Fig.3 it is clear that the observed total attenuation at 1000m link distance is 31dB whereas at 10km it becomes 124.9dB under bad weather condition however, under clear weather condition, the values are14.5dB and 55dB at 1000m and 10km link distance respectively. From Fig. 3 we obtain an optimal FSO link range of 633.5m for a total attenuation 28dB under bad weather condition whereas for clear weather condition with an attenuation of 16.7dB the optimal link range is found to be 1558m.

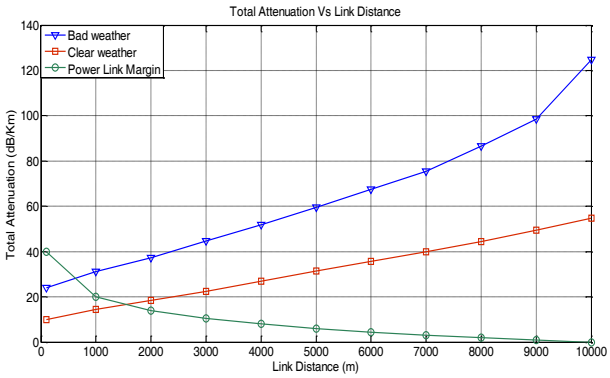

Fig. 3. Total attenuation Vs power link margin under different weather condition

IV. CONCLUSION

In this work, both theoretical and numerical analyses have been carried out to study the feasibility of FSO communication system under different atmospheric conditions for the city of Bhubaneswar. The result shows that the under bad atmospheric condition when the loss is 28dB the maximum attainable FSO distance for Bhubaneswar is 633.5m, however, under clear weather condition with a loss of 16.7dB, an FSO link distance of 1558m was observed. This work is based on mathematical models which take several considerations of weather conditions. The performance may further be improved by adopting hybrid modulation formats and space diversity receiver technique, which needs further studies and analysis.

REFERRENCES

[1] F. Nadeem, V. Kvicera, M.S. Awan, E. Leitgeb, S.S. Muhammad and G. Kandus, "Weather effect on hybrid FSO/RF communication link", IEEE J. Comm, vol. 27, pp. 9, 2009.

[2] J. Perez, Z. Ghassemlooy, S. Rajbhandari, M. Ijazand, H. Le Minh, "Ethernet FSO communications link permance study ununder a controlled fog environment", IEEE Communication letter, 16(3), 2012.

[3] H.A. Fadhil, A. Amphawan, H.A.B. Shamsuddin, T.H. Abd, Hamza M.R. Khafija, S.A. Aljunid, N Ahmed, "Optimization of free space optics parameters: An optimum solution for bad weather conditions", ELSEVIER Optik, vol. 124, pp. 3969-3973, 2013

[4] Phuc V. Trinh, Ngoc T. dang and Anh T. Pham, "All optical relaying FSO system using EDFA combined with optical hard limiter over atmospheric turbulence channel", Journal of Lightwave Technology, vol. 33, pp. 19, 2015

[5] M.R. Handur, K.M.Ndjaver, C.N.Nyirend, T.O.Olwa, "Determining the feasibility of Free Space Optical Communication in Namibia", ELSEVIER Optics Communications, vol. 366, pp. 425–430, 2016.