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Research paper

Performance Analysis of Single and Multiple Channel FSO System under Turbulent Conditions Using Various Models

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Abstract

Telecommunications occupying the major part of research across the world, has become a part and parcel of present day human's life. As a part of research many new technologies emerged among which free space optics was found to be highly efficient and a competent technology. So, replacing the present microwave communications, in future free space optics provides many advantages like higher bandwidth, higher data rate (capable of sending up to 1.25 Gbps of data, voice, and video communications simultaneously through the air), low bit error rate and license free long-range communications etc. As a known fact that every coin has two sides, free space optics besides providing the above advantages also suffers from many range limiting factors like fog, beam dispersion, atmospheric absorption, rain attenuation, snow, terrestrial scintillation amongst which rain, scintillation and fog are popular in tropical regions like India. In this paper the effect of rain on FSO link is analysed in 1/1 and 4/4 channel cases and the results were analysed.

Keywords: *Telecommunications, bandwidth, rain, fog, channel, tropical region, free space optics.*

1. Introduction

Free space optics is a perfect line of sight communication where the carrier which supports the communication makes it unique and an efficient technology that provides high quality and uninterrupted transmission [1]. The carrier used here is of the order of Tera Hertz which can carry large data and can reach the destination with the speed of light. These two major qualities make free space optics profitable to the field of communication. Free space optics follows the same mechanism of the conventional communication systems where the difference lies only in the carrier which is an optical signal (light) [2]. As the signal travels in the free space to reach the receiver it encounters many obstacles that interrupt their natural flow. Some of the atmospheric effects that degrade the strength of the signal include rain, fog, haze, snow, scintillation etc. As India is a tropical country rainfall plays a prominent role in changing the climate of the place [6][8]. Simultaneously rain also shows similar effect on the signal travelling in free space. So, for tropical countries like India the effect of rain on free space communication link is to be studied in advance before creating a link such that a better-quality communication can be achieved [3][11]. Here the effect of rain on a single channel and a 4/4 channel is studied with the help of simulation and the results generated. The single channel system consists of a single transmitter and a receiver and 4/4 system consists of 4 transmitter and receiver pairs. The schematic of the systems designed for simulating the effect of rain are given as

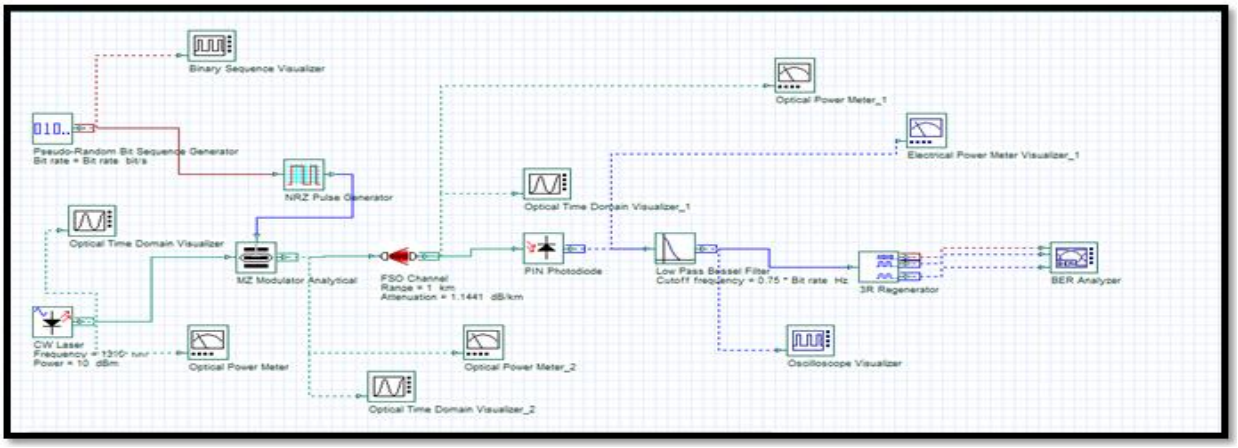


Fig. 1: Single Channel FSO communication system

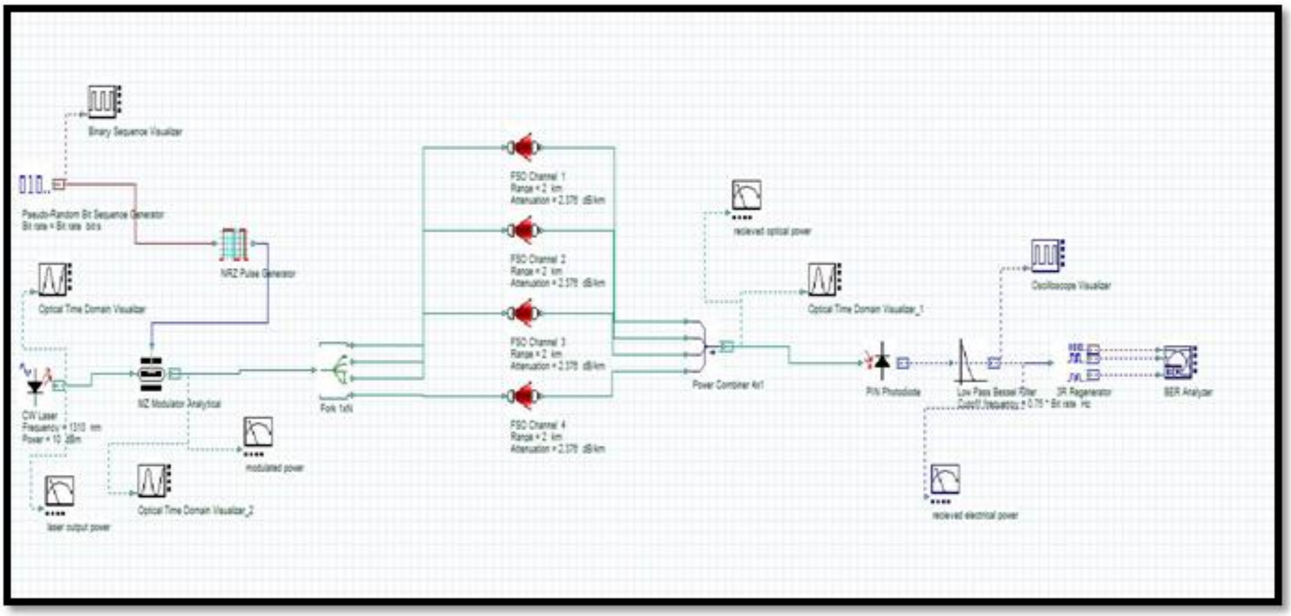


Fig. 2: Four Channel FSO communication system

Both the simulations are designed with a range of 2 km operation at 1310 nm and with an input power of 10dBm.The only difference between them is the number of transmitter and receiver pairs [4]. The effect of rain on the two systems that are designed is simulated. As the raw rain data cannot be used for the simulation purpose the corresponding specific attenuation needs to be estimated such that the simulation can be performed [5].

For estimating the specific attenuation due to rain, the raw data which is the rain rate (mm/hr) is necessary. This data is obtained from the disdrometer recordings and the necessary calculations are performed to obtain the specific attenuation. The specific attenuation calculations done with the help of models like Japan, Carbonneau proposed by ITU-R and the other models like Samir, Suriza developed based on tropical climate.

2. Specific Attenuation Models

2.1 Japan Model

This model is proposed by the International Telecommunication Union based on the measurements made in Japan. The recommendation R-REC-P.1814 clearly explains the characteristics of the specific attenuation models designed based on the Japan climate [7]. The equation for estimating the specific attenuation due rain using Japan model is given as

$$\gamma_{rain} = k.R^{\alpha}$$

where

γ_{rain}-Specific Attenuation due to Rain dB/km.
k, α- Power Law Parameters.
R-Rain Intensity mm/hr.

Here power law parameters are temperature and frequency dependent. The values of k and α for the Japan model are given as

Table 1: Power law parameters for Japan Model

Location	k	α
Japan	1.58	0.63

2.2 Carbonneau Model

The second most famous model for estimating the specific attenuation due to rain recommended by ITU-R is the Carbonneau Model which was developed based on the measurements made in France. The specific attenuation observed due to rain developed by Carbonneau model is given by the equation

$$\gamma_{rain} = k.R^{\alpha}$$

where

γ_{rain}-Specific Attenuation due to Rain dB/km.
k, α- Power Law Parameters.
R-Rain Intensity mm/hr.

Here power law parameters are temperature and frequency dependent. The values of k and α for the Carbonneau model are given as

Table 2: Power law parameters for Carbonneau Model

Location	k	α
France	1.076	0.67

2.3 Samir Model

The Samir model was developed based on the tropical climate [10]. The equation for estimating the specific attenuation using Samir's model is given as

$$\gamma_{rain} = k.R^{\alpha}$$

where

γ_{rain}-Specific Attenuation due to Rain dB/km.
k, α- Power Law Parameters.
R-Rain Intensity in mm/hr.

Here power law parameters are temperature and frequency dependent. The values of k and α for the Samir model are given as

Table 3: Power law parameters for Samir Model

Climate	k	α
Tropical	2.03	0.74

2.4 Suriza Model

Suriza Model is based on the formulation based on the tropical climate like the Samir model but experimented in a different location. The equation for the Suriza model is given as

$$\gamma_{rain} = k.R^{\alpha}$$

where

γ_{rain}-Specific Attenuation due to Rain dB/km.
k, α- Power Law Parameters.
R-Rain Intensity mm/hr.

Here power law parameters are temperature and frequency dependent. The values of k and α for the Suriza model are given as

Table 4: Power law parameters for Suriza Model

Climate	k	α
Tropical	0.4195	0.8486

Using the four models the specific attenuation was calculated at different rain rates and are incorporated into OptiSystem. Then the performance of the systems in the presence of rain is analysed with the help of the results obtained.

Eye diagram is one of the important parameters that describe the behaviour of the communication system [9]. The eye diagrams that are obtained after simulating the rain effect on 1/1 and 4/4 channels which are given in figure 3 and 4.

By observing the eye diagrams of single channel, it is clear that as the rain intensity is increasing the eye opening is getting reduced and at the maximum rain rate the eye is totally closed with a maximum bit error rate of 1 which means that the system is in an outage period.

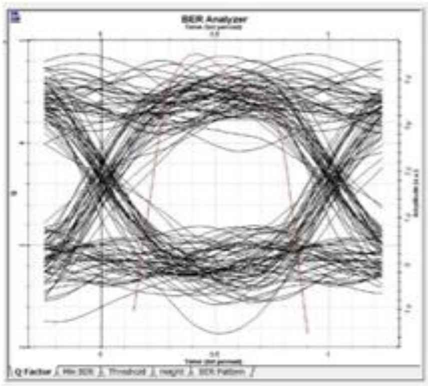
The eye diagrams of the 4/4 channel system show the efficiency of the system over the single channel one. The eye opening is very much wider in the case of 4/4 system because of the presence of multiple transmitters and receivers.

The multiple transceiver system also followed the same pattern of the single channel system, but the extent of the eye closing is very little. As both the systems are simulated for a 2 km distance the eye diagrams conclude that a multiple transceiver system perform far better than the single channel systems in the presence of rain avoiding the occurrence of outage period.

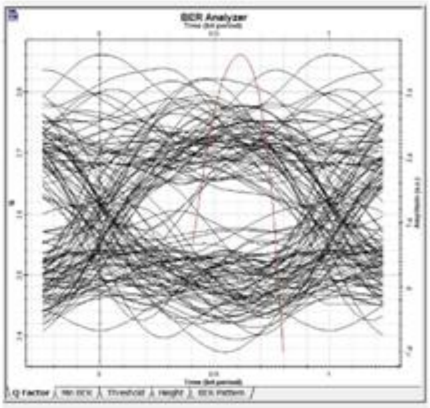
3. Results

Along with the eye diagrams the other prominent parameters that characterise the system performance are the received optical power, received electrical power and the quality factor. All these parameters are estimated for the designed free space optical communication system and the graphs are generated in both the single and multiple channel systems.

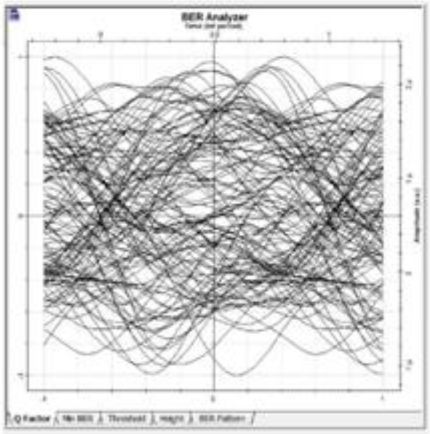
At different rain intensity levels, the values of received optical power are obtained from the simulation and the plots are generated. The variation in the received optical power for a single channel system separated with a 2km distance is given in figure 5.



a. R=0.583 mm/hr

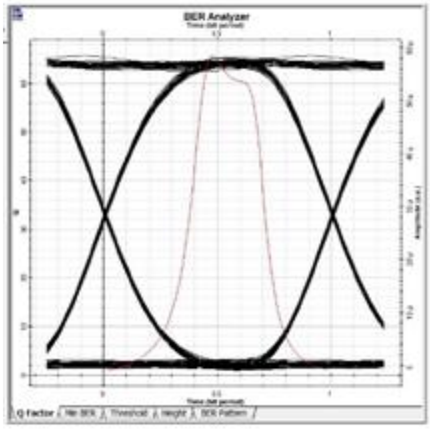


b. R= 1.668 mm/hr

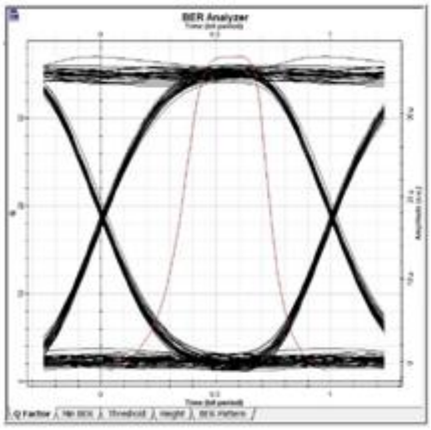


c. R= 3.262 mm/hr

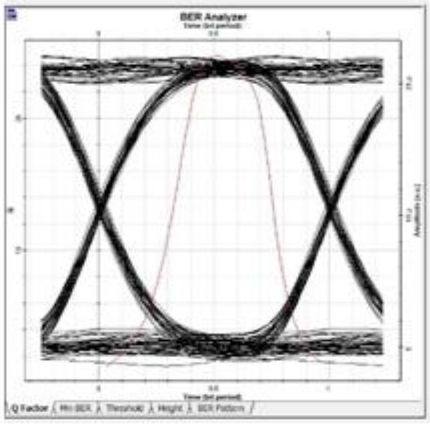
Fig. 3: Eye Diagrams of single channel system at different rain rates



a. R=0.583 mm/hr



b. R= 1.668 mm/hr



c. R= 3.262 mm/hr

Fig. 4: Eye Diagrams of 4/4 channel system at different rain rates

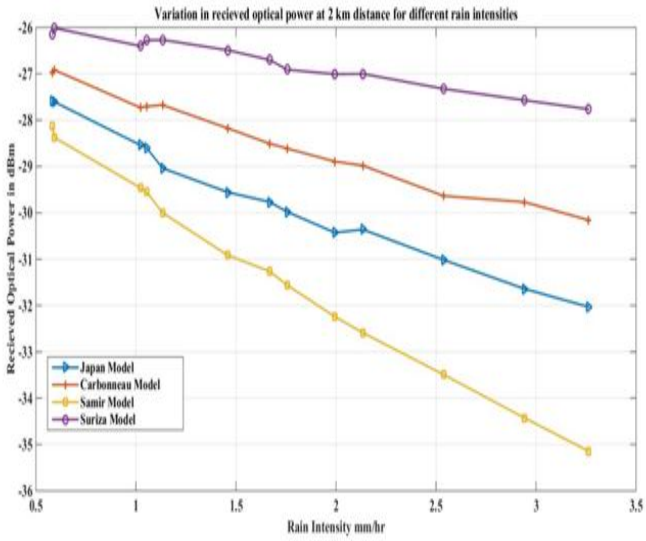


Fig. 5: Variation in received optical power for a single channel system

Here the maximum received power was found to be -26.1493 dBm for Suriza model which o. The power levels obtained for the other two models lie in between the Samir and Suriza models. The variation in the received optical power in multiple channel case is given as

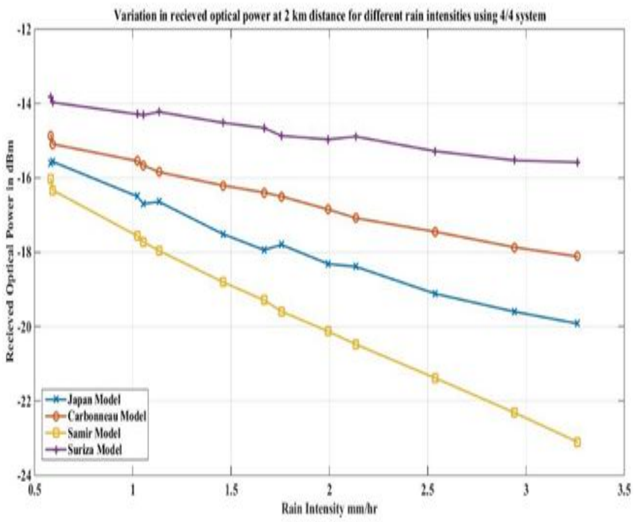


Fig. 6: Variation in received optical power for multiple channel system

The variations in the received optical power for a multiple channel follows a similar pattern with that of the single channel but the received power levels are very much enhanced in the case of the multiple channel system. The highest received optical power was found to be around -13.8238dBm which is almost double the power that is captured by the single channel system at the same distance under rainy condition.

The variation in the received electrical power also follows the same pattern of that of the optical power. For the single channel system, the variation is given as

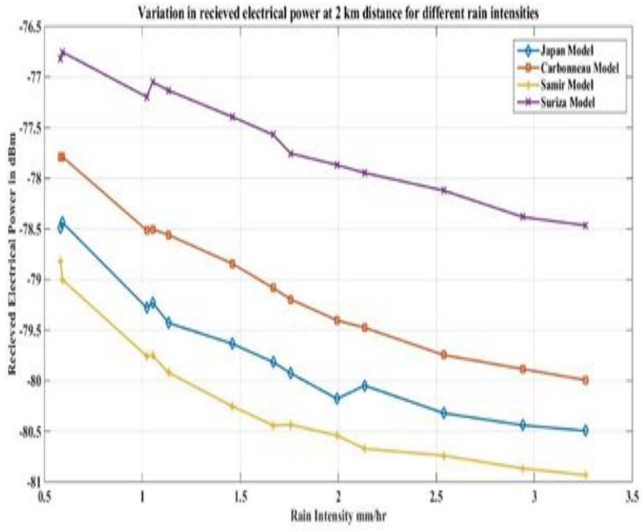


Fig. 7: Variation in received electrical power for single channel system

As all the measurement devices work with electrical power it is necessary to convert the optical signal to electrical and perform analysis. The maximum electrical power was found for the Suriza Model and the lowest power was found for the Samir Model at lower rain rate.

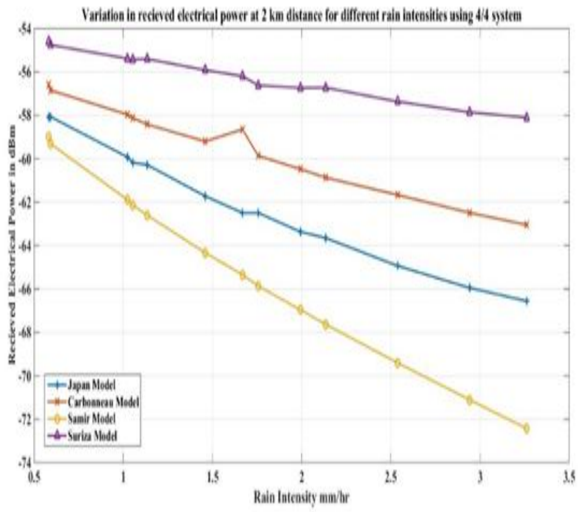


Fig. 8: Variation in received electrical power for multiple channel system

The variation in electrical power followed the same pattern with that of the optical power like high power was observed at low rain intensities and lower at higher rain rates. The maximum power observed was -54.5983dBm.

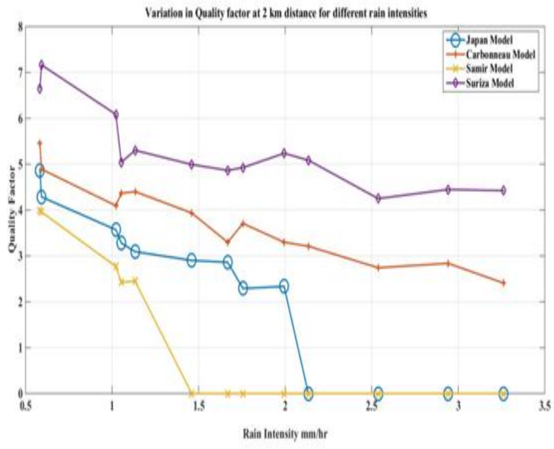


Fig. 9: Variation in Quality Factor for single channel system

The highest Quality factor was observed for Suriza model at lowest rain rate which is around 7.16. At higher rain rates greater than 1.5 mm/hr the system was totally turned off due the intensity of the rain at 2 km distance.

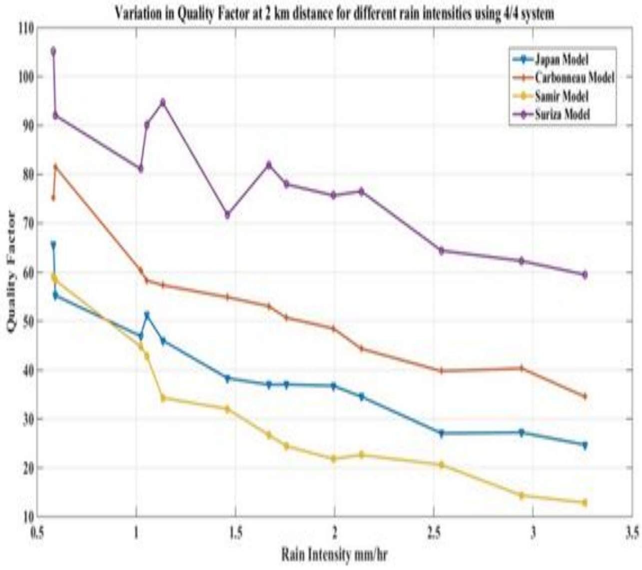


Fig. 10: Variation in Quality Factor for multiple channel system

As the number of channels are more in the above case the quality factor of the system for all the four models raised to a very high value compared to that of a single channel system. This is due to the presence of multiple number of channels.

4. Conclusion

The above results conclude that at any rain rate the performance of the multiple channel system is better compared to the single channel system in the view of received power and quality factor. The received optical power was found to be twenty times higher in the case of multiple channel over the single channel system. An increase in the received electrical power was also observed in the case of multiple system which is obvious as it depends on the received optical power. The raised power level was almost like the optical power pattern. The quality factor also showed a huge difference between the single channel and multiple channel system which is greater than double of its value. It can be concluded that multiple channel systems multiple channel systems can perform better than single channel systems when scaled with respect to parameters like electrical and optical powers and also Quality factor even when the system is experiencing turbulence.

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