Performance Analysis of Multi-Identity High Power Codes (MIHP) Over Free Space Optical Communication System

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Abstract : Optical code division multiplexing and free space optical communication integration provides an ultimate solution to provide enhanced reach and enhanced data rates. In this research work, a high speed data streams are supported over multi-identity high power codes (MIHP) over FSO. Simultaneous 10 users are catered 5 Gbps over diverse link lengths (2 km-10 km) and different beam divergences are also investigated. Moreover, diverse weather instabilities such as clear weather, light haze, heavy haze, rains are studied over FSO link and results are observed in case Q factor and BER. Comparison of double diagonal weight and multi-identity high power codes has been accomplished. It is perceived that MIHP codes performs superior than DDW codes due to high SNR because the potential of MIHP codes is high to carry high power levels.

***IndexTerms* - Free space optics (FSO), Multi-identity high power codes (MIHP), optical code division multiplexing (OCDMA), Weather instability, Data rate**

I. INTRODUCTION

With the advent of technology, optical fiber communication emerges as a promising method to transfer information from one location to other. However, fiber optical is suffering from some limitations such as high installation costs, licenses requirement, trenching and bending losses etc. [1] [2] [3]. Free space optical technology is an ultimate candidate to provide solutions to issues which emerges in optical fiber communication. Laser source carriers are transmitted through air and save the cost of installation by trenching [4] [5]. It is the most excellent substitute for wireless communication systems to cater high data rate. Furthermore it offers operations without any license. But, despite many benefits of the FSO, it suffers from some limitations such as weather instabilities [6] [7] [8]. Atmospheric turbulences degrade the system performance because it affects the line of sight of the signal also decrease the visibility such as in case of rain, fog, haze etc. Some other factors are geometric losses, beam divergence, scattering of light etc. Scattering is also prominent issues of signal degradation because it disperses the light signals. Raindrops and snow are outcome the Geometrical scattering because the molecules of raindrops and snow are large and similar to Rayleigh scattering. In free space optical system, analysis of diverse weather condition is an important requirement [9].

For the capacity enhancement, optical code division multiple access is ubiquitously operational in optical communication system. However OCDMA system suffer from different noises such as short noise, thermal noise, phase intensity induced noise (PIIN), multiple access interference (MAI). Multiple access interference is emerged in the OCDMA systems with cross correlation codes and MAI is performance degrading factor [10]. Spectral amplitude coding is a superior way out to decrease the effect of multiple access interference by using codes with zero cross correlation [11]. Some of the mostly used spectral amplitude codes are enhanced double weight (EDW), multi-diagonal (MD) codes, diagonal double weight (DDW), etc [4] [11] [12] [13] [14] [15] [16] [17].

In this paper performance of multi-identity high power code is analyzed due to fixed cross correlation, less complexity and ability to cater high power under different weather conditions in free space medium.

II. CONSTRUCTION OF MULTI-IDENTITY HIGH POWER CODES (MIHP)

First and foremost define an identity matrix of I_N size, N represents the total users for which code will be constructed. In MHIP codes, two diverse matrices used and for first multi-identity matrices, cross correlation is zero. Basic significance of the multi-identity codes is that it can decrease the PIIN noise in spectral coding. (M_I) represents multi-identity matrix and size of the matrix is given as N x N. Here, M is the total users.
Let total users for example are 4 then and value of diagonal is i=4
Matrix becomes $M_I=[I_{4,1}]=[I_{4,1}, I_{4,2}, I_{4,3}, I_{4,4}]$

$$MI=\begin{Bmatrix} 1000\ 1000\ 1000\ 1000 \\ 0100\ 0100\ 0100\ 0100 \\ 0010\ 0010\ 0010\ 0010 \\ 0001\ 0001\ 0001\ 0001 \end{Bmatrix}$$

Formation of All One matrix

In order to increase the weight of the multi-identity value equals to the code weight, a matrix having '1's is created. In this matrix, there are N number rows which are same as users and for the total columns, w-i is used where i are diagonals and w is code weight.

Consider an example of 4 users and set the value of diagonals equal to 2. Therefore '1' matrix having two columns ad matrix is given as:

$$\text{Ones}=\begin{Bmatrix}1\ 1\\ 1\ 1\\ 1\ 1\\ 1\ 1\end{Bmatrix}$$

For the calculation of the total length of the MHIP code, a relation is given between length, users and weight

$$L= (n_u \times i) + (w-i) \qquad (1)$$

Final code is realized using two matrices such as - [multi identity, All one matrix]

In this SAC code, number of Users and weight can be fixed to any value

Code construction of MHIP for Nu=3 and i=1

From the calculations of the code length from equation (1)

Length of the code is comes out to be 5

$$\text{MIHP}=\begin{Bmatrix}100\ 11\\ 010\ 11\\ 001\ 11\end{Bmatrix}$$

Wavelengths in the MHIP code for diverse users

User 1= λ1 , λ4, λ5

User 2= λ2 , λ4, λ5

User 3= λ3 , λ4, λ5

More flexibility in the selection of parameters like weight and k is a prominent property at the time of construction of MIHP code, and which makes system simple and can support large number of users.

III. Simulation Setup

Figure 1 represents the block diagram of analysis optical code division multiplexing based free space optical system using multi-identity high power codes. Spectral amplitude codes are employed with laser sources. A continuous wave laser array of 11 output frequencies is placed for the light pulses of diverse wavelengths. Lasers are selected based on the code length of MIHP as given in the matrix (1)

Users=10, W=2 and i=1

Code length= (users x i) + (w-i)

Code length= (10 x 1) + (2-1) =11

$$\text{MIHP}=\begin{Bmatrix}10000000001\\ 01000000001\\ 00100000001\\ 00010000001\\ 00000100001\\ 00000010001\\ 00000001001\\ 00000000101\\ 00000000011\end{Bmatrix}$$

Frequencies are started from 193.1 THz and conventional band is considered due to minimum scattering. Spacing between channels is considered 100 GHz and power at each channel is taken as 0 dBm. Laser linewidth is 10 MHz and initial phase is zero. Data rate of each user is 5 Gbps and wavelengths' at each user are given below:

User 1= 193.1 THz, 194.1 THz
User 2= 193.2 THz, 194.1 THz
User 3= 193.3 THz, 194.1 THz
User 4= 193.4 THz, 194.1 THz
User 5= 193.5 THz, 194.1 THz
User 6= 193.6 THz, 194.1 THz
User 7= 193.7 THz, 194.1 THz
User 8= 193.8 THz, 194.1 THz
User 9= 193.9 THz, 194.1 THz

User 10= 194 THz, 194.1 THz

Pseudo random bit sequence generators are included in the system for binary sequence generators in the form of 1's and 0's. In order to provide electrical pulse form, non return to zero modulation formats is incorporated in the system. Modulator is used to convert NRZ pulses into optical pulse forms by getting drive from multiplexer which has frequencies from lasers according to code pattern.

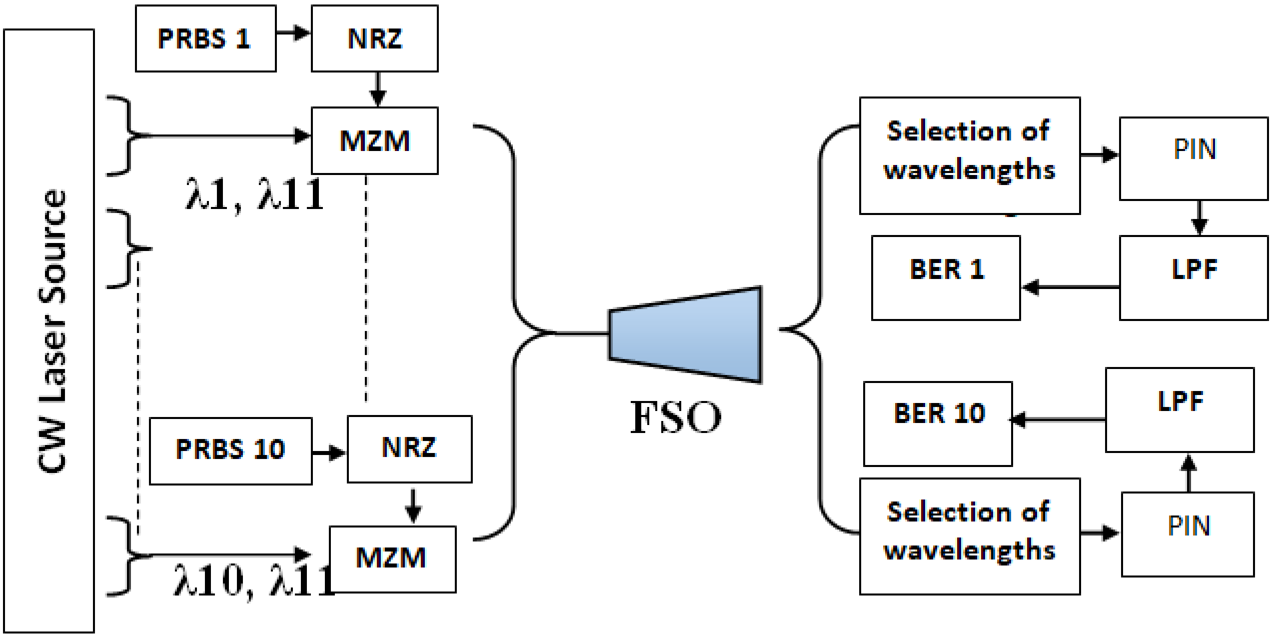


Figure 1 Block Diagram of OCDMA-FSO based system using MIHP

Table 1 System Specifications

Parameters	Values
Data Rate (Gbps)	5 Gbps
Users	10
WDM Spacing (GHz)	100 GHz
SAC Code	MIHP
Transmitter Antenna diameter (cm)	10
Receiver Antenna diameter (cm)	25
Beam divergence	2 mrad
Distance (km)	1-10 km
Clear weather attenuation (dB/km)	0.23
Light Haze (dB/km)	0.55
Heavy Haze (dB/km)	2.37
Light rain, medium rain, heavy rain attenuation (dB/km)	6.27, 9.64, and 19.28 respectively

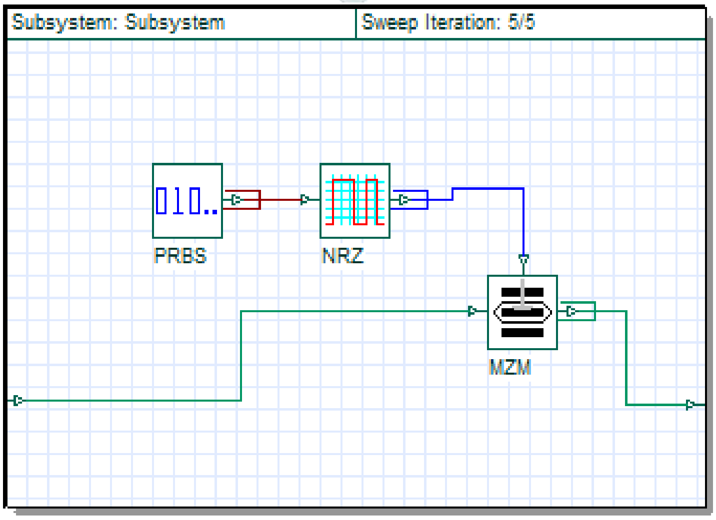


Figure 2 Internal structure of transmitter

Figure 2 depicts the internal diagram of transmitter. Multiplexed signals of all the 10 users are sent over free space optical system having reference wavelengths of 1550 nm. Antenna size of the transmitter aperture is 10 cm and receiver aperture is 25 cm. Beam divergence of the FSO is fixed to 2 mrad and different attenuations are considered. Distance is fixed to 2 km to 10 km and system specifications are given in Table 1. After FSO, signal is fed to de-multiplexer and followed by the optical filters according to the code wavelength selection. Filtered chips are passed through low PIN for optical to electrical conversions which are then followed by low pass Bessel filter and BER analyzer.

IV. Results and Discussions

Performance of the implemented system based on optical code division multiplexing over free space optical communication has been analyzed in this work. In order to study the system, spectral amplitude coding based multi-identity high power codes are deployed in the system for supporting ten users at 5 Gbps bit rate. Analyzers present in the optisystem software library are beneficial to check signals time to time and let us know about signal availability and faults. Therefore, first and foremost, output of optical spectrum analyzer for MIHP codes is depicted in Figure 3. Figure 3 (a) depicts the optical spectrum of first user and (b) represents the output of OSA for tenth user. Basically it provides the information about the power on each carrier and also their center frequencies. Further Figure 3 (c) represents the multiplexed signals of the total 10 users. It is perceived that stating frequency of the spectrum is 193.1 THz and it lasts till the frequency of 194.1 THz with the input power level of 0 dBm. However, the output power which shown in the Figure is less than 0 dBm due to the different insertion loses of diverse components in the analysis system.

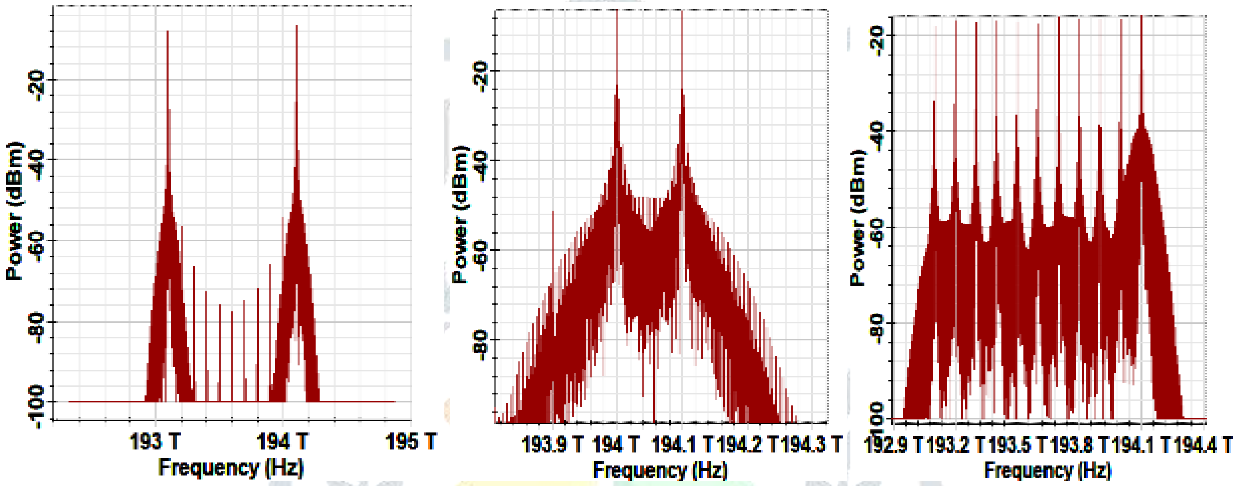


Figure 3 Optical spectrums of analysis system after (a) 1st user (b) 10th user (c) multiplexer

For the deep observation of the transmission bits of the system, spectral amplitude coding based multi-identity high power codes, optical time domain analyzer are incorporated in the system. These analyzers also present in the software library and are beneficial to check bit time of each pulse with their amplitude. OTDV representation of the analysis system in terms of bit time for MIHP codes are depicted in Figure 4. Figure 4 (a) shows the time domain of bits for first user and (b) represents the output of OTDV for tenth user. Basically it provides the information about the amplitude of each pulse and also their bit duration. Further Figure 4 (c) depicts the multiplexed OTDV signals of the total 10 users.

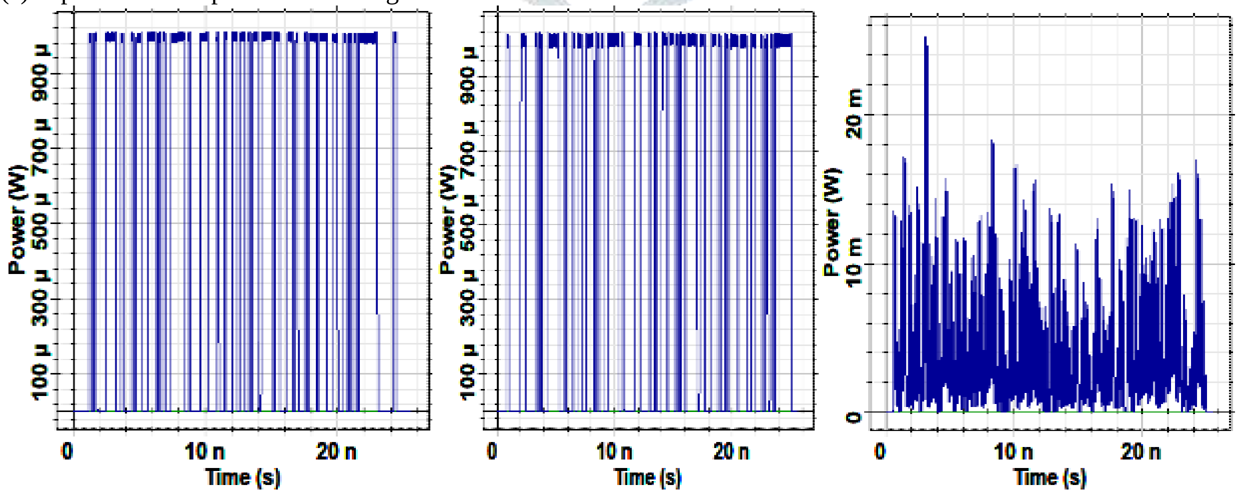
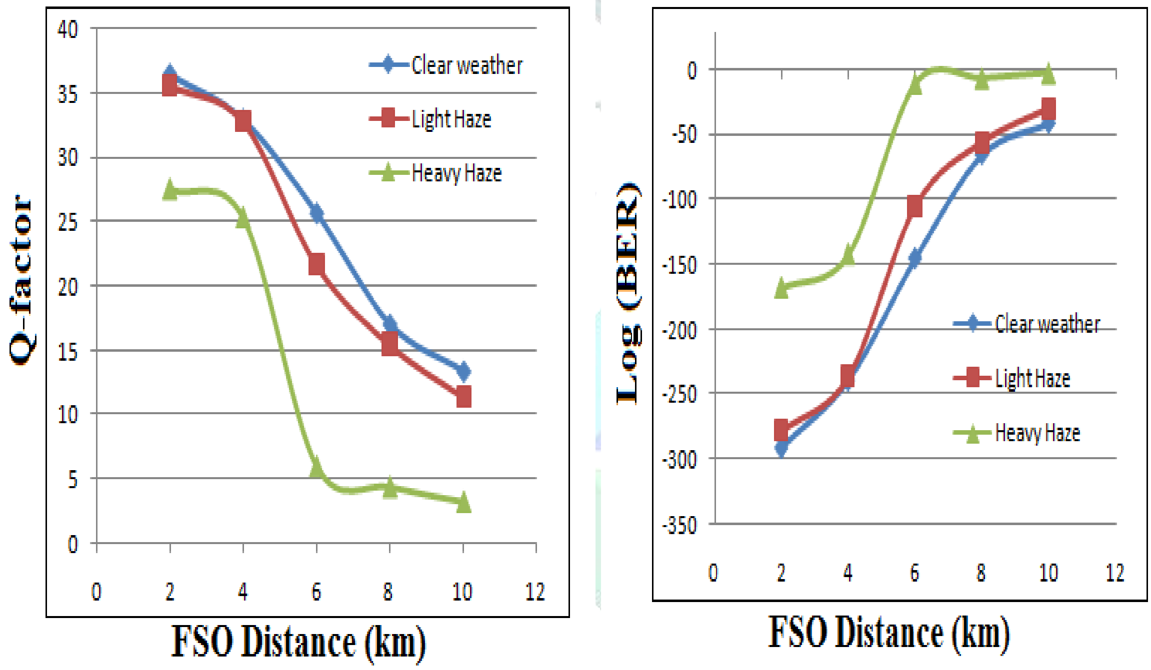


Figure 4 Optical time domain vizualizers output of analysis system after (a) 1st user (b) 10th user (c) multiplexer

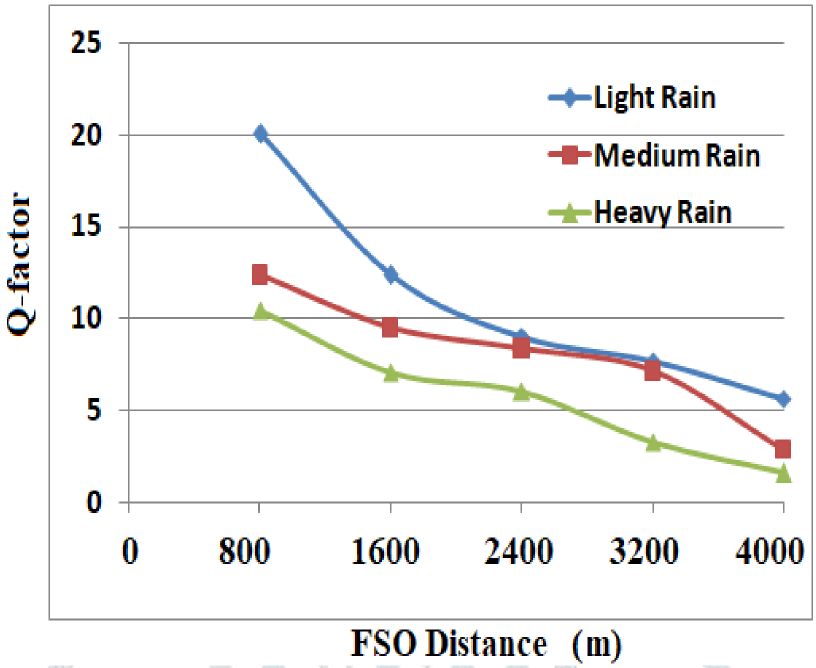
Further, in order to evaluate the performance of the system at diverse link lengths, distance is varied from 2 km to 10 km. Results are analyzed in terms of Quality factor and bit error rate at diverse link lengths under the effects of clear weather and haze only. Figure 5 (a) depict the performance of the system in terms of Q factor at diverse distance and it is perceived that lower distance (2 km) has greater quality factor than longer distance (10 km) under clear weather and haze also. However, Q factor of clear weather is highest as compared to light haze and heavy haze. For getting the effects of haze and clear weather in the system, attenuations are varied from free space optical communication link. Attenuations are mentioned in Table 2 with weather conditions in dB/km. Performance of the analysis system at light haze is greater than heavy haze but falls below performance of the system at clear weather. Light haze performance is followed by heavy haze respectively. It is observed that with the severity in the haze conditions, Q factor decreases. After that results are analyzed in terms of Log BER at diverse link lengths under the effects of clear weather and haze only.

Figure 5 (b) depict the performance of the system in terms of Log BER at diverse distance and it is perceived that lower distance (2 km) has least BER than longer distance (10 km) under clear weather and haze also. However, Log BER of clear weather is highest as compared to light haze and heavy haze. Log BER of the analysis system at light haze is lesser than heavy haze but falls below performance of the system at clear weather. Light haze performance is followed by heavy haze respectively. Further, performance of the system is compared for different rain conditions such as light rain, medium rain and heavy rain in terms of Q factor and Log BER.



(a) (b)

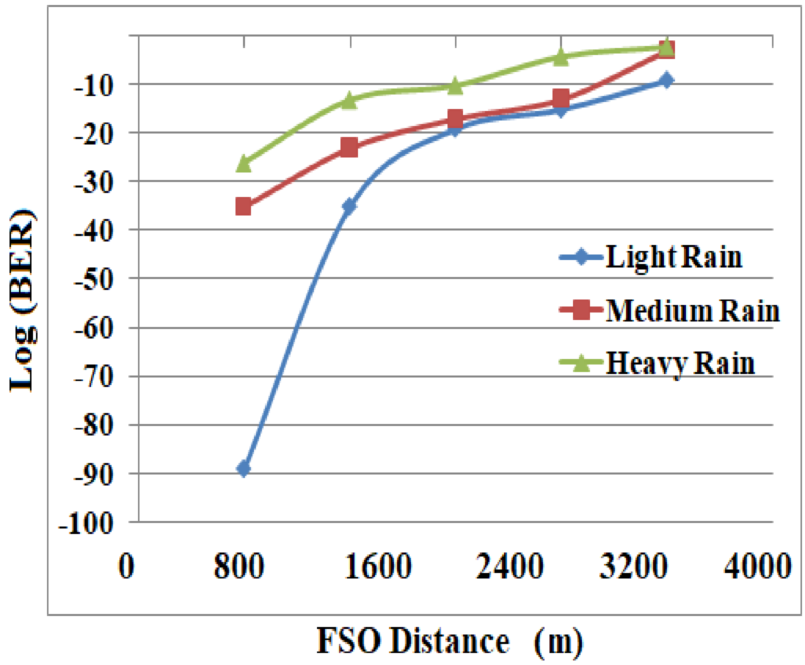
Figure 5 Performance analysis of MIHP-OCDMA-FSO system for haze at varied distances in terms of (a) Q factor (b) Log BER



(a)

Figure 6 (a) Performance analysis of MIHP-OCDMA-FSO system for Rain at varied distances in terms of Q factor

Figure 6 (a) depicts the performance of system at different link lengths in terms of Q for light rain, medium rain and heavy rain. Distance is varied from 800 m to 4000 m with the difference of 800 m. It is perceived that rain has greater performance deteriorating effects than haze due to high attenuations. Major factors to degrade the performance of the systems are attenuation, dispersion and light scattering. It is observed that maximum distance of 4000 m with Q factor 5.63 is covered for light rain where distance in case of medium rain and heavy rain is 3200 m (7.11) and 2400 m (6.01) respectively.

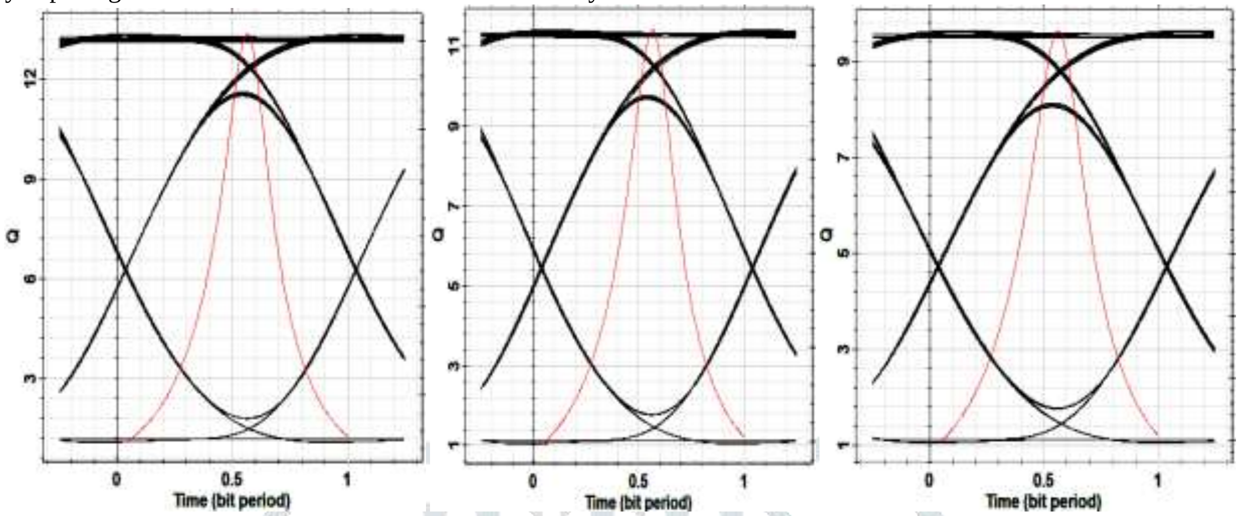


(b)

Figure 6 (b) Performance analysis of MIHP-OCDMA-FSO system for Rain at varied distances in terms of Log BER

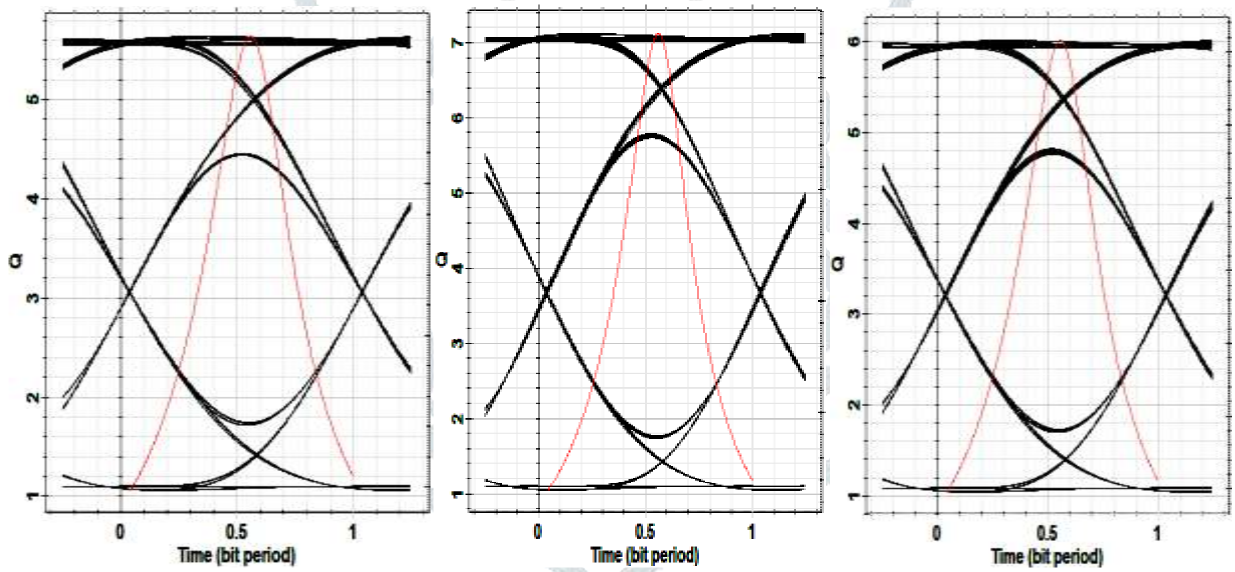
Performance of the system is compared for different rain conditions such as light rain, medium rain and heavy rain in terms of Log BER. Figure 6 (b) depicts the performance of system at different link lengths in terms of Log BER for light rain, medium rain and heavy rain. Distance is varied from 800 m to 4000 m with the difference of 800 m. It is perceived that rain has greater performance deteriorating effects than haze due to high attenuations. Results revealed that maximum distance of 4000 m with Log BER -9 is covered for light rain where distance in case of medium rain and heavy rain is 3200 m (-13) and 2400 m (-10) respectively. Figure 7 represents the eye diagram of analysis system for different weather condition.

Figure 7 (a) depicts the Eye diagrams at 10 km in case of clear weather, Figure 7 (b) represents the Eye diagram at distance 10 km in case of light haze, Figure 7 (c) represents the Eye diagram at distance 10 km in case of heavy haze, Figure 7 (d) represents the Eye diagram at distance 4000 m in case of light rain, Figure 7 (e) represents the Eye diagram at distance 3200 m in case of medium rain and Figure 7 (f) represents the Eye diagram at distance 2400 m in case of heavy rain. Results revealed that in clear weather eye opening is maximum and it is lowest in case of heavy rain.



(a) (b) (c)

Figure 7 Eye diagrams incase of (a) clear weather at 10 km (b) distance 10 km in case of light haze (c) distance 10 km in case of heavy haze



(d) (e) (f)

Figure 7 Eye diagrams incase of (d) distance 4000 m in case of light rain (e) distance 3200 m in case of medium rain (f) 2400 m in case of heavy rain

IV. CONCLUSION

A 5 Gbps multi-identity high power codes (MIHP) based integrated OCDMA and free space optical communication is analysis. Simultaneous 10 users are catered 5 Gbps over diverse link lengths (2 km-10 km).Diverse weather instabilities such as clear weather, light haze, heavy haze, light rain, medium rain and heavy rain are studied over FSO link and results are observed in case Q factor and BER. Comparison of double diagonal weight and multi-identity high power codes has been accomplished. It is perceived that MIHP codes performs superior than DDW codes due to high SNR because the potential of MIHP codes is high to carry high power levels. BER of 10-41 is observed in case of MIHP codes at 10 km and for the same distance; DDW codes provide BER of 10-25. . Moreover it is observed that analysis system works for maximum distance of 4000 m with Log BER -9 for light rain where distance in case of medium rain and heavy rain is 3200 m (-13) and 2400 m (-10) respectively in case of MIHP codes. Where in case of DDW codes maximum distance of 2500 m with Log BER -9 for light rain where distance in case of medium rain and heavy rain is 2200 m (-9) and 1500 m (-9) respectively. Therefore analysis system is enhanced in terms of Q factor and BER.

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