Study of performance and analysis of SDM for free space optical satellite communication systems

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Abstract- This paper proposes an M-ary SDM based free space optical satellite communication by using lasers and analyses its system performance. The system is simulated under the different intensities of atmospheric turbulence and order of modulation to derive a correlation between bit error rate of link and power of transmission. The results show that M-ary SDM modulation order increases with an increase in turbulence intensity, performance of the SDM modulation and SDM optical links degrades. This allows for the evaluation of performance and parameters for further development of SDM optical links in satellite laser communication by providing a reference.

Keywords – M-ary, SDM, satellite laser communication

I. INTRODUCTION

Microwave communication methods, which are mostly utilised by satellites, with the increase in amount of data transmitted by various spacecrafts, are currently not able to meet the high-capacity satellite communication required with advancement in technology that have enabled high resolution data collection such as synthetic aperture radar, prompting the growth of the laser communication systems. Satellite laser communication technology transmits data at a pace 100 times faster than conventional wireless microwave communication techniques. It will be able to meet the growing requirement for higher data transmission rates in space along with accurate real-time performance and could be made the primary mode of space communication as it provides the best solution to the existing problem of data transmission. Furthermore, it showcases high frequency, large bandwidth, and narrower beam directivity which may enable safe and high-speed transmission satellite laser communication[1]. However, the satellite laser link performance is influenced by combined impacts of unstable atmospheric losses, transmission loss, transmitter to receiver alignment inaccuracy, and impairment of satellite laser communication channel which could be caused due to dispersion due to particles such as atmospheric gases, radiation, dust, precipitation, and fog. Frequency selective atmospheric scattering channels are prone to fading, also known as frequency selective fading effect[2]. To overcome this effect, space division multiplexing (SDM) modulation is used, which utilizes multiple spatial channels. SDM is a multimode modulation method in which a particular frequency is utilized for a specific amount of time. Advantages include good performance through unstable atmospheric condition, fast data rate, strong anti-interference ability and high spectrum efficiency[3-5]. This paper suggests and examines the laser based free space optical satellite communication system based on SDM for its performance parameters, under various situations of air turbulence and M-ary SDM modulation order, the correlation between power of transmission and bit error rate of link is simulated[6-10].

II. SYSTEM REPRESENTATION

The block diagram of the proposed SDM based satellite laser communication system is represented in Figure 1. In this system, the data is generated by the signal generator and then received by the serial to parallel data converter for serial to parallel data conversion, which divides the serial data into N parallel data, the converted parallel data is then subjected to SDM modulation, then this modulated signal is operated on by Inverse Fourier Transform (IFFT). IFFT converts the data's spectrum expression into the time domain, then assigns bits to each carrier, and plots them with respect to the amplitude and phase of the carrier signal. Guard interval are specific amount of time used to separate each transmission to eliminate intersymbol interference (ISI) between the transmitted signals as much as possible. This can be implemented in two different ways: Adding a cyclic prefix (CP) is one effective technique and setting all the symbols representing guard interval to value of zero is another method. In the first method, at the beginning of each cycle of transmission, the head of the frame is added with a portion of the symbol. Then, in the space channel, the transmission takes place to Photodiode (PD) and optical receiving antenna by optically modulating signal with SDM on to the optical transmitting antenna via a laser.

By studying the characteristics of channel between the ground station to satellite and other optical links of communication in inter-satellite, a correlated perceptual optical system channel is introduced, and these correlations are applied in conjunction with framework of practical implementation. In order to successfully analyse and study optical communication links in space, effects of turbulence in atmosphere have to be taken into account for the given system as a primary concern. There are numerous statistical models proposed to describe fluctuations in optical intensity caused by unstable nature of the atmosphere, including the negative exponential distribution, Gamma-Gamma distribution model and lognormal distribution. The parameters mentioned above accurately complies to the characteristics of turbulence in atmosphere, allowing them to describe the variations more accurately. In addition to turbulence caused due to atmosphere, the pointing errors caused due to misalignment between the transmitters and receivers of the optical links between two systems, affect the variations in the intensity of optical signals.

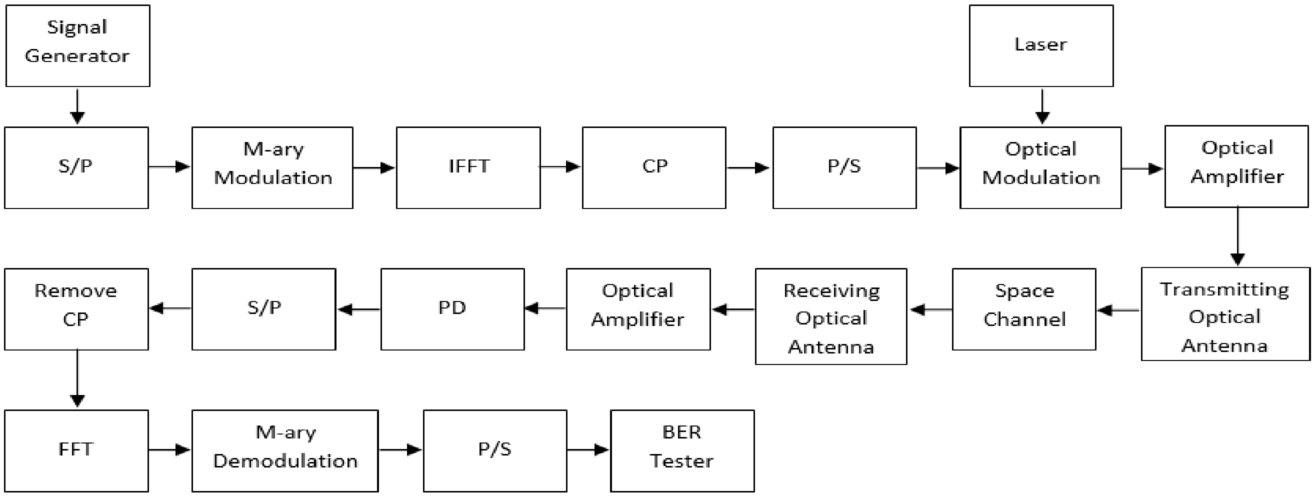

Fig. 1. M-ary SDM based satellite laser communication system

On the receiver side, upon receiving of data, it is first subjected to serial to parallel conversion, and then to the removal of cyclic prefix added at the transmitter end, before the signal is operated using FFT to convert the signal back to frequency domain from the time domain after which demodulation is performed, the demodulator or on the receiving end, the operations are basically the reverse to that of transmitting end in order to extract the original signal generated[13-14]. We are now using specific numbers to explain the modulation and demodulation progress. After performing IFFT on the input symbols and adding a cyclic prefix, n symbol represented data is now represented by n+l symbol data. To put it simply, at the beginning of each data streams, the last n symbols are being added. The operation of Inverse Fast Fourier Transform on a modulated signal generates the SDM signal at baseband. The size of an SDM symbols are fixed. Assume T is the required period of an SDM symbol. Tg, represents length of a cyclic prefix which are added at the beginning of every SDM symbol, which is created by adding the last l symbol to the beginning of a SDM symbol. In order to be useful, Tg must always be greater than impulse response time of the channel. The following formula is given for each carrier:

$$v(t) = \sum_{k=-n}^{n} C_k \, exp\,(j2\pi f_k t), 0 \le t \le T \qquad (1)$$

Where, frequency of SDM symbol's complex exponentials is represented by f_k=k/T and 2n+1 is the number of carriers. This signal sent through an optical channel only after it is upconverted.

At the receiver, it is down converted, the cyclic prefix is removed, the timing is synchronised and FFT is used.

III. EXPERIMENTAL RESULTS

The parameters are initialised as follows for the simulating the system: The signal generator or the source generates a pseudo-random sequence with a bit rate of 1P bit/s. The modulation of message signal onto different carriers in the time-domain is carried with the help of 1024 point IFFT variations. The guard interval is one-eighth the length of the parallel output sequence from IFFT. A DFB semiconductor laser serves as the light source. The spectral width of a laser is 15MHz.

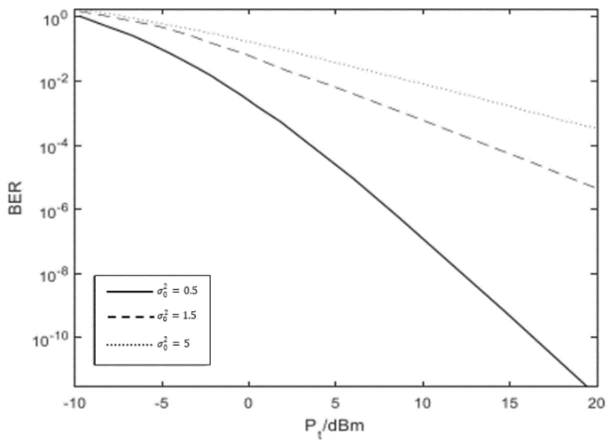

Figure. 2. The correlation of the BER and power transmitted P_t for variation in strengths of turbulence.

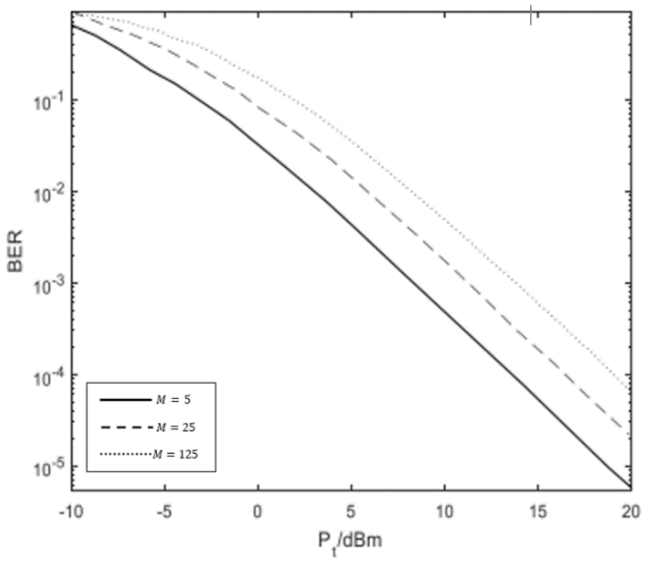

Figure. 3. The correlation of BER and power transmitted P_t in M-ary modulation.

Figure 2 depicts study between the average of total bit error rate(BER) and transmit power under the influence of turbulence caused due to atmospheric conditions for a SDM link. Figure 3 depicts the study between an SDM link's average bit error rate(BER) and transmit power when M-ary modulation is used by the carrier signal. Strength of turbulence σ_0^2, is set at 0.5, 1.5 and 5 respectively. M is set at 5, 25and 125 respectively. As shown in Figure 3, as M increases, average bit error rate (BER) of SDM optical connection increases also the parameters determining performance of communication system degrades; however, when transmission power is increased, average bit error rate (BER) of the connection could depreciate in value, which in turn improves parameters of performance for communication. The degree of improvement achieved upon scaling the power of transmission is on par or same for different base M-ary SDM modulation.

V. CONCULUSION

The study is conducted on M-ary SDM based free space optical satellite communication by using lasers with an objective to derive a correlation between the bit error rate(BER) of SDM optical connection and transmitted power is investigated by virtue of various conditions such as varying turbulence in atmosphere at different intensities and M-ary order of modulation. The experimental results draw attention to the fact that as there is increase turbulence intensity, the M-ary order of modulation also increases to improve signal strength and the performance of SDM optical links/connection degrades continuously. The findings of this study acts as a remark for further studies in evaluating the performance based on SDM satellite laser communication.

VI. REFERENCES

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