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Experimental Investigation of Pulse Modulation Schemes in Free Space Optical Communication Under Turbulence

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Abstract. When we allow an optical beam to travel through Free Space Optical (FSO) Communication system, the optical beam faces immense issues due to so many factors such as diffraction, scattering, signal absorption, etc. These factors put down the quality rate of FSO communication system. In this experimental analysis, an artificial controlled turbulence chamber was built to create FSO communication with optical source laser. The signal to be tested is generated with the help of a LASER source, is allowed to pass on through the immense turbulent states by employing various pulse modulation schemes such as Pulse Amplitude Modulation (PAM), Pulse Duration Modulation (PDM), and Pulse Position Modulation (PPM) separately. In all the three modulation schemes, the parameters such as phase Jitter and 3dB bandwidth are observed and the observed values are compared. The results show that phase jitter value is 9.8414 radians for PPM. Also, PPM has the highest ability to overcome jitter than the remaining two schemes under high atmospheric turbulence parameters. However, in the case of Bandwidth utilization, PDM modulation reduces its utilization to 12MHz.

Keywords. Free Space Optical communication; PPM; PAM; PDM; Phase Jitter; 3dB bandwidth, performance, measurement.

1. Introduction

In the current scenario, free space optical (FSO) communication focuses a deep attentiveness in optical community because of its immeasurable advantages such as huge amount of data transmission over unlicensed spectrum, wireless communication technique used to send and receive various types of data at faster rate, larger bandwidth, gives high performance in optical networks, etc. [7-12]. Although, along with the advantages FSO faces certain troubles due to the presence variety of turbulent factors present in the environment which effects its performance [1,13]. FSO chooses Laser as

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an optical source compared to other sources, but the transmitted signal over atmosphere get distorted due to turbulence. Experimental demonstration of OOK and BPSK-SIM modulation schemes on scintillation in fixing the threshold value on an FSO system is shown in [2,14]. The presence of turbulence causes error in the received data [13]. By properly observing the jitter values the degree of deviation of the received signal from the actual transmitted can be found out clearly. A variety of statistical models were used for studying the impact of pointing errors on FSO communication systems [5-6]. By using PPM, a good channel capacity can be achieved in an optical link [15]. In PAM, data is transmitted by varying the amplitudes of the individual pulses. In PDM, long pulses expend considerable power while bearing no additional information [18]. Here, phase jitter, time jitter, and 3dB parameters are used for FSO analysis experimentally by using various modulation schemes for propagating the data in a specially designed artificial turbulence chamber for FSO communication and the outputs are compared. Description of problem and FSO test bench are discussed in section 2. The results and discussion is highlighted in section 3 and section 4 deals with conclusion [19-21].

2. Problem Description and FSO Test Bench

The quality of transmitted data can be degraded due to the fluctuation in phase and intensity of laser beam [14, 18]. The range of FSO link, atmospheric attenuation and pointing error under various weather conditions have been studied [4]. Compensation of phase fluctuation is very essential to achieve a very high data rate. Scintillation, beam spreading and beam wandering are some other problems that affects laser beam [17]. Therefore, proper studies and compensation techniques are important so that the reliability of data transmission through FSO can be increased.

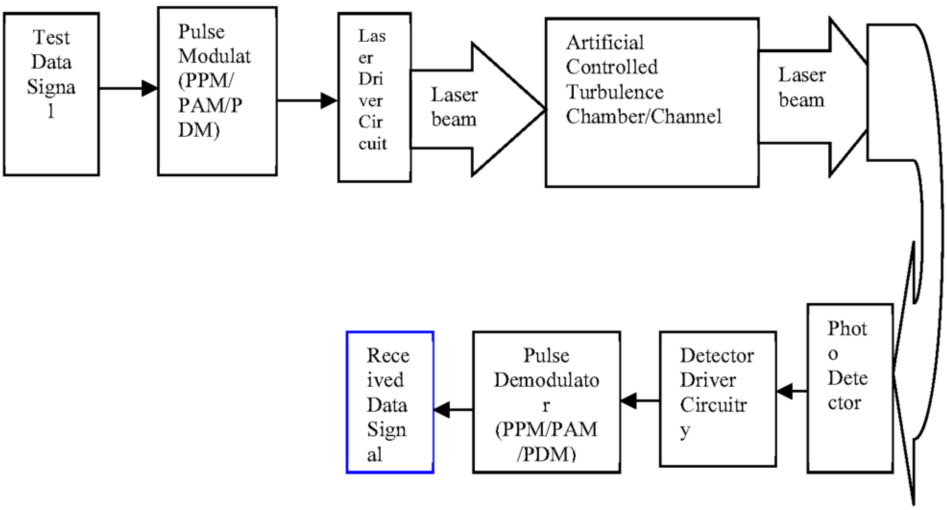

Figure 1. Free Space Optical Communication Test Bench Experimental Setup

The test bench setup used for experimenting FSO system is shown in Figure 1, which consists of a transmitter-receiver for transmission and receiving data, and channel for communicating. In the transmitter section, signal generator is used to generate test data. The modulating signal frequency is 4 KHz. The modulation scheme may be either PPM or PAM or PDM. The laser source is driven by the modulated signal and the wavelength of laser ranges between 650-680nm. The test bench maintains line of sight between transmitter and receiver ends. The separation between both ends are maintained as 125cm throughout the experiment. The optical beam after modulation travels through the turbulence chamber. The turbulence chamber is artificially filled with various atmospheric turbulence components such as smoke and fog. The LASER beam affected by the various turbulence inside the chamber are allowed to receive by the PIN photo detector. By applying the demodulation in a proper manner, we can measure the phase and time jitter of the received signal with the help of a spectrum analyzer. The experiment is repeated for each pulse modulation technique namely PPM, PAM, and PDM. Turbulence chamber dimension is 125x25x25 cm^3. The temperature inside the chamber is regulated in such a way that it will always maintains 45 degrees and also, from the beginning till the end of the experiment turbulence conditions were maintained constant.

3. Results and Discussion

The FSO system explained above is tested experimentally by the proposed artificial turbulence chamber. In this experiment, the frequency spectrum with center frequency is 1.5GHz and span of frequency is 3GHz are considered. First, the system is tested by giving test data as input to different modulation scheme (PAM, PDM, PPM) under without turbulence. The output readings are taken using standard spectrum analyzer, which is connected with the demodulation kit. Figure 2 shows the phase and time jitter measurement using spectrum analyzer for different modulation scheme without turbulence. The phase and time jitter measurement in PAM with no turbulence is shown in figure 2(a) and the output shows that 9.8598 radians and 1.0955nsec is the value for phase and time jitter. Same analysis method and modulation scheme is employed in PDM with no turbulence and figure 2 (b) represents the result. It is monitored that the 9.854 radians and 859.55psec is the value for phase and time jitter. When using PPM, 7.7359 radians and 1.0972nsec is the value for phase and time jitter, which is shown in figure 2 (c).

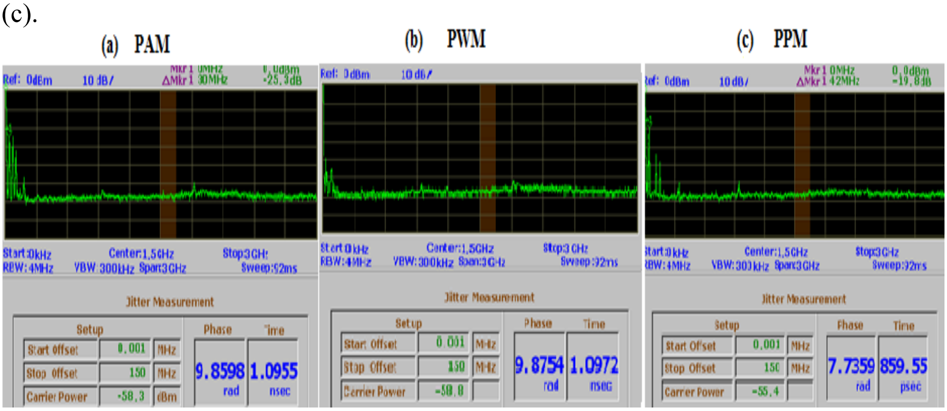

Figure 2. Phase and time jitter without turbulence, a) PAM b) PDM c) PPM

Figure 3 represents the phase and time jitter measurement using spectrum analyzer for different modulation scheme with turbulence. The phase and time jitter measurement in PAM with turbulence is shown in figure 3(a) and it is monitored that 10.445 radians and

1.1605nsec is the value for phase and time jitter. Same procedure is done using PDM in the presence of turbulence, which is shown in figure 3 (b), the observed value is 10.195 radians and 1.1329psec for phase and time jitter. When using PPM modulation, the noted phase jitter is 9.8414 radians and time jitter is 1.0934nsec and it is representing in figure 3 (c). Next, bandwidth utilization is analyzed experimentally for all the different three modulation schemes without and with turbulence.

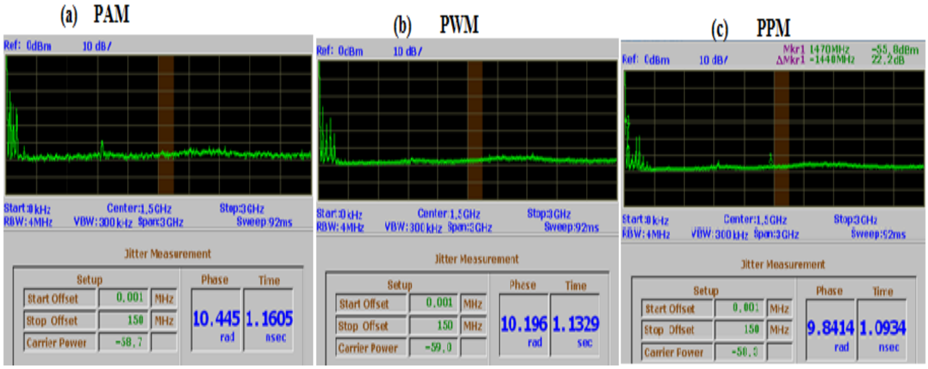

Figure 3. Phase and time jitter with turbulence, a) PAM b) PDM c) PPM

The 3dB measurement of bandwidth utilization is measured using spectrum analyzer for different modulation scheme under without turbulence conditions. The 3dB bandwidth measurement using PAM without turbulence is observed as 30MHz.The same method applied for PDM and PPM under without turbulence, the bandwidth is 30MHz for PDM and 12MHz for PPM. The 3dB measurement of bandwidth utilization with turbulence condition shows that using PAM, the bandwidth is 30MHz. For PDM and PPM under turbulence conditions bandwidth is 12MHz and 30MHz.The experimental results of different pulse modulation techniques with and without turbulence of phase and time jitter is shown in table 1. In which it is clearly shows the phase jitter is very low in PPM when compared with PDM and PAM under with and without turbulence conditions. From this it is clearly analyzed and verified that the huge amount of data transmission over unlicensed spectrum, wireless communication technique with high performance computing will send and receive various types of data at faster rate, larger bandwidth, gives high performance in optical networks, etc. Therefore, in optical high performance networks, using laser as optical source and selecting PPM modulation scheme for modulating laser source, we can achieve high data transmission rate with less jitter.

Table 1. Comparison of Modulation schemes

Parameter	PAM		PDM		PPM	
	Without Turbulence	**With Turbulence**	**Without Turbulence**	**With Turbulence**	**Without Turbulence**	**With Turbulence**
Phase Jitter	9.8598rad	10.445rad	9.8754rad	10.196rad	7.7359rad	9.8414rad
Time Jitter	1.09555nsec	1.1605nsec	1.0972nsec	1.1329sec	859.55picosec	1.0934nsec
3dB Bandwidth	30MHz	30MHz	30MHz	12MHz	12MHz	30MHz

4. Conclusion

It is apparent from the results that over dense atmospheric turbulence, the signal strength immunity level of PDM and PAM are very low than that of PPM. Very high phase jitters are observed in PDM and PAM making them in efficient modulation techniques for consistent data transmission over FSO. Results shows that PPM is the best modulation technique based on Jitter analysis. In the point of view of bandwidth utilization, PDM is the best choice than PPM, but in the case of phase and time fluctuation, PPM is considerable modulation choice. Therefore, in optical high performance networks, using laser as optical source and selecting PPM modulation scheme for modulating laser source, we can achieve high data transmission rate with less jitter. Work is currently in progress to increase the length of channel and by applying other digital modulation techniques to identify Jitter performance.

Annexure:

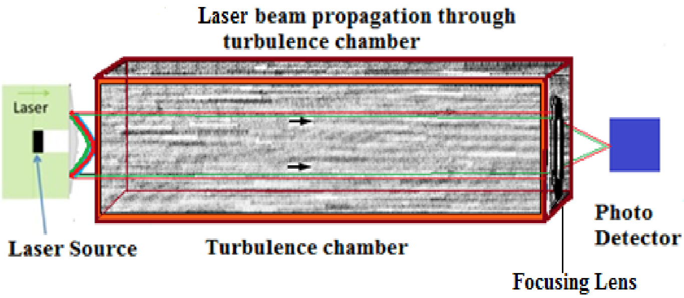

Figure 4. Laboratory FSO experimental setup

Table 2. Experimental System Parameters

Laser Source	Turbulence Chamber	Focusing Lens	Photo Diode
Laser color: RED Wavelength:650nm±10 Laser max. output power: 3mW Grade: Class IIIA(Betatx) Size :65 x 14 x 14mm.	Dimension:125x25x25cm^3 Artificial Turbulence: Fog and Smoke Condition: 45^{0}C	Type: Convex type Material=UV fused silica with refractive index value n is 1.4585. Lens diameter=12.5mm . Edge thickness =4mm. Focal length : 13.1mm	Silicon NPN type :2N5777

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