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Bit Error Performance Analysis of Intensity and Pulse Modulation for Satellite Laser Communications

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Abstract

This paper presents that communication quality of two modulation techniques IM and BPPM is analyzed for satellite-to-ground laser communication. Laser communication have many advantages for aspects of high data rate, security, electromagnetic interference, frequency license, size reduction. Usually, intensity modulation and pulse position modulation are being used in practical satellite laser communication experiments, such as NASA, ESA, NICT projects. To verify appropriate modulation technique for satellite laser communications, laser transmission systems applied two common modulation methods are designed and simulated. The performances of two modulation schemes are evaluated based on bit error performance for low earth-orbit satellite laser transmission system with variable data rate. As a result, it was verified that binary PPM modulation has high power efficiency about 3dB compare to intensity modulation method in every data rate.

Keywords - Satellite communication, Laser communication, Optical wireless communication, Communication signal processing.

I. INTRODUCTION

Conventional satellite radio communication has many limitations aspects of interference, bandwidth, and security, while laser communication has many advantages such as robustness to electromagnetic interference, ultra-wideband, inherent security, and size-reduction. Also, laser has a single wavelength and is excellent in straightness, and high power, narrow beam width is maintained even in long distance transmission, and power efficiency is excellent. Data transmission capacity of satellite increases rapidly every year. Specially, it is expected that the resolution of observation satellite sensors will increase gradually and the observation width and observation frequency will increase. Recently, satellite laser communication has been put into practical use as a technical alternative to satellite radio communication [1]-[4]. Attempts to apply lasers to satellite communications have not been long. In the future, laser-based satellite communication technology can be used in various fields that require broadband data transmission.

Most common modulation schemes are intensity modulation and pulse position modulation (PPM) for satellite laser communications. NASA has performed experiment using pulse position modulation (PPM) at 622 Mbps data transmission between space-to-ground (LCRD project) [5]. ESA has performed experiment using intensity modulation (IM) at 50 Mbps data transmission between GEO satellite and ground station (SILEX project) [6]. NICT has performed experiment using intensity modulation (IM) at 50 Mbps data transmission between low earth-orbit satellite and ground station (OICETS project) [7],[10].

In this paper, we have evaluated and compared the bit error performance of two common modulation methods used in practical satellite-to-ground laser communication system through computer simulation. Satellite-to-ground laser transmission system is described in section 2. In section 3, the computer simulation results and analysis are presented. Lastly, the conclusion is given in the section 4.

II. DESIGN OF SATELLITE LASER TRANSMISSION SYSTEM

Two satellite laser transmission systems are designed to simulate bit error performances. Firstly, the block diagram of satellite-to-ground laser transmission system using binary pulse position modulation (BPPM) is shown in figure 1.

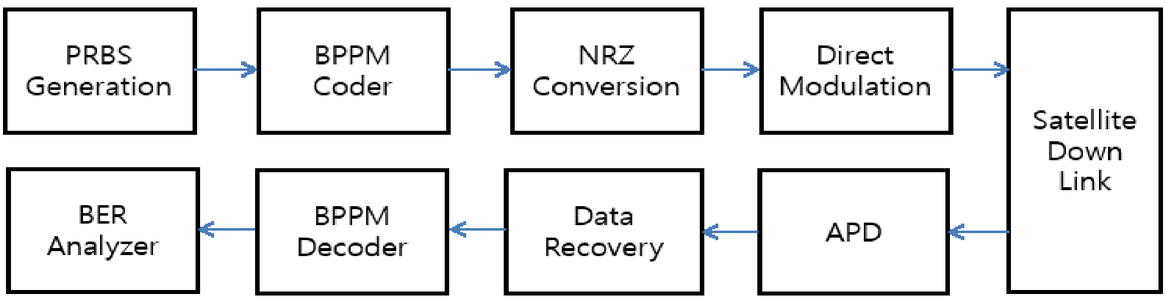

Fig. 1. Block diagram of BPPM satellite laser transmission system

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The PRBS (Pseudo Random Bit Sequence) block generates the data to be transmitted. The second block generates sequence of bits using binary PPM. The third block is NRZ pulse generation from BPPM coder output. The fourth block is direct modulation function. The optical receiver comprises of APD (Avalanche Photo Diode), data recovery and BPPM decoder. The optical signal is converted back into electrical signal and recovered binary data by data recovery function and BPPM decoder function. The last block is BER analyzer, which measures bit error performance.

In second, configuration of laser transmission system using intensity modulation is shown in figure 2. The first block generates the data to be transmitted. The second block is NRZ pulse generation from PRBS generator. The fourth block is direct modulation function. The optical receiver blocks comprise of avalanche photo diode, data recovery. The optical signal is converted back into electrical signal and recovered binary data by data recovery function. The last block is BER analyzer.

Fig. 2. Block diagram of IM satellite laser transmission system

III. SIMULATION AND DISCUSSION

The simulation was performed using optic simulation software [10]. Figure 3 shows the layout diagram of designed satellite-to-ground laser transmission system using intensity modulation. Figure 4 shows the layout diagram of designed satellite-to-ground laser transmission system using binary PPM modulation. They were simulated for different data rates at 25, 50, 75, 100 Mbps. The laser path consists of 707km of free space path and 20km of atmospheric path. Distance of atmospheric path is defined as 20 km from ground. Parameters of satellite link were referred to NICT's experiment system for simulation [7] and the common parameters were summarized in table 1.

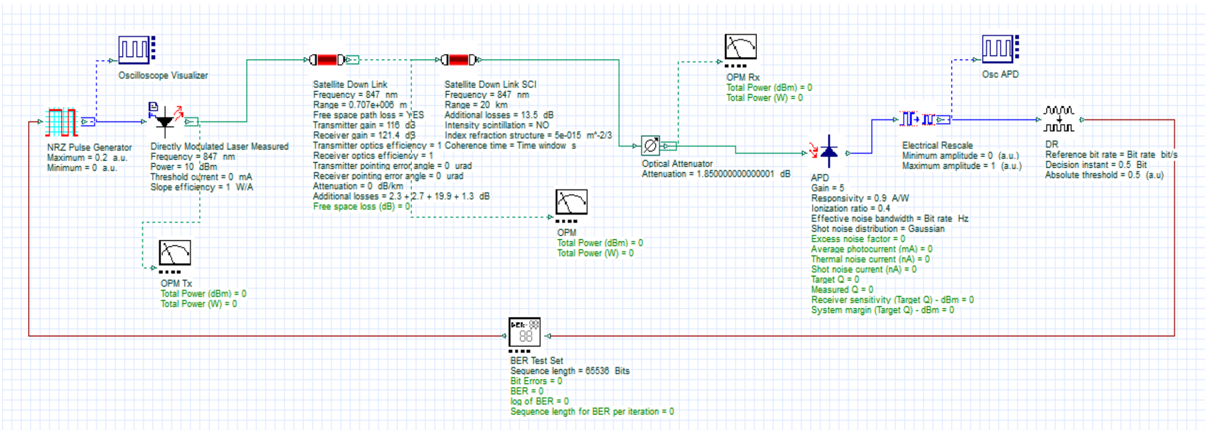

Fig. 3. Layout diagram of IM/DD simulation

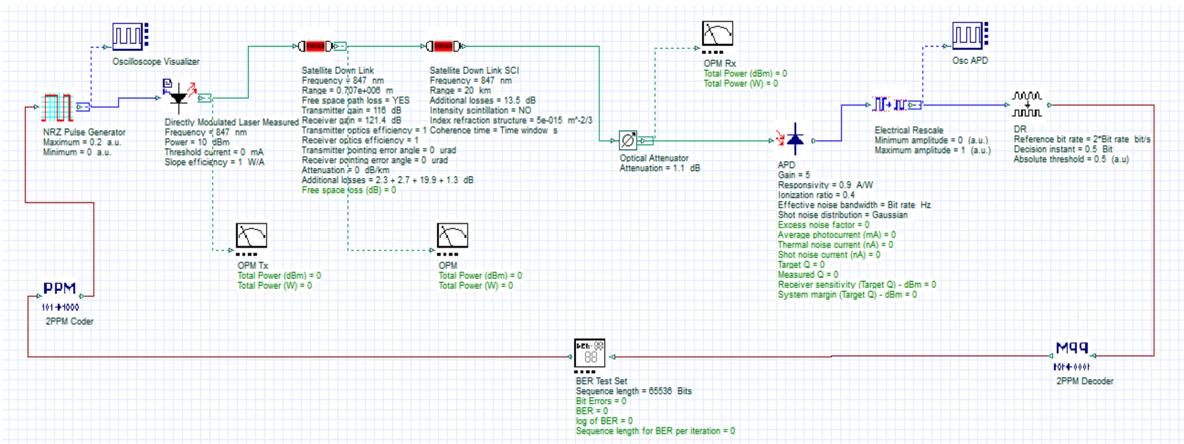

Fig. 4. Layout diagram of BPPM simulation

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Table 1. Simulation parameters

Parameters	Values
Laser frequency	847nm
Laser output power	10dBm
Distance	727Km
Tx aperture diameter	20cm
Rx aperture diameter	11.8cm
Data Rate	25,50,75,100 Mbps
APD gain	5

Figure 5 shows bit error performance of intensity modulation and binary pulse position modulation at different rates of 25, 50, 75, 100Mbps. Figure 6 and 7 show BER difference of two modulation methods at same rate.

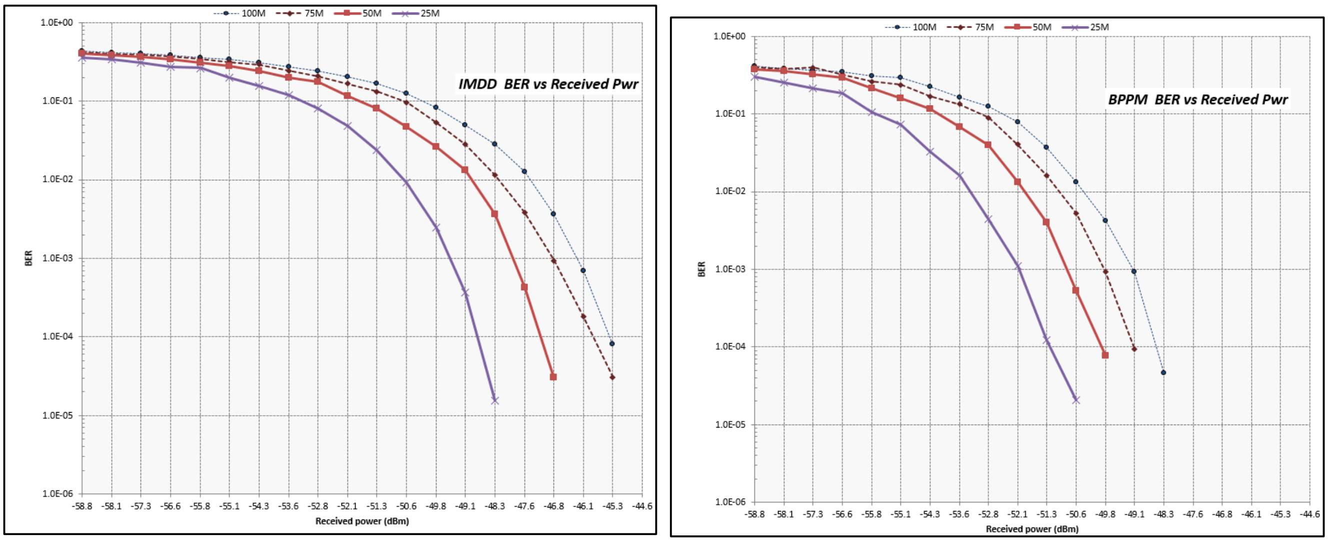
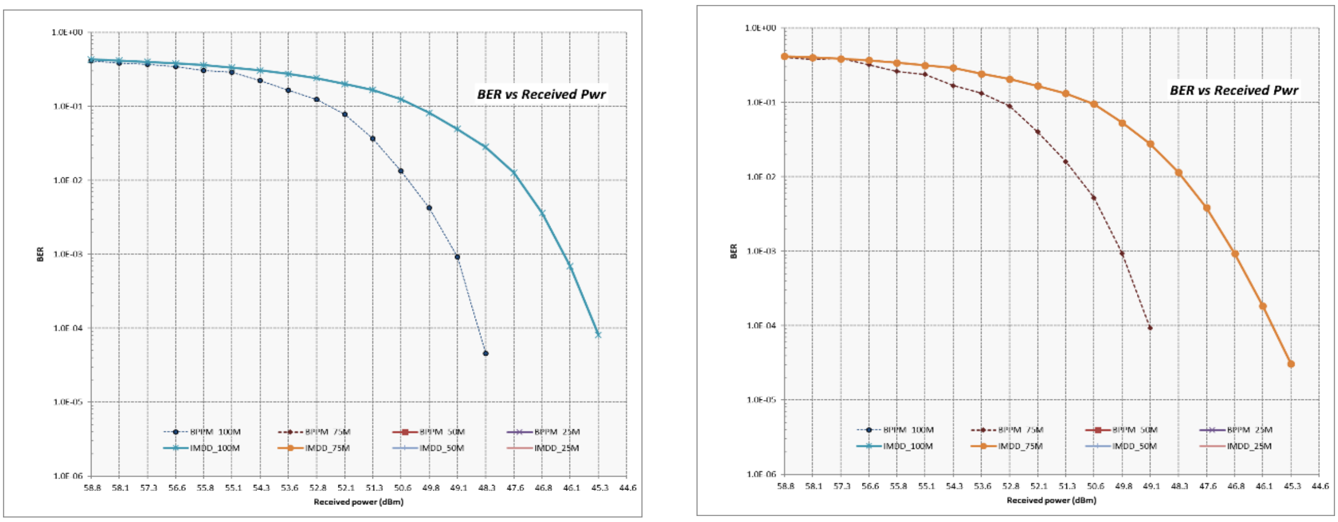
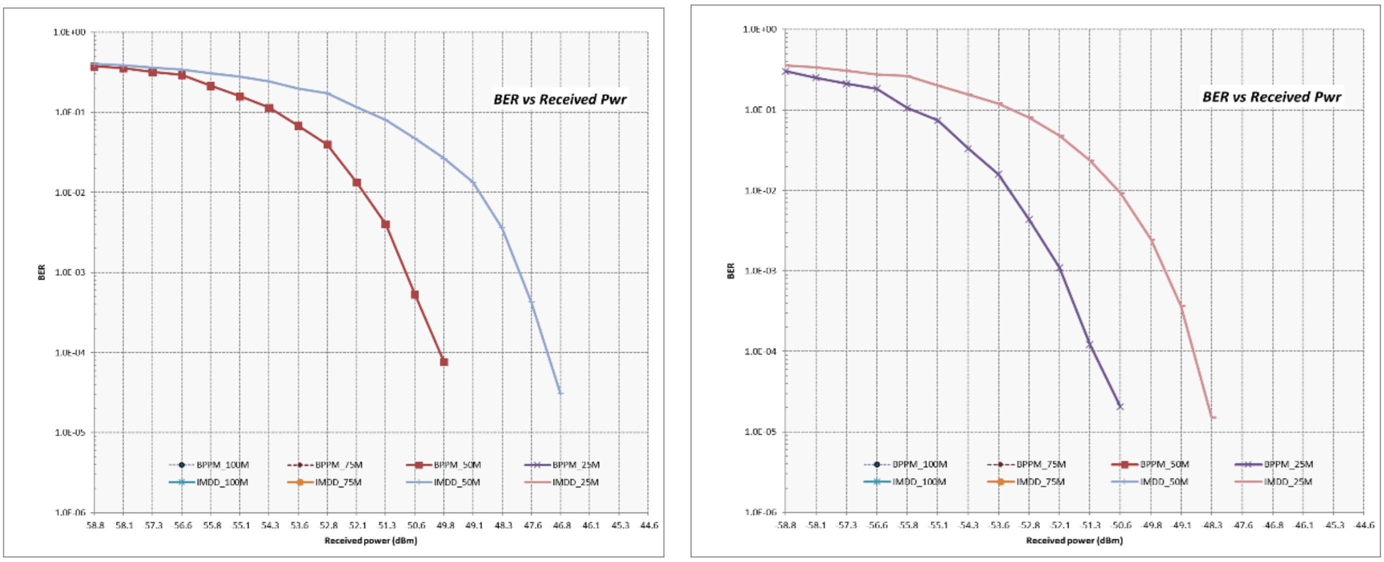


Fig. 5. BER of two modulation methods at different data rates



(a) 100Mbps (b) 75Mbps

Fig. 6. BER difference between IM and BPPM at 100Mbps, 75Mbps



(a) 50Mbps (b) 25Mbps

Fig. 7. BER difference between IM and BPPM at 50Mbps, 25Mbps

The simulation results showed that bit error performance of BPPM was better than intensity modulation under same conditions. BER difference values are 3.2dB at 100Mbps, 3.3dB at 75Mbps, 3.1dB at 50Mbps, and 2.8dB at 25Mbps. About 3dB of difference observed between IM and BPPM at BER of 1.0E-04. In other words, binary PPM has high power efficiency compare to intensity modulation. As a result, binary PPM can be appropriate modulation technique for satellite laser transmission that has big transmission losses due to atmospheric turbulence. In addition, intensity modulation system may suffer synchronization loss if a sequence of zero is encountered. In BPPM system, pulse is present in the symbol frame regardless of the transmitted symbol.

IV. CONCLUSION

In this paper, BER performances are analyzed for satellite laser transmission systems applied common two modulation techniques. In practical satellite-to-ground laser communication system, intensity modulation and binary pulse position modulation are commonly used. To compare performance between intensity modulation and binary PPM, two satellite transmission systems were designed and simulated. The simulation results showed that BER of binary PPM was better than intensity modulation under same conditions. It is verified that binary PPM system has high power efficiency about 3dB compare to intensity modulation system. In conclusion, binary PPM technique can be used as suitable modulation method for power efficient satellite laser transmission. In the future, we will study more powerful transmission methods that use channel coding to improve BER performance.

ACKNOWLEDGEMENTS

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