

Performance Evaluation of Intensity Modulation for Satellite laser Communication

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ABSTRACT

This paper presents performance analysis of intensity modulation for LEO satellite laser transmission. Satellite laser communication systems have advantages such as very high bandwidth, inherent security, robustness to electromagnetic interference, unlicensed frequency band. For high speed data transmission from observation satellite to ground system, satellite laser communication has been put into practical use as a technical alternative to satellite radio communication. In this paper we have evaluated the performance of intensity modulation for LEO satellite laser transmission system with variable data rate and distances. The performance of the system was evaluated on basis of quality-factor and bit-error-rate through computer simulation. It was shown as distance of transmission increases, the Q-factor decreases, and the value of BER increases as distance increases.

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

I. INTRODUCTION

Satellite radio communication has many limitations such as radio interference, transmission capacity, and communication security, while laser communication has many advantages such as robustness to electromagnetic interference, ultra-wideband, inherent security, and size-reduction. Current satellite radio communication reaches the limit of massive data transmission capacity of satellite which 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. Studies are being actively conducted in advanced

countries such as the United States-NASA, Europe-ESA and Japan-NICT. Currently, the NASA has plans to carry out 2.88Gbps data transmission experiment between space-to-ground. In the future, laser-based satellite communication technology can be used in various fields that require broadband data transmission such as weather observation, disaster monitoring, and environmental monitoring, etc.

The 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. However, transmission quality is degraded by various factors such as system loss, geometric loss, misalignment loss, atmospheric loss. In this paper, we have evaluated the performance of satellite laser communication applied to attenuation loss only. The performance of the system is evaluated on basis of qualitative parameters such as Q-factor and BER through Optisystem software simulation.

II. SATELLITE LASER TRANSMISSION SYSTEM

The configuration of LEO satellite laser transmission system is shown in figure 1.

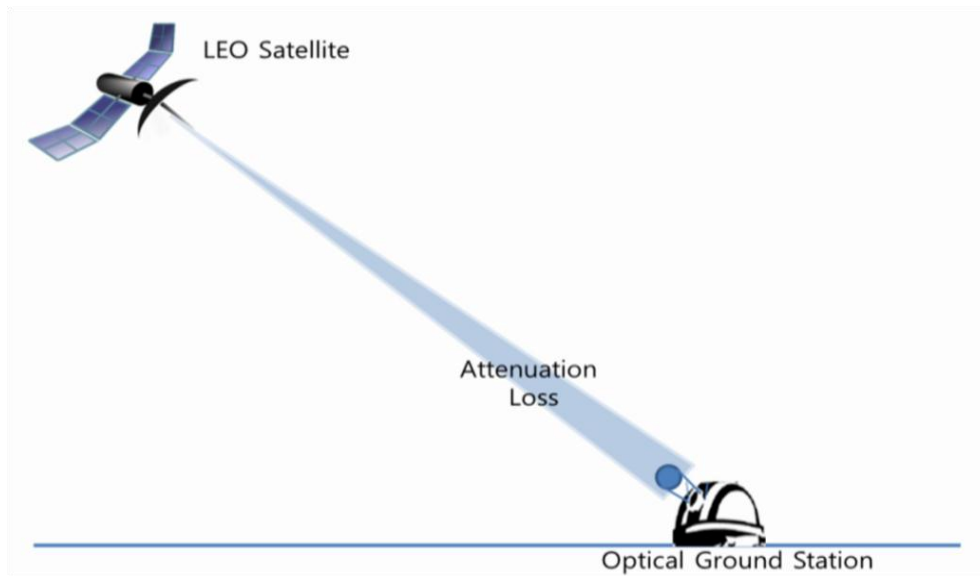


Figure 1. Concept diagram of satellite laser transmission

The channel loss is caused by various factors such as system loss, geometric loss, misalignment loss, atmospheric loss. Consequentially, they appear in the form of signal attenuation at receiver station. The degradation of the communication quality is up to 20dB[1].

The block diagram of satellite laser transmission system for simulation is shown in figure 2. For performance analysis, from satellite to ground transmission link is considered.

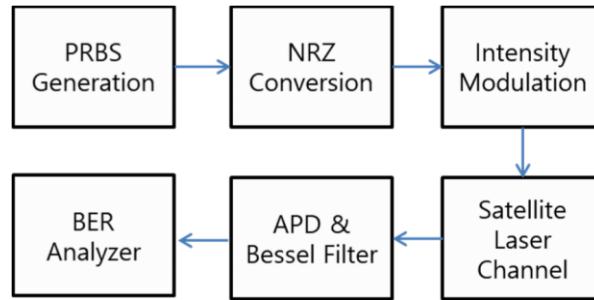


Figure 2. Block diagram of satellite laser transmission system

The PRBS generation block generates the random data to be transmitted. The second block is NRZ pulse conversion which encodes the data from PRBS generator. The third block is intensity modulation by using MZ modulator with CW laser which operates on wavelength of 1,550 nm because of low attenuation characteristics in laser transmission. Satellite laser channel block inserts attenuation loss. It consists of two sub-blocks such as free space pass sub-block and atmospheric pass sub-block. The optical receiver comprises of a photo detector followed by a low pass Bessel filter. The optical signal is converted back into electrical signal. The APD (avalanche photodiode) is used because of its high gain property. The last block is BER analyzer which gives Q-factor and BER values.

III. SIMULATION AND DISCUSSION

The computer simulation is performed using Optisystem software. Figure 3 shows the layout diagram of the proposed satellite laser transmission scheme. It has simulated at different data rates at 1, 5, 10 Gbps for transmission range of 500, 1000, 1,500km. The transmission channel is considered as laser channel with attenuation loss only. The laser channel is separated in free space path block and atmospheric path block. Low-earth-orbit distance is from 500km to 1,500km and distance of atmospheric path is regarded as about 20 km from ground.

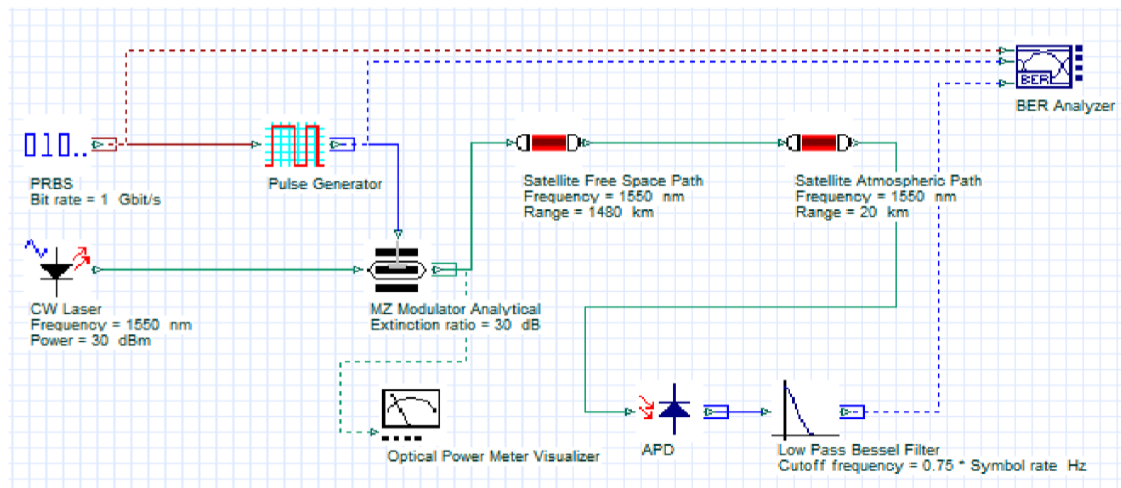


Figure 3. Layout diagram of simulation software

The simulation results were summarized in table 2 and table 3. It showed that as the range of transmission increases, the quality factor of the system decreases. As the distance of transmission increases, the Q-factor decreases, and the value of BER increases as distance increases. Each eye diagrams are shown in figure 4, 5, 6. These eye diagrams showed that eye diagrams have larger window at short distances and they have less distortion. The summarized simulation parameters are listed in table 1.

Table 1. Simulation parameters

Parameters	Values
Laser frequency	1,550nm
CW power	30dBm
Modulator Extinction ratio	30dB
Tx aperture diameter	20cm
Rx aperture diameter	20cm
Attenuation of atmospheric path	0.75 dB/km
APD gain	3

Table 2. Max. Q-factor values with variable bit rates at 500, 1000, and 1500km

Bit Rate (bps)	500km	1,000km	1,500km
1G	75.459	20.475	11.714
5G	43.890	15.308	7.463
10G	39.863	12.715	6.422

Q-factor characterizes the quality of a digital signal from an analog point of view, therefore it is judged as a signal-to-noise ratio. In practical measurements can be determined the difference of a signal level from a noise level.

Table 3. Min. BER values with variable bit rates at 500, 1000, and 1500km

Bit Rate (bps)	500km	1,000km	1,500km
1G	0	1.768e-93	5.293e-32
5G	0	3.365e-53	4.178e-14
10G	0	2.376e-37	6.618e-11

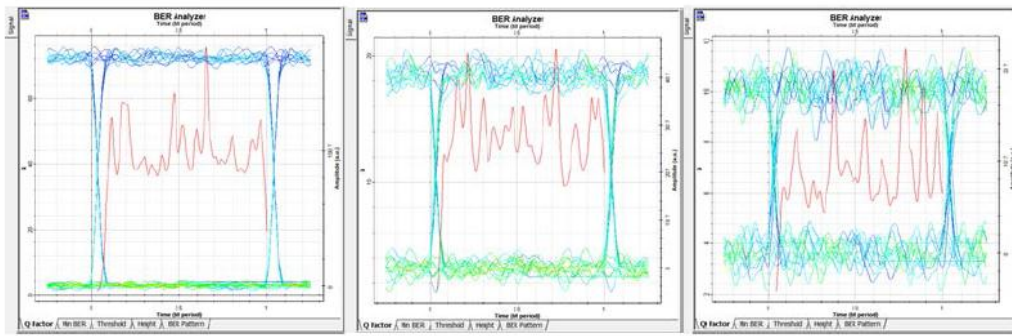


Figure 4. Eye diagrams for 1Gbps at different distances, 500km, 1000km, 1500km

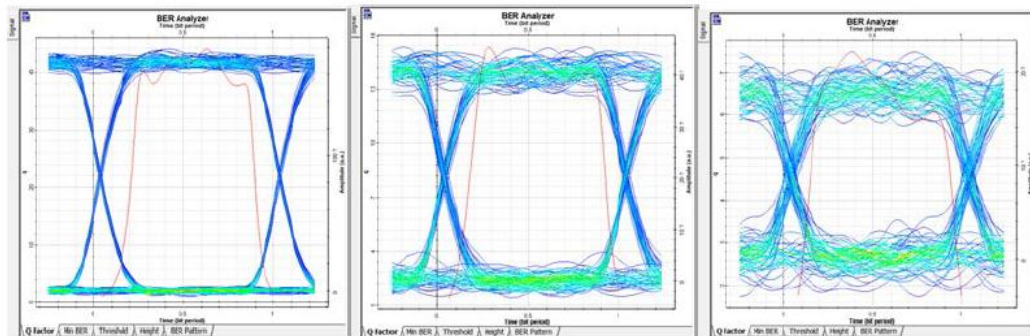


Figure 5. Eye diagrams for 5Gbps at different distances, 500km, 1000km, 1500km

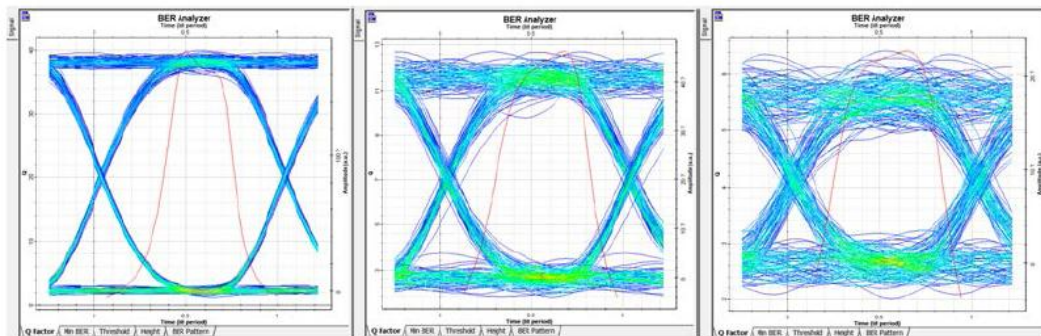


Figure 6. Eye diagrams for 10Gbps at different distances, 500km, 1000km, 1500km

IV. CONCLUSION

In this paper, performances of satellite laser transmission system were analyzed under simple conditions of attenuation loss and low orbit. It has evaluated at different transmission distances of 500, 1,000, 1,500km and data rates of 1, 5, 10Gbps. Simulation results shows that as distance of transmission increases, the Q-factor decreases, and the value of BER increases. In the future, we are going to analyze the performance of satellite laser communication by considering more actual channel environments.

ACKNOWLEDGEMENTS

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