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Original Scientific Paper

ANALISYS OF THE INFLUENCE OF COMMUNICATION PARAMETERS OF FSO CHANNELS ON THE RECEPTION QUALITY

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ABSTRACT

In this paper, the signal transmission in the Free-Space Optics (FSO) communication system using the software package OptiSystem 7.0 is analyzed. The influence of parameters FSO (Free-Space-Optics) channels (Range, Attenuation, Beam Divergence, Transmitter Loss, Receiver Loss, and Additional Losses) on the reception quality is considered. The reception quality is analyzed according to the values of BER (Bit Error Ratio) and Q factor. Graphics and tables of the changes of BER and Q factor depending on the parameters of FSO are given. Also, the eye diagrams for the characteristic parameter values are given.

Keywords: Free-Space Optics (FSO), BER (Bit Error Ratio), Additional Losses, Q factor.

INTRODUCTION

Some specific applications require relatively quick point-to-point high bandwidth and low cost connectivity. Typically, such applications aggregate multi-type traffic at an access enterprise point and transport it to another point located from hundreds of meters to few kilometers away. This technology does not use fiber on the link but a laser beam in free space and therefore it necessitates line of sight; typically from rooftop to rooftop. Because this technology does not need fiber installation and right-of-way licenses, it is deployed quickly and inexpensively (Kartalopoulos, 2008; Zyskind & Berry, 2002).

However, FSO (Free-Space-Optics) has a severe drawback. Laser light is severely absorbed by fog but not as much by rain. Interestingly, microwaves are affected by rain and not as much by fog. Thus, the two technologies are complementary and can work side by side. If fog is present, the microwave link switches in and if not the FSO does. FSO is preferred because it can transport much more bandwidth (more than 1 Gb/s) than the microwave link (few Mb/s) (Kartalopoulos, 2008).

FSO technology may also include multiple wavelengths thus utilizing WDM (Wavelength Division Multiplexing) technology, in which case the aggregate bandwidth is multiplied by the number of wavelengths in the beam (Agrawal, 2001; Agrawal, 2002).

FSO is already considered in satellite network applications to interconnect a cluster of satellites in a 3-D mesh topology (Kartalopoulos, 1997; Ramaswami & Sivarajan, 2002). Optical transmitters suited to this application use neodymium yttrium-aluminum-garnet (YAG) solid-state lasers. Although satellites are thousands of kilometers apart, space is free from atmospheric phenomena and exerts insignificant attenuation and thus a laser beam travels far. However, maintaining connectivity as satellites move requires good tracking. In addition, as the laser beam travels for many kilometers it diverges and thus the receiver must have a large aperture telescope, typically about 10 cm in diameter (Kartalopoulos, 2008).

Installation of FSO is relatively simpler and faster (about a day) than the typical fiber-optic network (weeks to months). FSO transceivers are installed on top of existing buildings (some deployments provide links from window to window). FSO needs no spectrum licensing since it does not use radio electromagnetic waves. It is immune to electromagnetic interference. It does not impose any hazard to life as the laser beam is few megawatts (it uses typical communication laser devices (800–1,550 nm).

FSO links are short (~ 2 km) as compared with fiber optic links (20–100 km). FSO links provide less bandwidth (~ 2.5 and perhaps 10 Gb/s) than fiber optic links, which can carry aggregate traffic exceeding Tb/s. FSO suffers from fog and heavy snow attenuation.

The attenuation and the wavelength over the FSO link is related to particle parameter $\sigma = 2\pi r/\lambda$, where it is assumed that particles are spherical with radius r. In general, the longer the wavelength, the lower the atmospheric attenuation and therefore most FSO systems prefer wavelengths at 1,550 nm over 800 nm, in addition (Kartalopoulos, 2008; Goralski, 2001).

FSO suffers from scattering caused by particles airborne in the atmosphere. Scattering is classified into three mechanisms: Rayleigh, Mie, and Geometric (Ramaswami & Sivarajan, 2002). FSO suffers from scintillation caused by air temperature fluctuations and atmospheric turbulence. However, attenuation due to scintillation is small (few dB/km) as compared with fog and snow (medium fog 30 dB/km attenuation and thick fog with >50 dB/km attenuation) (Kartalopoulos, 2008; Zyskind & Berry,

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2002). FSO requires accurate line of sight alignment. The transceiver aperture and tracking mechanisms must account for sway of tall buildings during strong winds to maintain alignment.

The output laser beams comply with the Gaussian beam distribution with beam divergences of 6 mrad for the 830 nm and 12 mrad at 1550 nm wavelengths (Pesek et al., 2010).

SYSTEM MODEL

The appearance of the network for analysis in OptiSystem (Spalevic et al., 2012) software is given in Fig. 1. It consists of an optical source, FSO channel, optical receiver, and BER analyzer. The intensity emitted by the source is 10 dBm. The system operates at a wavelength of 830 nm. FSO channel parameters are: Beam Divergence = 6 mrad, Transmitter Loss = 1 dB, Receiver Loss = 1 dB, Additional Losses = 1 dB. Range (R) is moving in the scale from 0.25 to 2 km, and Attenuation (A) has a value of 10 dB/km, 20 dB/km, 30 dB/km, 40 dB/km, 50 dB/km, 60 dB/km and 70 dB/km.

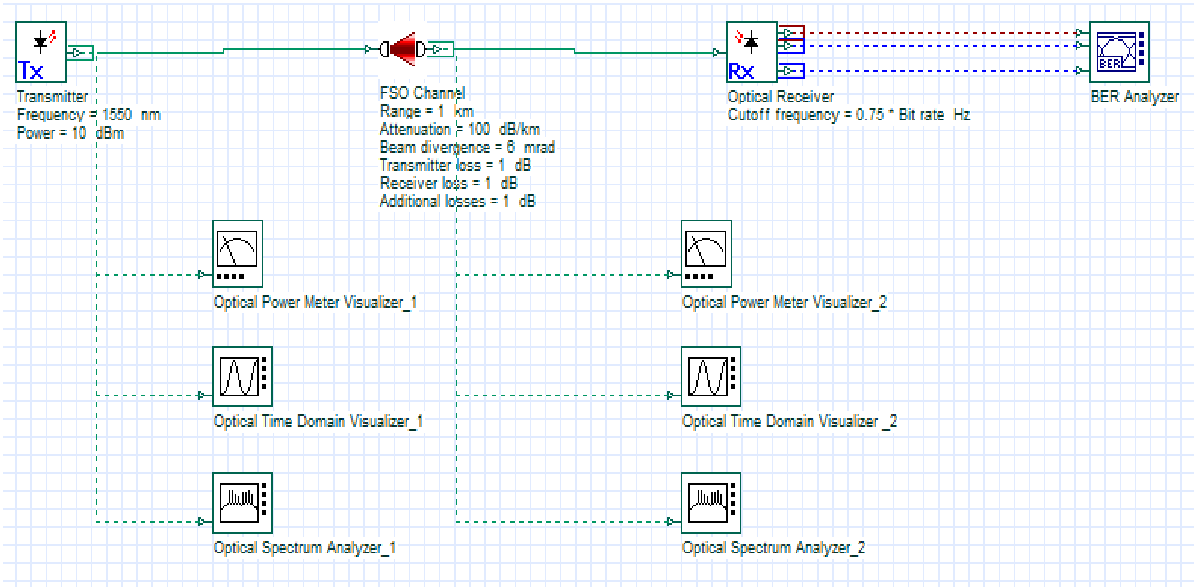

Figure 1. The change of the Q factor depending on the length of FSO channel

The criteria that is commonly applied to the optical receiver is that Bit Error Ratio (BER) is less than 10^{-9}. BER with optimal decision threshold adjustment depends only on Q parameter:

$$BER = \frac{1}{2} erfc\left(\frac{Q}{\sqrt{2}}\right) \approx \frac{\exp\left(-Q^2/2\right)}{Q\sqrt{\pi}}, \qquad (1)$$

where *erfc* is complementary error function (Abramowitz & Stegun), defined as:

$$erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^{+\infty} \exp\left(-y^2\right) dy. \qquad (2)$$

Parameter Q can be written as (Agrawal, 2001; Agrawal, 2002):

$$Q = \frac{I_0 + I_1}{\sigma_0 + \sigma_1} \qquad (3)$$

where σ_1^2 and σ_0^2 are respectively appropriate noise variance for the symbols 1 and 0. In WDM networks, the transmission quality is achieved for values of Q> 5.4.

SIMULATION RESULTS

Fig. 2 shows the change of Q factor depending on the length of the FSO channels, and for different values Attenuation (A) is shown.

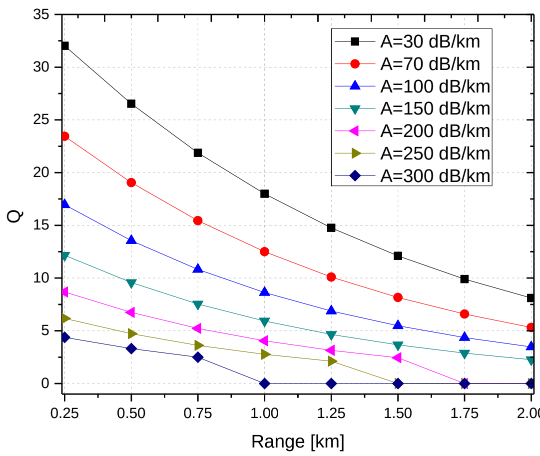

Figure 2. The change of the Q factor depending on the length of FSO channels.

This figure shows that Q factor decreases with the length of the FSO channel. If we take Q=5.4 as a border of transmission quality, we can see that only for A = 10 dB / km we have quality transmission over the entire section of 2 km. With the reduction of A = 60 dB / km and 70 dB / km, transmission quality cannot be achieved over 250 m.

Fig. 3 shows the curve of the Q factor for A=10 dB/km and for the Range 0.25 km and 1.5 km. The maximum value of the Q factor is lower for longer FSO channels.

In Table 1 are given the values of BER parameter, obtained in the simulation for the above mentioned parameters. The values of BER parameter increase with the increasing length of FSO channels and with increasing attenuation.

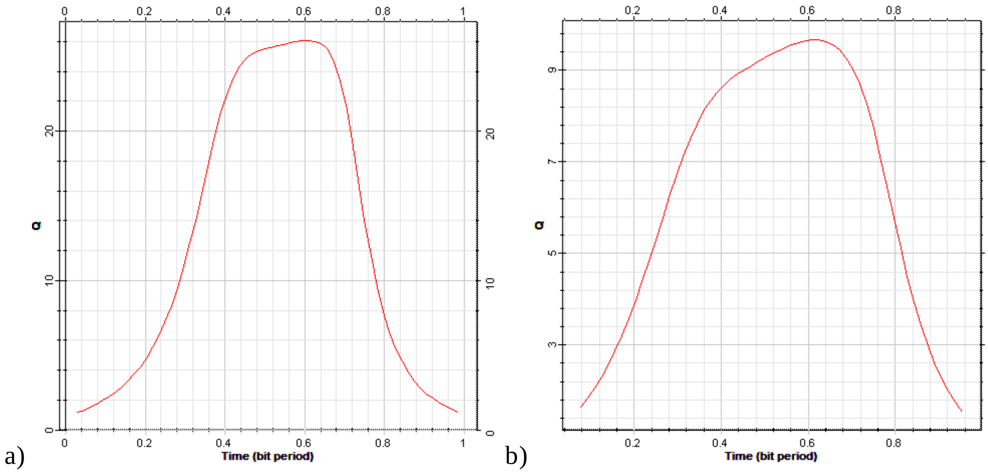

Figure 3. Diagram of Q factor for A=10 dB/km, and a) R=0.25 km, and b) R=1.5 km.

Table 1. BER values for different values of the length of FSO channels and attenuation

Attenuation	0.25 km	0.5 km	0.75 km	1.0 km
10 dB/km	2.3972E-255	2.2336E-155	1.9694E-106	1.1099E-072
20 dB/km	7.1062E-122	2.9390E-081	4.0252E-054	3.8309E-036
30 dB/km	8.9430E-065	3.8439E-042	1.4409E-027	3.2085E-018
40 dB/km	2.4592E-034	4.9831E-022	2.4326E-014	1.5470E-009
50 dB/km	1.9788E-018	7.9352E-012	8.4216E-008	2.4572E-005
60 dB/km	3.3589E-010	1.1310E-006	1.4633E-004	2.7726E-003
70 dB/km	5.9936E-006	4.6738E-004	6.1889E-003	1
Attenuation	**1.25 km**	**1.5 km**	**1.75 km**	**2.0 km**
10 dB/km	1.2298E-049	5.2744E-034	1.9268E-023	2.5616E-016
20 dB/km	2.7156E-024	1.6804E-016	2.2187E-011	5.2056E-008
30 dB/km	3.1220E-012	2.1608E-008	6.3911E-006	2.5368E-004
40 dB/km	1.5795E-006	1.2400E-004	1.9817E-003	1.1758E-002
50 dB/km	8.1565E-004	7.2588E-003	1	1
60 dB/km	1.6857E-002	1	1	1
70 dB/km	1	1	1	1

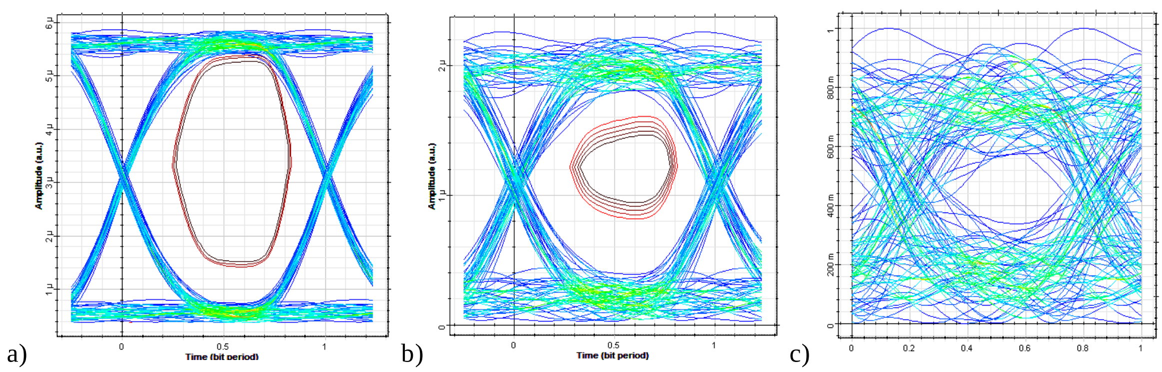

Figure 4. Eye diagram for the length of FSO channels of 0.25 km and a) A=10 dB/km, b) A=40 dB/km, and c) A=70 dB/km.

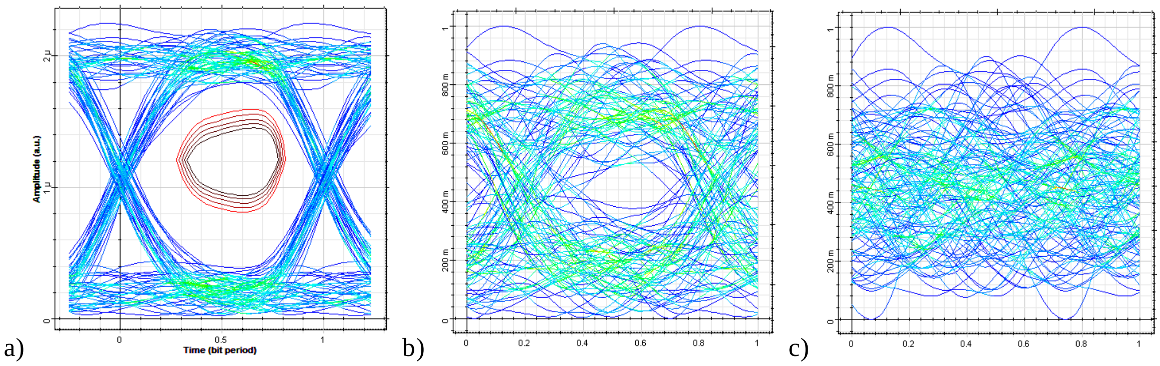

Figure 5. Eye diagram for the length of FSO channels of 1.5 km and a) A=10 dB/km, b) A=40 dB/km, and c) A=70 dB/km.

Fig. 4 gives the appearance of eye diagram for the case of the transmission of 0.25 km, and Fig. 5 gives eye diagram for the case of the transmission of 1.5 km of FSO channels. Closed curves represent sectors of BER values from 10^{-8} to 10^{-12}. The opening of the eye corresponds to a change of the Q-factor in Fig. 2, and to a change of BER parameter in Table 1.

CONCLUSION

The influence of communication parameters on quality transmission is shown by simulation of FSO channels in the software package OptiSystem. The quality of signal transmission is estimated based on the obtained value, the Q factor, and BER for different values of the length of FSO channels and Attenuation. Based on the obtained values, optimum FSO systems can be projected with high-quality signal transmission.

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