FREE SPACE OPTICS - MEASUREMENT OF TRANSMISSION QUALITY LINK PARAMETERS

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This contribution deals with the measurement of transmission quality of free space optical (FSO) link. The example of measurement results made by test FSO link is shown. Steady and statistical model of the FSO link is presented. The calculation of the link unavailability and probability of burst error are shown.

Keywords: Free space optics, FSO, transmission quality parameters, atmosphere

1. INTRODUCTION

FSO is a full duplex link that uses optical carrier wave in the atmospheric transmission medium, whose output power is concentrated to one or more narrow beams and which is designed for information transmission with digital modulation IM-OOK.

FSO systems represent good alternative of optical fiber systems for high bit rate. In case when an underground laying of an optical cable is inconvenient (temporary usage, adverse terrain, etc.) FSO is acceptable.

However, FSO are affected by atmospheric effects those can reduce link availability and may introduce burst errors, which does not occur in fiber transmission. The main atmospheric phenomena effecting beam propagation are:

- An attenuation of the optical irradiance caused by absorption, scattering and refraction on gas molecules and aerosols (fog, snow, rain)
- An attenuation of the received power caused by beam deflection (temperature or mechanical deformation of consoles)
- Short-term interruptions of the beam caused by birds- Fluctuations of optical irradiance caused by air turbulence - Background radiation

The test FSO link is placed between two university buildings in Brno (Purkynova 118 and Technicka 2). The distance between transceivers (heads of the FSO link) is 750m, test link operates with bit rate of 155 Mb/s and maximum bit error rate is 10^{-9}.

A single beam transmission and also multi beam transmission in the test FSO link are used.

The preparation of methodology of the link availability determination in whichever locality the FSO link is placed is goal of this research work.

2. STEADY MODEL OF THE FSO LINK

The power balance of the FSO link expressed by the average power level is called steady model of FSO link. It could be expressed by the power balance equation or by using graphical representation.

Steady model involves the output transmitter power P_t, receiver sensitivity P_0, propagation losses L_{prop}, transmitter and receiver optical system losses $L_{opt,t}$, $L_{opt,r}$, receiver optical system gain $G_{opt,r}$, margin of the link M and standard atmospheric attenuation $\alpha_{atm,1}$. The power balance equation in decibels is [1]:

$$P_0 = P_t + G_{opt} - L_{atm} - L_{opt} - M \ ,$$

where

$$L_{atm} = L_{prop} + \alpha_{atm,1}.V_{atm} \, ,$$

$$L_{opt} = L_{opt,t} + L_{opt,r} \, ,$$

and V_{atm} is the distance between the transmitter and the receiver in kilometers. The example of graphical representation of the power balance equation is in Fig. 1. [1]

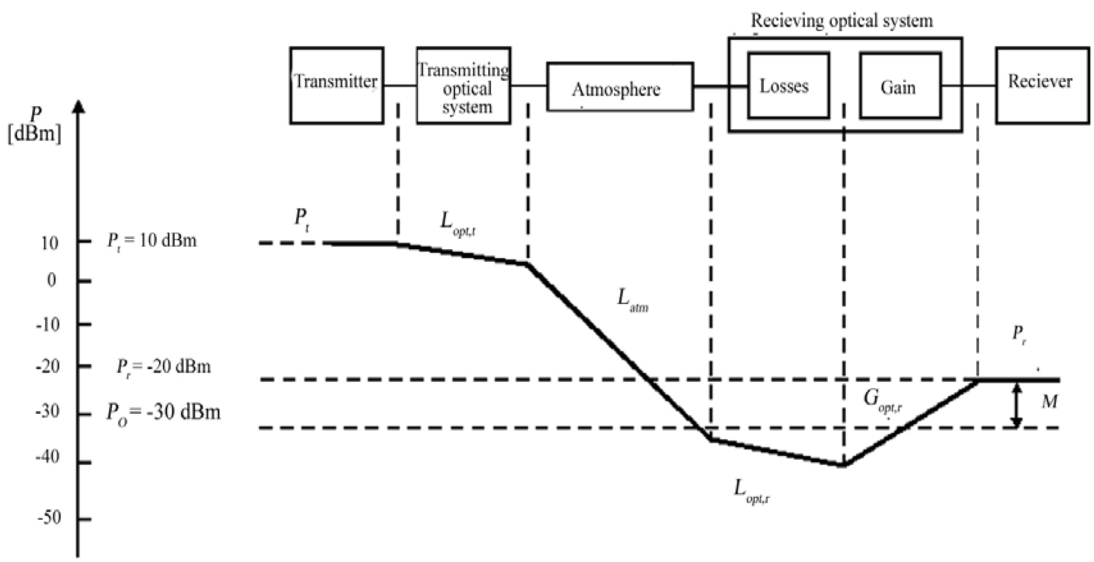

Fig.1. Graphical representation of the power balance equation (P_r - received power)

3. Statistical model of the FSO Link

Statistical model of the FSO link involves the probability density function of short-term losses (order of 10 milliseconds) $p_{short}(L)$, the probability density function of long-term losses (order of 10 minutes) $p_{long}(P_r)$ and formulas by which could be calculated probability of burst errors PBE and link unavailability P_{un} for certain link margin M.

Sometimes it happens that in certain time interval are the random losses in the atmosphere higher than the link margin M or the receiving optical power P_r is higher than maximum detecting power. In the first case the value of the receiving optical power P_r is lower than sensitivity of the receiver P_0. In the second case saturation of the receiver is coming up. It means that the value of the received optical power P_r is higher than the received power saturation level P_{sat}. See Fig. 2. [1]

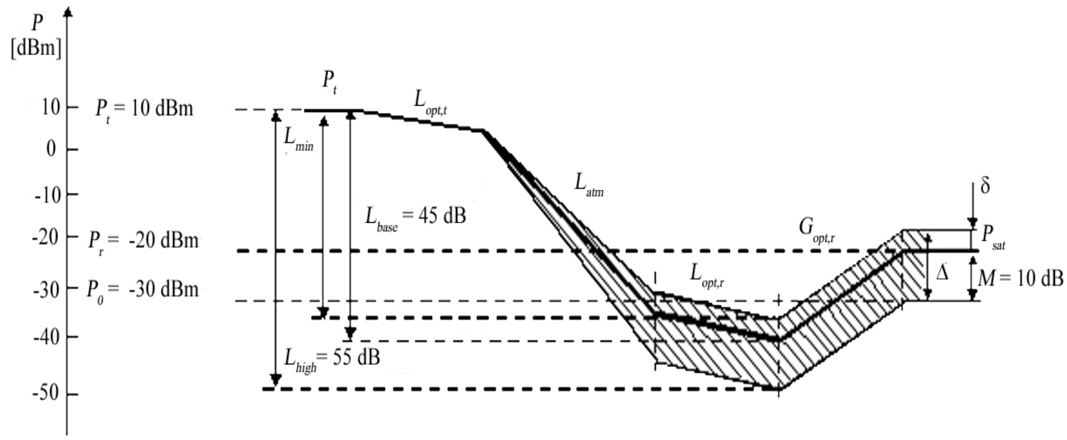

Fig. 2. Graphical representation of random losses effect on power link balance

Where: L_{base} – average losses (see steady model), L_{min} – losses "decreased" by constructive interference (received optical power level equals to the receiver saturation level), L_{high} – losses, which corresponds to the receiver sensitivity and Δ – the receiver dynamic range.

$$\delta = \Delta - M$$
$$L_{min} = L_{base} - \delta$$
$$L_{high} = L_{base} + M$$

In the both cases, that are described over, the bit error rate *BER* will increase. The probability of density function of this situation could be determined.

Long-term losses are evaluated by the link unavailability P_{un}. The experimentally obtained histogram of received power is presented in Fig. 3.

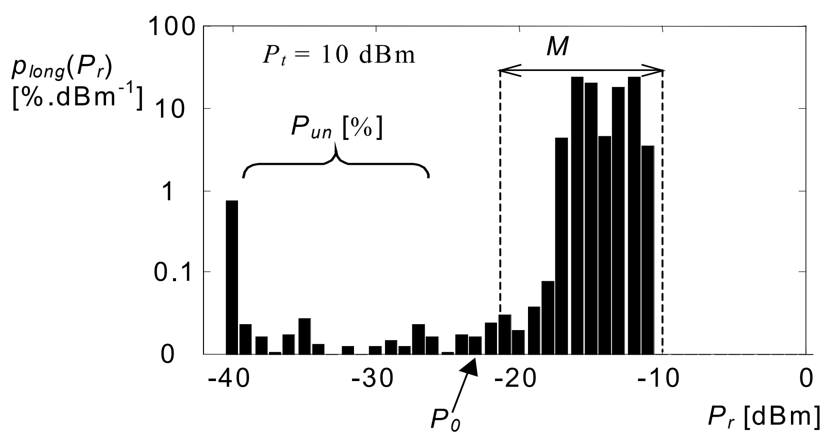

Fig. 3. Received optical power P_r histogram

The unavailability P_{un} is given by expression (see Fig. 4.):

$$P_{un} = \int_{-\infty}^{P_0} p_{long}(P_r)\, dP_r \,.$$

Long-term random losses are caused by beam refraction, scattering and refraction on gas molecules and aerosols and temperature deformation of consoles.

The short-term interruption probability *PBE* (probability of burst error caused only by events certain length τ). The short-term interruption probability *PBE* caused only by events whose length τ is more than τ_a and less than τ_b .see Fig. 4. is given by [3]:

$$PBE = \left[1 - \int_{L_{\min}}^{L_{high}} p_{long}(L)dL\right] \frac{\int_{\tau_a}^{\tau_b} \tau_i \quad pdf_\tau(\tau_i)d\tau_i}{\int_0^\infty \tau_i \quad pdf_\tau(\tau_i)d\tau_i}.$$

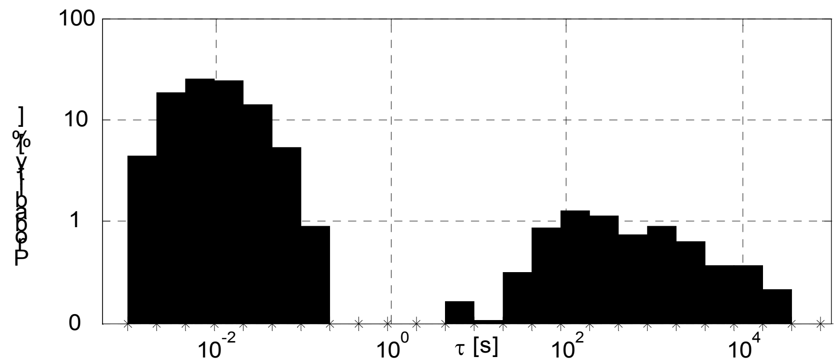

Fig. 4. Estimation of the probability density function of fade durations pdf_τ

4. Measurements

In the Fig. 5 are shown measured values on testing FSO link [3].

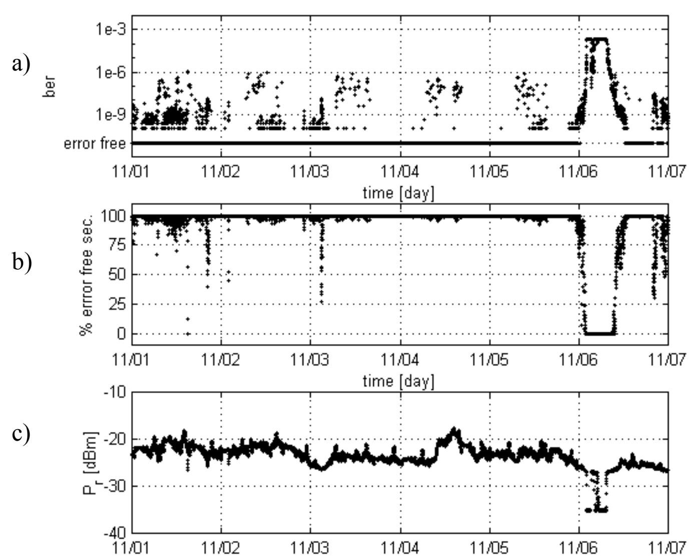

Fig. 5. The example of measurement of the quality link parameters (single beam)
a) Bit error rate, b) percent of time error free seconds, c) received optical power

In the Fig. 5 some examples of measurement that were made by the testing link are shown. This picture shows the measurement at the beginning of November last year. Bit error rate, percentage of error free seconds and level of received power were recorded. On the right side of the graph the effect of heavy fog is presented. On the left side of the graph increase of BER is presented which is affected by birds.

5. CONCLUSIONS

This contribution shows the problems concerning the FSO link design optimalization. Preparation of the methodology of link availability determination in any locality of the link installation is the goal of these measurements. Therefore it is necessary to measure the transmissions quality parameters. There is also very important to know the weather conditions like: local temperature, atmosphere pressure and humidity.

The results of measurements should give us answer which of FSO system (single beam or multi beam) for the certain application and the locality is the optimum solution.

6. ACKNOWLEDGEMENTS

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