# THE INCREASE OF AVAILABILITY OF FSO DATA LINKS BY REDUCING THE DISTANCE OF FSO'S HEADS

**Jan Šporik, Vladimír Tejkal**
Doctoral Degree Programme (1), FEEC BUT
E-mail: xspori01@stud.feec.vutbr.cz

Supervised by: Miloslav Filka
E-mail: filka@feec.vutbr.cz

## ABSTRACT

This paper deals with a function of Free-Space Optics data link (FSO) and focuses on the impact distance of FSO‘s heads on level of the received signal. The work employs discussion about effect of shortening of a distance on link margin and about reducing resistance to unwanted movement of buildings. At the theoretical level, there is described the influence of geometrical loss and atmospheric attenuation. Obtained data from test FSO are used for calculation of availability at different distances of FSO‘s heads.

## 1. INTRODUCTION

Free-space Optics data links (FSO) are commercially available and they support data rates from 1 Mb/s up to 10 Gb/s. It is an ideal solution for first mile application. FSO works in unlicensed frequency band and it is rapidly deployable in hours rather than in weeks or months. The key factor of using FSO is resistance to weathering and the weather condition in the place where it operates. Type of FSO which is used for testing is TereScope 700/G from MRV Communications, Inc. It is designed for short distance with data rate up to 1.25 Gb/s. MRV guarantees high availability and full transmitted data rate up to distance 425 m and atmosphere attenuation up to 30 dB/km, which corresponds to medium fog.

## 2. ATMOSPHERIC TRANSMISSION MEDIA

The biggest limiting factor for FSO is paradoxically using the atmosphere as transmission media. From the physical point of view, the atmosphere can be described as tenuous matter containing sets of solid and liquid particles which are spread into a gaseous environment. The troposphere, the lowest part of Earth's atmosphere, contains a substantial amount of water vapor present in the atmosphere. There are created clouds and atmospheric precipitation in the troposphere and mainly this part of the atmosphere is used by FSO. Optical power transmitted through the ATM (Atmospheric Transmission Media) is affected by these following events:

- absorption and scattering of light on molecules of gases and aerosols,
- optical intensity fluctuation due to atmospheric turbulence,
- background radiation,
- short-term interruption of the beam(e.g. a flying bird).[1,2]

## 3. LINK BUDGET FOR TERESCOPE 700/G

Single-beam TereScope 700/G link consists of two units which are utilized for optical beam transmission through the atmosphere. Every unit consists of both the transmitting and the receiving system. The transmitting system consists of LD (Laser Diode), used as optical source with overall optical power $P_{LD}$ = 16 mW, transmitting optical lens TXA (Transmitter Aperture) with diameter $D_{TXA}$ = 6.5 cm and CWTX (Cover Window of Transmitter). The Receiver consists of CWRX (Cover Window of Receiver), receiving optical lens RXA (Receiver aperture) with diameter $D_{RXA}$ = 11 cm, IF (Interferential Filter) removing useless wavelengths and PD (Photo Detector) APD (Avalanche Photo Diode) with sensitivity $P_{0,PD}$= -33 dBm.

The simplified model of FSO is shown in Fig.1. This figure shows place where attenuation of power occurs. Attenuation of imperfect coupling of LD and TXA, RXA and PD are named $\alpha_{LD,TXA}$ and $\alpha_{RXA,PD}$. Their values are not measured. Attenuations caused by the passage of light through TXA, RXA, CWTX, CWRX and IF are named $\alpha_{TXA}$, $\alpha_{RXA}$, $\alpha_{CWTX}$, $\alpha_{CWRX}$ and $\alpha_{IF}$. This attenuation and pointing loss $\alpha_{PL}$ are not measured too. This additional attenuation is determined as $\delta = \alpha_{LD,TXA} + \alpha_{RXA,PD} + \alpha_{TXA} + \alpha_{RXA} + \alpha_{CWTX} + \alpha_{CWRX} + \alpha_{PL}$ = 6 dB. Gain of RXA $\gamma_{RXA}$ is calculated by (3) and it is equal to 7.57 dB. Beam divergence *Div* is 3.5 mrad. FSO operates at wavelength of 830 to 860 nm. [3]

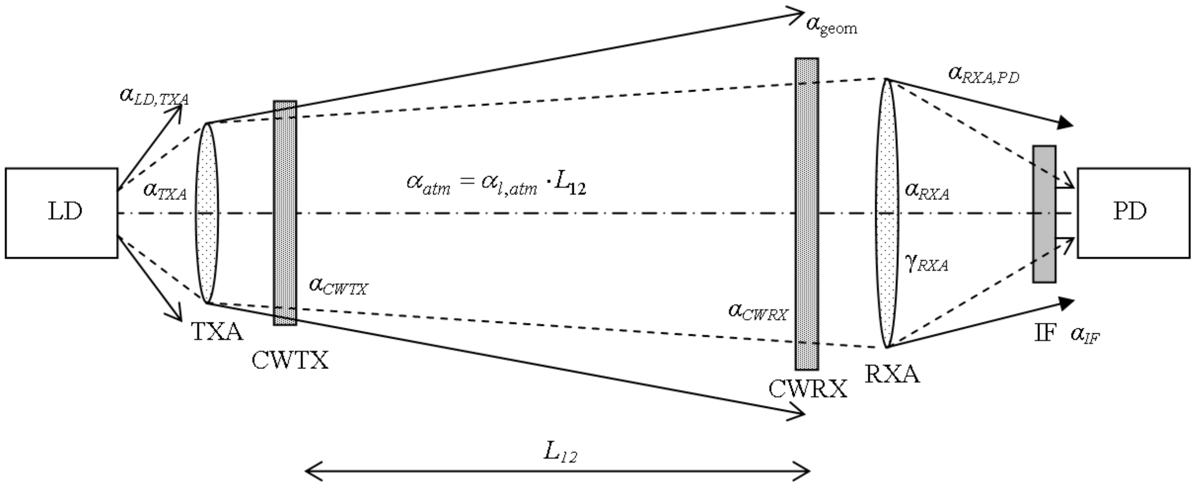


**Fig. 1:** Simplified model of FSO data link.

For used FSO is simply equation of link budget described by (1).

$$P_{PD} = P_{LD} - \alpha_T + \gamma_T \,, \qquad \text{(dBm; dBm, dB, dB)} \quad (1)$$

where $P_{PD}$ is power of received signal. $P_{LD}$ is mean power of LD, $\alpha_T = \alpha_{atm} + \alpha_{geom} + \delta$ is sum of all attenuation and $\gamma_T$ is sum of all gains.

Power $\tilde{P}_{PD}$ is received, when the atmosphere is standard clear and $\tilde{\alpha}_{l,atm}$ = 0.5 dB/km. It can be described by (2). Atmospheric attenuation $\tilde{\alpha}_{atm} = \tilde{\alpha}_{l,atm} \cdot L_{12}$ and it shows atmospheric attenuation at the distance $L_{12}$.

$$\tilde{P}_{PD} = P_{LD} - \alpha_{geom} - \tilde{\alpha}_{atm} - \delta + \gamma_{RXT} \qquad \text{(dB; dB, dB, dB, dB, dB)} \quad (2)$$

Geometrical attenuation $\alpha_{geom}$ is given by (3), where $L_0$ is auxiliary length [1].

$$\alpha_{geom} = 20\log\left(\frac{L_0 + L_{12}}{L_0}\right),\ L_0 \cong \left(\frac{D_{RXA}}{Div}\right) \qquad \text{(dB; m, m), (m; m, rad)} \qquad (3)$$

Only gain of receiving optical aperture $\gamma_{RXA}$ is contributed to the sum of gain $\gamma_T$ and it is given by (4):

$$\gamma_{RXA} = 20\log\left(\frac{D_{RXA}}{D_{TXA}}\right) + 3 \qquad \text{(dB; m, m)} \qquad (4)$$

There is shown link budget of TereScope700/G in the Fiq.2.

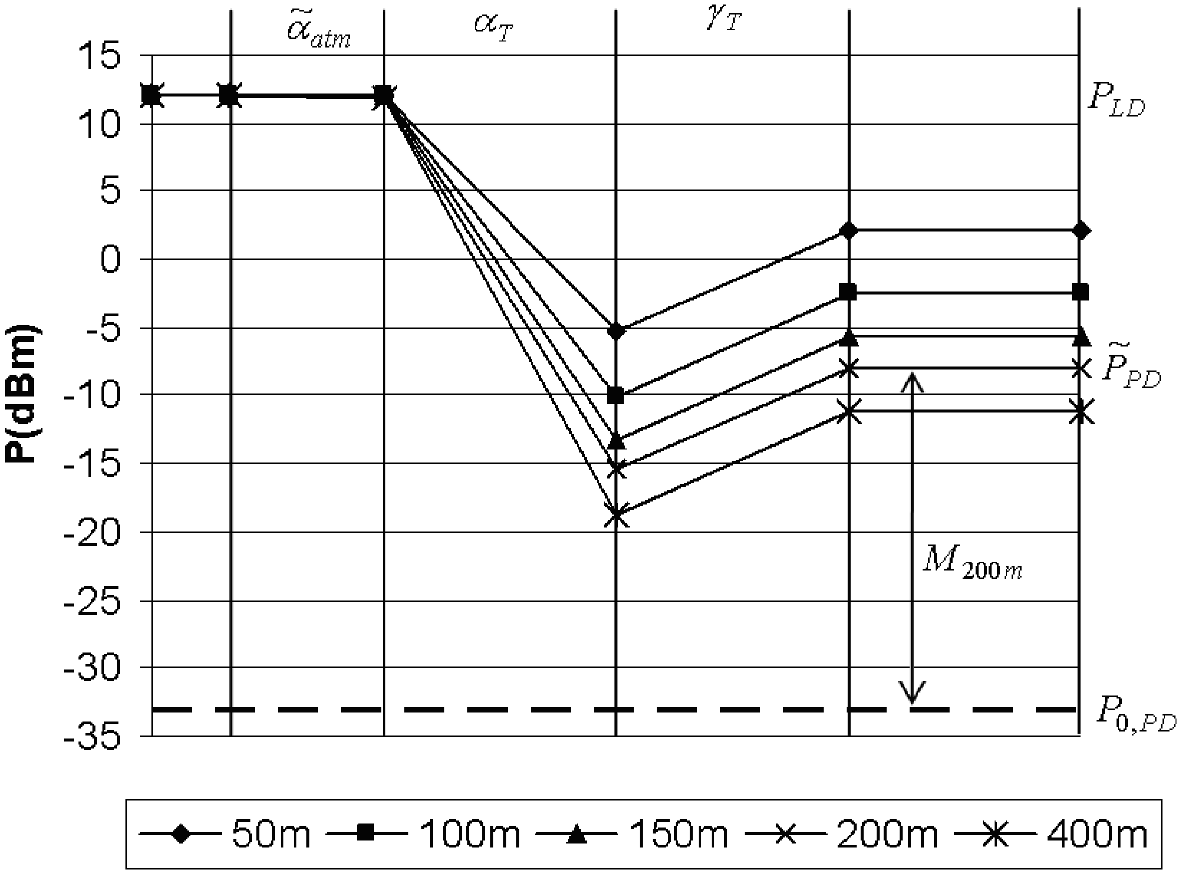


**Fig. 2:** Link budget of TereScope 700/G for different distances and $\tilde{\alpha}_{l,atm} = 0.5\ dB/km$

$P_{0,PD}$ =-33 dBm represents sensitivity of the receiver, $P_{LD}$ represents power of the LD and $M_{200m}$ is a margin at a distance of 200 m in Fig.2.

The link margin M is equal to (5) and shows resistance to weathering.

$$M = \tilde{P}_{PD} - P_{0,PD} \qquad \text{(dB; dBm, dBm)} \qquad (5)$$

The margin changes with changing distance of FSO‘s heads. It is value in dB which atmospheric attenuation can reach without the fact that receiving power goes under receiver sensitivity. It is shown in Fig.3. [1,2]

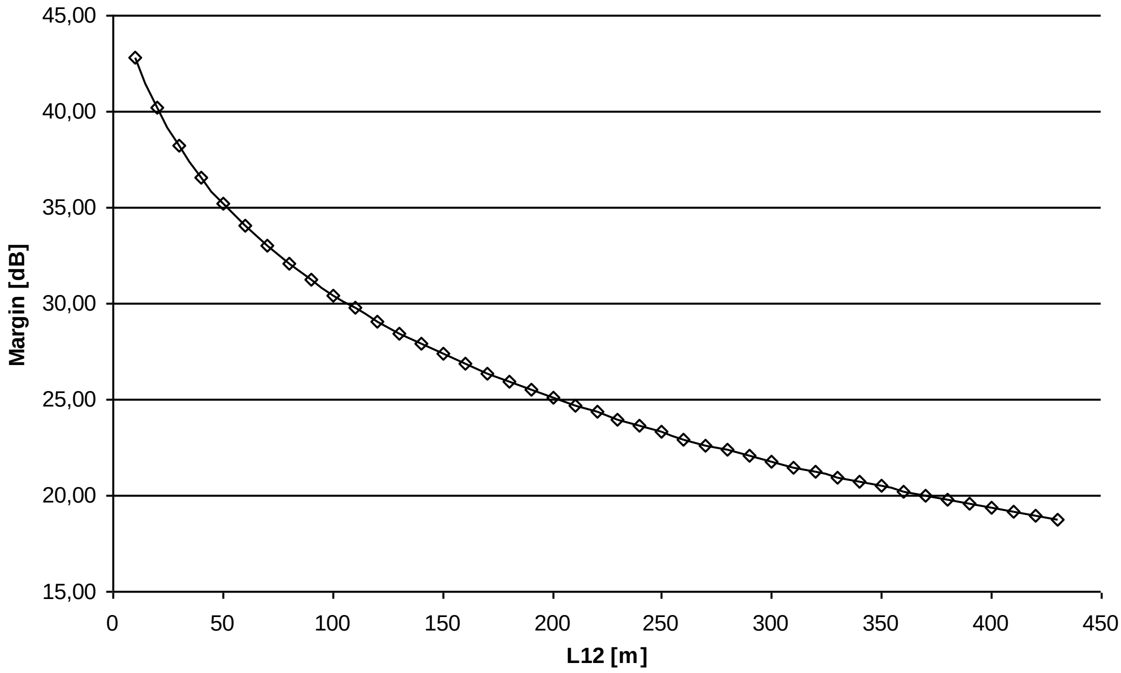


**Fig. 3:** Margin of TereScope 700/G for different distances and $\tilde{\alpha}_{l,atm} = 0.5\ dB/km$

## 4. AVAILABILITY

The influence of atmospheric attenuation can be shown on RSSI (Received Signal Strength Indication) which is measured in the receiver. Values of RSSI are used for determination of atmospheric attenuation during 3 month. They are saved in the interval of 5 minutes. Test FSO is set up in the distance of about 200 m. Maximum designed distance is 425 m. The value of RSSI is shown in Fig.4.

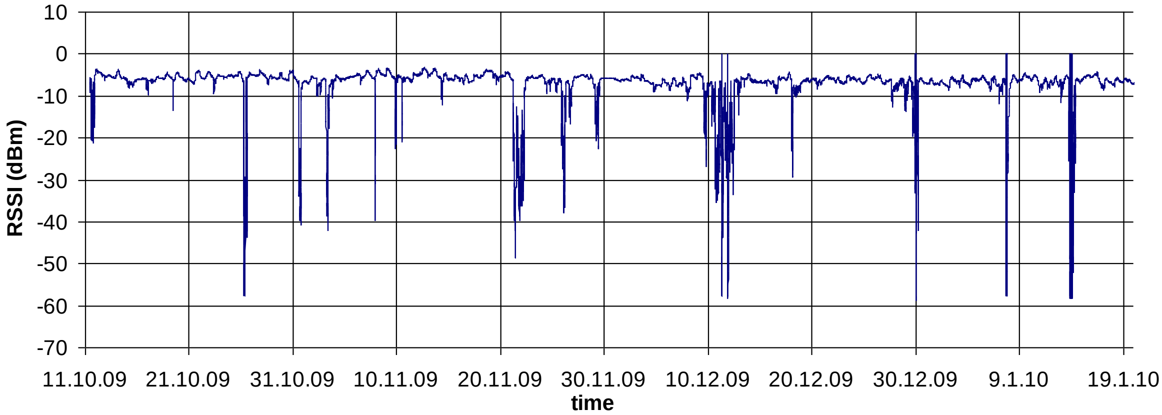


**Fig. 4:** RSSI of test FSO data link

Availability from long-term fades which occur when received power $P_{PD}$ is under receiver sensitivity $P_{0,PD}$, is able to determine from measured data. Availability is calculated as 100 % minus count of values under sensitivity of receiver divided by count of all values. Short-term fades effect the BER and those, which took less than 5 minutes, are not employed in a compute of availability. Measured values are for distance 200 m. Other values are calculated from the theoretical model of FSO, link budget and known atmospheric attenuation. For every distance are calculated geometrical loss $\alpha_{geom}$ and atmospheric attenuation $\alpha_{atm}$ from measured values of RSSI. There is used (1) to show when value of $P_{PD}$ is under $P_{0,PD}$. Values of availability, system down time for the period of 3 months and diameter *Dx* of exposed area at a distance of receiver are in Tab.1. Availability for 1 year is calculated for the assumption that there is no failure for the rest of the year.

| $L_{12}$ (m) | 50 | 100 | 150 | 200 | 300 | 400 |
|---|---|---|---|---|---|---|
| Availability for 3 month (%) | 100 | 100 | 99.6941 | 98.6970 | 96.9512 | 95.9061 |
| System down time (hours) | 0 | 0 | 7.4200 | 31.8333 | 73.9144 | 99.2500 |
| Availability for 1 year (%) | 100 | 100 | 99.9154 | 99.6367 | 99.1563 | 98.8672 |
| Dx (m) | 0.24 | 0.42 | 0.59 | 0.77 | 1.12 | 1.47 |

**Tab. 1:** Availability of FSO

## 5. CONCLUSION

This study shows the influence of shortening of a distance on availability of FSO data link. The link margin grows with shortening of a distance due to reducing geometrical loss. Also influence of random atmospheric attenuation is decreased. This paper also mentions the process showing link availability which does not correspond with ITU-T G.826. At the distance of 200 m, availability of 98.67 % stands for more than 31 hours out of 101 days. Other values of availability are shown in Tab.1. There is shown a diameter *Dx* which can show difficulty of focusing the system. Receiver aperture has diameter 0.11 m and if *Dx* approaches double of 0.11 m there is risk of system down due to building movement in a few mrad.

## REFERENCES


[1] Wilfert, O.: Modelování atmosférických optických spojů. Současný stav, trendy vývoje a výuka. Brno:VUTIUM, 2007. 38 p. ISBN 978-80-214-3395-3.

[2] WILFERT, O. Fotonika a optické komunikace. Lectures. Brno:VUTBR, 2007. 128 s. ISBN 978-80-214-3537-7.

[3] TS700 and TS800 User Manual, Document number ML48237.Rev.6.0, August-2007.