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LONG TERM MONITORING AVAILABILITY OF FSO SYSTEM

M. Márton[1*], Ľ. Ovseník[1]

[1]Technical University of Košice, Košice, Slovak Republic

Abstract. Nowadays are very popular applications of optical technologies for communications systems. These applications are usually based on usage of optical fibers which provide transmission of optical signals. One of new possibilities for transmission of optical signal without using physical optical fibers is technology FSO (Free Space Optics). FSO systems use for transmission different wavelengths. In our case FSO system is working on 850 nm. To ensure communication between both sides is needed secure conditions for LOS (Line of Sight). Both optical heads contain optical lasers which allow full duplex communication. Because as transmission medium is used atmospheric channel (free space) contains atmospheric particles which have dominant impact to quality of transmission signal. Occurrence of particles is different for each of weather conditions. Measurement of these parameters which are different for each of weather. We monitor one of these parameters in long term. This parameter is visibility and the point of this paper include possibility for measurement visibility.

Keywords: *FSO, visibility, weather.*

Corresponding Author: *Michal Márton, Technical University of Košice, Department of Electronics and Multimedia Communications, Košice, Slovak Republic,*
e-mail: *michal.marton@tuke.sk*

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1. Introduction

FSO is a license free telecommunication technology which offers full duplex communication. FSO uses infrared beams of light to provide optical broadband communication and it can be installed in less than one day. Data rates go through range from hundreds of megabits to several gigabits [1]. An idea of FSO is very simple. It is based on optical duplex wireless connectivity between two units (heads) which have optical transceivers and receivers. Each optical head uses optical source and detector, lens or telescope to transmit/receive beams of light through the atmosphere to receiving lens which receives the transmitted signal [3, 6].

Due to transmission medium (air) the FSO system depends on climatic and weather conditions. Atmospheric phenomena such as scattering, absorption, diffraction and attenuations make losses which decreasing receiving optical power. It is important to know an environment in which is the FSO system situated. It can be done by monitoring of air quality. The most important phenomenon in the atmosphere which influence on FSO quality is fog [4]. We can talk about fog, when the visibility is less than 1 km. The fog consists of water droplets with 100 nm in diameter, which corresponds with a wavelength used in FSO systems [6, 8]. It causes scattering and attenuation which have negative effects on infrared optical laser beam. Rain is formed from the water vapor contained in the atmosphere. It consists of water droplets whose form and number are variable in time and space. Rain attenuation is due primarily to the scattering phenomenon as in the case of aerosol [3]. Among other hydrometeors belong snow, hail, etc. Snow generally falls in the form of flakes or ice crystal aggregates. The flake diameter can reach 15 mm. Attenuation is strongly related to humidity. For dry snow, attenuation can reach 40 dB/ km in the infrared region. Wet snow has attenuation varies from 4 to 8 dB/ km.

Chapter two of this paper describes experimental device for measuring atmosphere conditions in the campus of Technical University of Košice (TUKE). The third chapter introduce experimental FSO system installed in TUKE campus. The fourth chapter deals with availability calculations using software package called FSO System Simulator. Conclusions are covered in the last chapter.

2. FOG sensor

2.1 FOG sensor scheme

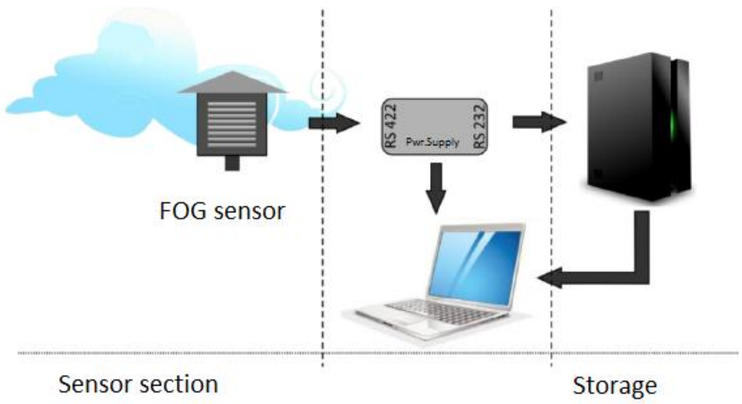

Figure 1. Block scheme of FOG sensor system

This low-cost device was developed for measuring three the most important parameters of atmosphere; density of fog [g/m^3], relative humidity [%] and temperature [°C]. FOG Sensors is situated in the box which allows free movement of air flowing through (Figure 1).

Measured data (fog, humidity and temperature) is stored in a database (Figure 2). This approach provides us an easy and very flexible statistical data selection. As it has been already mentioned, FSO systems encounter several weather conditions which deteriorate its operation. When weather conditions are bad enough to lower FSO link transmission to the certain critical level, a FSO channel should be substitute with some backup transmission channel. This can be accomplished by using a suitable RF (Radio Frequency) link from selected frequency range. It is well known that FSO system operate within a free license frequency range. That is why it is desired to find the same free license frequency band in RF interval, which offers adequate transmission velocity. One of the promising wireless range seems to be 60 GHz one. This frequency shows up as good enough to resist the negative weather event which fog indeed represents.

The next considered frequencies are 2,4 GHz, 5.2 GHz which are represented by similar characteristics. Fog is the main negative factor which has a tremendous impact on FSO link. It turns out that it is very important to track an overall and a real time atmospheric situation around FSO link to provide a hundred percent link availability and reliability. That is why we need to develop advanced monitoring techniques which will be capable of a fast and reliable response to the potential signal fades.

```
+--------------------+
| Tables_in_measures |
+--------------------+-------------+----------+-----+----+--------+
| companyfso         | Field       | Type     | Null| Key| Default|
| companyrf          +-------------+----------+-----+----+--------+
| meansure           | time        | datetime | NO  | PRI| NULL   |
| skuska             | fog         | int(5)   | NO  |    | NULL   |
| systemfso          | temperature | int(5)   | NO  |    | NULL   |
| systemrf           | humidity    | int(5)   | NO  |    | NULL   |
+--------------------+-------------+----------+-----+----+--------+
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Figure 2. Real time data processing with online MySQL database

2.2 Data collector

The software application saves data from FOG Sensor into MySQL database in real time (Figure 3). This is considered as a great advantage because data can be processed basically immediately.

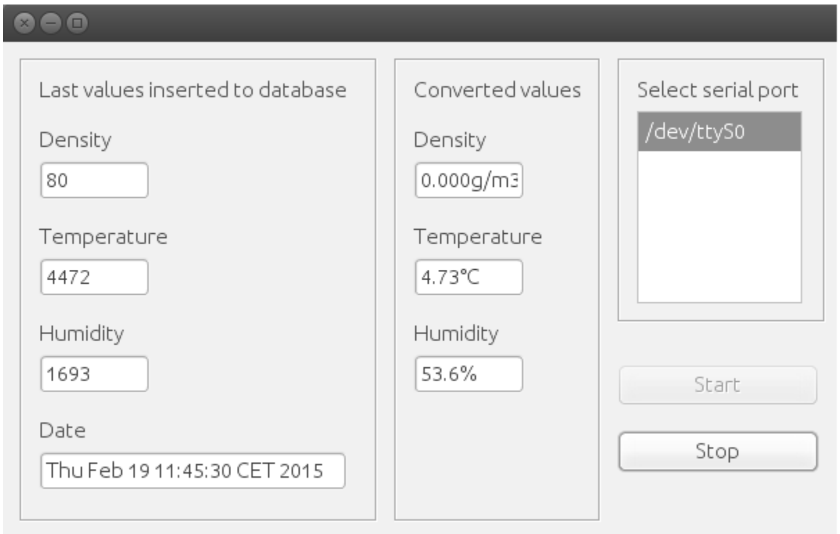

Figure 3. Fog Sensor collecting data software application

In Figure 3, we can see the raw values on the left side and converted values in the middle of this window. Right part is called “Select serial port” and it contains all serial ports available in server. In our case, we have this application on server with OS Linux with one serial port, called “ttyS0”. The all measured raw data is only numbers without unit. For calculation fog density, we use raw data from first column (Figure 2), by next equation:

$$F = (D_i \cdot \frac{5}{1024} - 0{,}87) \cdot \frac{0{,}5}{2{,}9}, \quad (1)$$

where F is a fog density and D_i is FOG sensor measured value (raw value). If we want to get exact value of liquid water content (LWC) we need to define a constant which helps us to convert value of fog to value of LWC. This constant is marked as C and it is from ratio between the average liquid water content values W_i and the FOG sensor output values D_i [8].

$$C = \frac{\sum_{i=1}^{n} W_i}{\sum_{i=1}^{n} D_i} = 0{,}7384 \quad [g / m^3], \quad (2)$$

where n is a quantity of samples during whole fog event. This constant is used to convert momentary sensor values D_i to momentary LWC values [8]:

$$LWC = F \cdot C, \quad (3)$$

from LWC is possible to calculate the visibility. For this calculation, we use the empirical formula for fog visibility as a function of fog density:

$$V = d \cdot (LWC)^{-0{,}65}, \quad (4)$$

where *V* is a visibility in [km] and parameter *d* takes specific values for different fog conditions as it is shown in Table 1 on the base of previous research published in [8].

Table 1. „*d*“ parameter for different fog conditions

Type of fog	k
Dense haze	0.013
Continental fog (dry and cold)	0.034
Maritime fog (wet and warm)	0.06
Dense haze and selective fog	0.017
Stable and evolving fog	0.024
Advection fog	0.02381

In this case, we have mentioned a stable and evolving fog for European area. It is characterized by stable air mass with cloud cover during the day, clear skies at night, light winds and moist air near the surface. These conditions often occur with a stationary high-pressure area [7]. Thus, parameter d takes value which corresponds with Continental fog in Table 1. Formula for visibility is given by following equations:

$$V = 0{,}024 \cdot (LWC)^{-0{,}65}. \quad (5)$$

Relation between LWC and visibility V is illustrated in Figure 4. As was mentioned above, fog event occurs when the visibility is lower than 1 km.

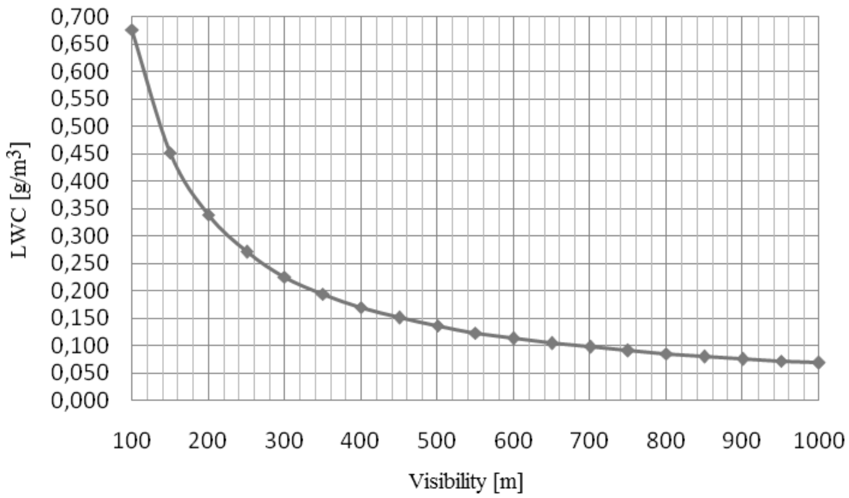

Figure 4. Fog Sensor dependence of visibility on LWC parameter

3. FSO experimental system

We have installed FSO link with 850 nm wavelength in TUKE Campus. In Figure 5 we can see the path of communication between Laboratory of Optoelectronics Systems (LOS) and TUKE main building.

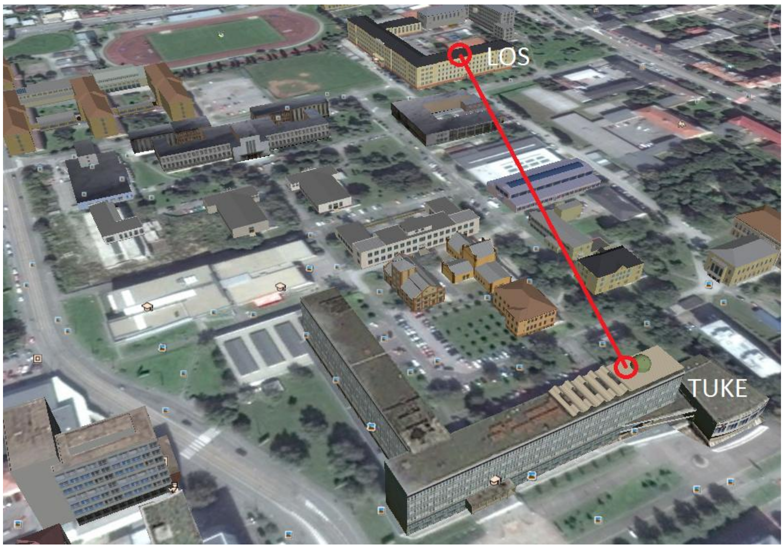

Figure 5. Transmission path between LOS and the main TUKE building

The FSO link is realized by FlighStrata 155E terminals. They provide full duplex communication with four laser beams technology. It offers better overall availability than one laser beam FSO systems. Flightstrata 155E terminals use active tracking system for achieving the best connection. Detailed parameters of FSO terminals are summarized in Table 2 [5, 9].

Table 2. Lightpoint parameters

Parameters	Lightpointe Flightstrata 155E
Wavelength	850 nm
Tx Power	160 mW
Rx Power	-30 dBm
Rx Diameter	8 cm
Directivity	2 mrad

Edge value of visibility, is calculated by software package FSO System Simulator. This software was created at TUKE. It calculates availability for specific FSO systems by physical models and energy balance of FSO connections [8].

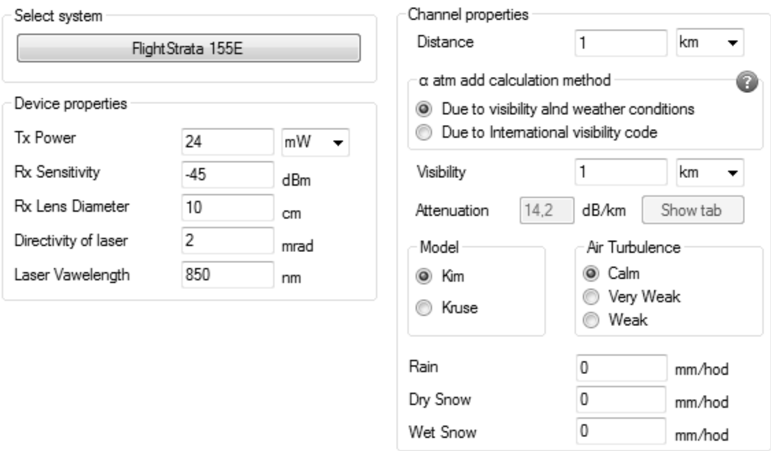

Figure 6. FSO input parameters

After entering inputs parameters of individual FSO system and optical channel properties (Figure 6), edge value of visibility is calculated. Edge visibility for 1 km long FSO link is 520 m for Lightpointe system Flightstrata 155E (Figure 7).

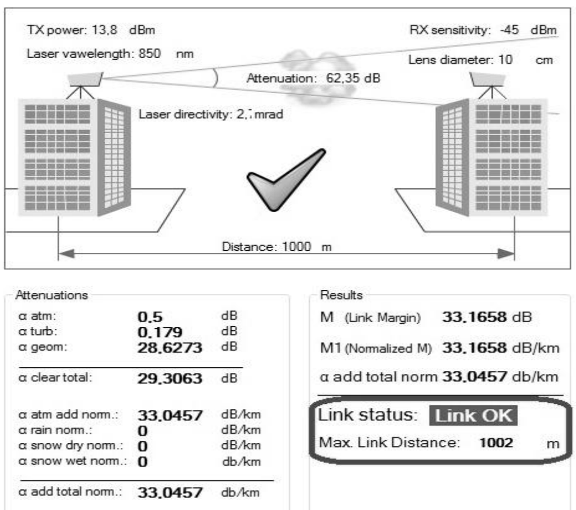

Figure 7. FSO edge visibility for 1 km FSO link with using LP system.

After obtaining edge values for FSO system we can analyse stored data from Fog sensor (Figure 8).

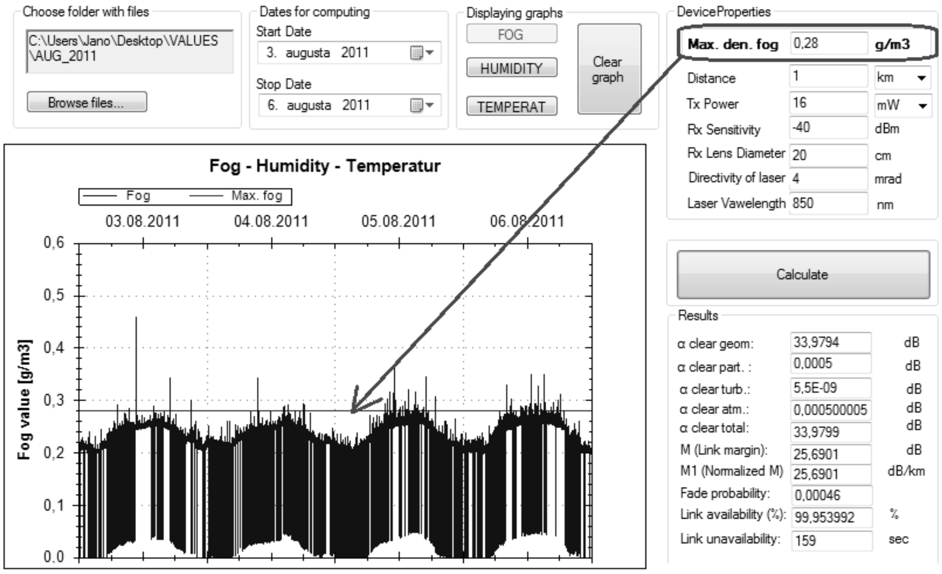

Figure 8. Graph of water droplets event.

From Figure 8 we can see that edge value of visibility is converted to parameter sign as “Max.den.fog” (i.e. Maximum density of fog) via equation (4). All values which are higher than threshold is saved in text file made by FSO SysSim. Each value which is entered in text file results in loss of optical connection. Number of fades is using to calculate availability of both FSO links during calendar year.

4. Experiments and results

From eight yearlong measurements using FOG sensor system we have gained FSO link availability results which are summarized in Table 3.

Table 3. FSO link availability

Year	Lightpointe Flightstrata 155E
2009	98, 1622 %
2010	98, 2942 %
2011	98, 6464 %
2012	98, 7545 %
2013	98, 1244 %
2014	98, 9898 %
2015	98, 2112 %
2016	98, 2778 %

We can find overall information about link availability for each particular year starting by 2009 until 2016 in Table 3. Graphical output of availability of FlightStrata 155E is illustrated in Figure 9.

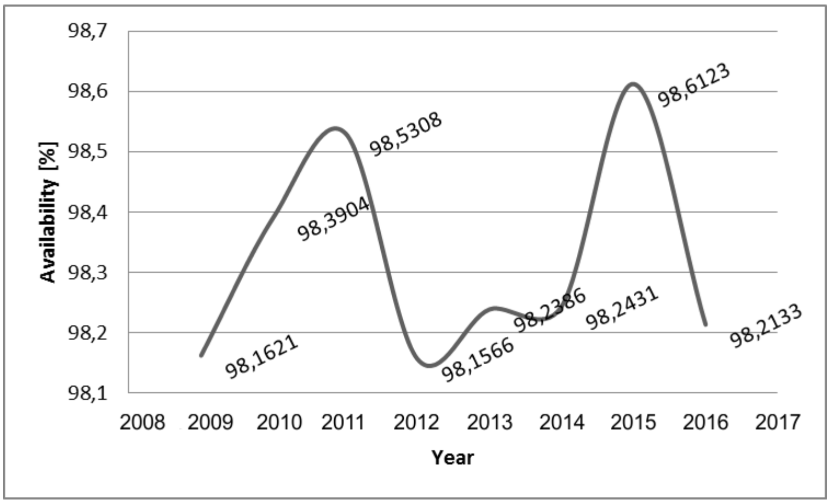

Figure 9. Graph of FSO availability per a certain year 2009 – 2016

5. Conclusion

The medial link availability during mentioned years calculated for experimental system Lightpointe, Flightstrata 155E is 98,3184 %. It is not bad, but for telecommunication purposes 99,999 % availability is needed. It is not an easy task to satisfy 99,999 % availability with FSO link. One of the promising solutions could be using of a backup microwave radio link, i.e. hybrid FSO/RF link. There are potentially many acceptable antennas however 2,4GHz, 5,2GHz and 60 GHz antenna seem to have the best properties for this purpose. In this area is place for next research. Comparison of antennas characteristics working in different frequency ranges and their appropriate application for FSO/RF hybrid systems. It is important to have detailed data (fog, humidity and temperature) along transmission line. This data serves as essential input to set up and calculate appropriate FSO simulator parameters. Statistical measurement gives helpful information (“a link footprint”) for the area. Furthermore, these results could act as the reference to decide if the FSO is beneficial and suitable in a chosen location. It turns out that FSO systems could be possibly used in much more industry field however, there are several challenges. Miniaturization, cost of the device, cheap and reliable backup links for these devices. Despite the fact that it is rather though to meet all these requirements, FSO links will be most likely much more popular in future. In order to achieve an actual availability, we are working on a complex metrological sensor system. This system should improve weather “FSO forecast” tremendously. Our ambition is developing of a RF system which will satisfactory backup FSO link.

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