SHORT TERM SCIENTIFIC MISSION (STSM)
SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15127 - 43913
STSM title: Quality of Service in FSO communications operating under various atmospheric effects
STSM start and end date: 14/04/2019 to 21/04/2019
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PURPOSE OF THE STSM:

Free Space Optical (FSO) communications are highly dependent on various tropospheric weather conditions such as fog, rain, snow and turbulence, as the fog effect is the major issue among them. Regarding these challenging atmospheric conditions, there are several important Quality of Service (QoS) parameters, which can evaluate the performance of FSO system in the presence of mentioned weather-based disruptions. In particular, during the current Short Term Scientific Mission (STSM) in Department of Electronics Engineering, Kaunas University of Technology, Lithuania, the FSO communication performance was fully examined based on a few QoS parameters including Bit Error Ratio (BER), Signal to Noise Ratio (SNR), etc..

Having a possibility to accomplish a STSM in Department of Electronics Engineering, Kaunas University of Technology, Lithuania, was very beneficial for my scientific research. In addition, it can be considered also as a significant contribution to my work within COST action CA15127 RECODIS and COST RECODIS book chapter 2.6 “Environmental Conditions Mitigation by Application of Quality-driven Techniques to Improve Wireless Communications Resilience”. During my STSM, I had possibility to work together with Prof. Rasa Bruzgiene over an evaluation of Quality of Service (QoS) parameters characterized FSO communication systems operating under various perturbation atmospheric effects. In this way, the system performance, namely the availability constrains in the presence of Mie scattering and namely fog effect, was examined. Consequently, the current analysis is fully related to Working Group 2 (WG2), which main goals are to investigate the reliability of FSO communication systems in the presence of various weather-based disruptions. I also has joint meetings with the other coauthors of book chapter 2.6 during which all results regarding carried out simulations and analysis was evaluated and discussed.

To sum up, the present STSM in frame of COST action RECODIS is very narrow related to WG 2 as the main results of it were considered as an important input for COST RECODIS book chapter 2.6. In addition, the carried out meetings between the co-authors of COST RECODIS book chapter 2.6 finalized and proved the validity of the carried out simulations and considerations.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

Considering the introduction to the current research topic and the accomplished work, the STSM is assigned to WG 2. In particular, the carried out research highly contributed to COST RECODIS book chapter 2.6. The current STSM provided detailed analysis of the QoS in FSO communication links operating under

atmospheric constrains. In other words, the already available measurements in terms of various atmospheric effects were investigated in terms of QoS constrains. The related work plan includes the following crucial points:

1) In frame of my stay, I had possibility to have good overview over the theory of different quality aspects with special focus on QoS one.
2) Apart from the well investigated topic related to Mie scattering, I had accomplish work over the influence of snow and rain effects. Both of them decrease significantly the reliability of FSO link. In other words, I summarized and investigated different atmospheric empirical models.
3) I selected an appropriate data based on which I investigated a few QoS parmeters including SNR, BER etc., which fully described the performance of a FSO system.
4) Considering the aforementioned calculations and simulations, I had information regarding the availability and reliability of a FSO system and its possibility to implement variety of communication services.
5) All simulations and considerations were presented and intensively discussed during several meetings between the coauthors of COST RECODIS book chapter 2.6.

The above plan was accomplished based on the following applied techniques:
1) I had access to laboratory facilities and already available methods for investigation of QoS in communication networks.
2) Theoretical and empirical approaches
3) Measurements related to various atmospheric effects including fog, rain and snow
4) Simulations were accomplished in Matlab modeling environment

In conclusion, the accomplished plan based on the listed techniques delivered significant results in terms of WG 2 and book chapter 2.6. The main introduction to the results included already in COST RECODIS book chapter 2.6 is given in the following part. I believe that the opportunity to carry out the current research in Kaunas University of Technology, Lithuania was an important one for COST RECODIS project as well as my PhD.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

Considering the previous points of the report in the current part a short introduction and description to the main results is given. In particular, the detailed outcomes of this STSM including sophisticated simulations are described in the following subchapters of COST RECODIS book chapter 2.6 - "3.1 Free Space Optical Communication System" and "4.1 Alert to React and Prevent Service Performance Degradation in FSO communication".

The operation of FSO system in the presence various weather conditions is evaluated based on a few important QoS parameters including BER, SNR, etc..The influence of atmospheric effects is evaluated based on visibility V parameter, which is directly related to the applied attenuation in the FSO channel. The visibility values corresponds to different attenuation values in terms of fog snow and rain are provided in Table 1.

Table 1 Visibility and attenuation values for various weather conditions influencing the FSO communication channel

Weather conditions	Visibility km	Attenuation dB/km
Dense fog	50	315
Moderate fog	500	28.9
Light fog	770	18.3
Rain (light->strong)	770 -> 5900	2 -> 18.3
Snow (light->strong)	770 -> 4000	3.1 -> 18.3

The most severe influence over FSO communication link has the fog effect, which can be divided into several different types. To address the problem, the fog attenuation versus visibility is provided in Fig.1.

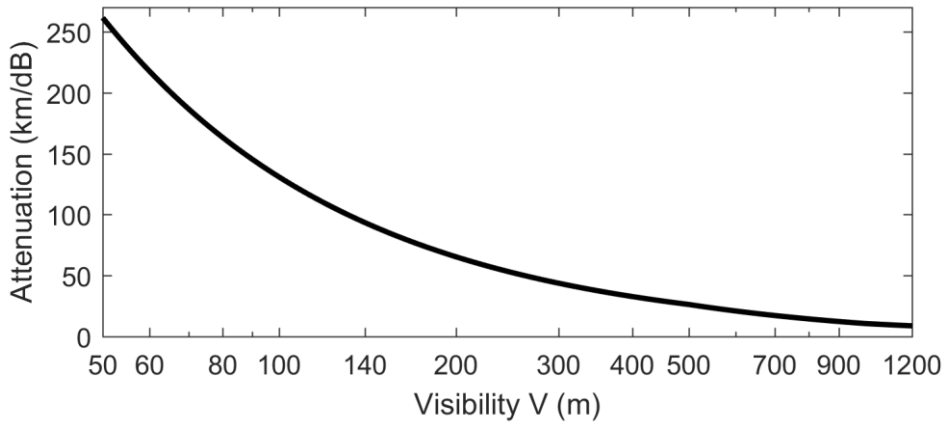

Fig. 1 Fog attenuation versus visibility

It is evident that the fog effect with its high optical attenuation values can severally deteriorated the performance of FSO communication system. To evaluate its influence over Quality of Service, several QoS parameters are applied, including the most important ones, namely BER and SNR parameters. Due to fact that the On OFF Keying (OOK) modulation is the simplest and most often applied modulation in the commercially available FSO systems, its derived BER formula is provided in equation (1).

$$BER = Q(\frac{1}{2}\sqrt{\frac{E_b}{2N_o}}) \quad (1)$$

Basically, there are two types of OOK modulations including Non Return to Zero (NRZ) and Return to Zero (NZ). The power in the transmitted optical pulse for the both cases are given in equation (2) and (3), where P_r is the average received optical power, T_b is the bit duration and R is the photodetector responsivity.

$$E_b = 2(RP_r)^2 T_b \quad (2)$$

$$E_b = 2(RP_r)^2 T_b/\gamma \quad (3)$$

Based on this introduction to the applied data and communication channel model, FSO system is examined in detail. As it was mentioned above, all considerations and simulations accomplished during the current STSM are given in the following subchapters - "3.1 Free Space Optical Communication System" and "4.1 Alert to React and Prevent Service Performance Degradation in FSO communication" – of COST RECODIS book chapter: "Environmental Conditions Mitigation by Application of Quality-driven Techniques to Improve Wireless Communications Resilience". All provided information introduce and examine fully the topic – "Quality of Service in FSO communications operating under various atmospheric effects" – which investigation is completely complied with the tasks in Working Group 2 (WG2).

FUTURE COLLABORATIONS (if applicable)

During my STSM in frame of COST action CA15127 RECODIS in Kaunas University of Technology, Lithuania, I obtained important knowledge in terms of FSO channel characterization based on QoS parameters including BER and SNR. More specifically, all tasks of the developed work plan for applying different techniques in terms of investigation of performance of FSO technology in the presence of various atmospheric effects were accomplished. The current problem was completely complied with WG2. The main results were included in COST RECODIS book chapter 2.6 "Environmental Conditions Mitigation by Application of Quality-driven Techniques to Improve Wireless Communications Resilience", namely in the following two subchapters - "3.1 Free Space Optical Communication System" and "4.1 Alert to React and Prevent Service Performance Degradation in FSO communication". All results were discussed during several meetings with other co-authors of book chapter 2.6. I will continue the initiated narrow collaboration with Kaunas University of Technology, Lithuania. In other words, the QoS parameters describing the behaviour of FSO system will be further examined. The future plans also include a publications in an appropriate conference or journal.