H-SPACE 2018

Selected papers of 4th International Conference on Research, Technology and Education of Space

February 15-16, 2018, Budapest, Hungary
at Budapest University of Technology and Economics

Organized by
Federated Innovation and Knowledge Centre of
Budapest University of Technology and Economics
and
Hungarian Astronautical Society

Editors
László Bacsárdi and Kálmán Kovács

MANT 2018

Selected papers of the 4th International Conference on Research, Technology and Education of Space (H-SPACE2018)
February 15-16, 2018, Budapest, Hungary
BME building 'I', Hall IB 026
Magyar tudósok krt. 2., Budapest, H-1117 Hungary

Created by the support of BME VIK, BME EIT and MANT.
Editors: László Bacsárdi and Kálmán Kovács

Publisher (Kiadó):
Hungarian Astronautical Society (MANT, Magyar Asztronautikai Társaság)
1044 Budapest, Ipari park u. 10.
www.mant.hu
Budapest, 2018

Felelős kiadó Dr. Hirn Attila főtitkár

This proceedings contains the papers as it was submitted by their authors. We have not edited their text or corrected misspellings.

ISBN 978-963-7367-17-5

WELCOME from the Organizing Committee

In 2018, the annual International Conference on Research, Technology and Education of Space has been held the 4th time. The host was the BME Space Forum operated by the Federated Innovation and Knowledge Centre (EIT) of the Faculty of Electrical Engineering and Informatics at the Budapest University of Technology and Economics (BME) – in cooperation with the Hungarian Astronautical Society (MANT), which is the oldest space association in Hungary.

The Federated Innovation and Knowledge Centre (BME EIT) was created at the Faculty of Electrical Engineering and Informatics of Budapest University of Technology and Economics (BME) in 2009 to stimulate the research and development activity and to assist the exploitation of research achievements at the Faculty. Currently, BME EIT operates the BME Space Forum which mission is to harmonize and coordinate the activity of departments at BME participating in space activities by a common vision and strategy, to recognize the joint human and technical resources and amazing achievements, to make internal and external knowledge transfer more efficient, and to utilize opportunities lying in synergies granted by joint capabilities and unified representation. The common aim of BME Space Forum members is to become the bridge between academic research and production, service application, and to participate all phases of research/development/innovation and application processes of space activity. Currently, 12 Departments of 4 BME Faculties participate voluntarily in the activities of Space Forum.

The Hungarian Astronautical Society (MANT in Hungarian) is a civil organization in Hungary that gathers space researchers, users of space technology and everyone who is interested in the interdisciplinary and state-of-the-art uses and research of outer space. The society was established in 1956 in Budapest, and it is the only Hungarian member of the International Astronautical Federation (IAF) since 1959. The aim of MANT is to raise public awareness about space activity and space applications. The society also provides an opportunity for space enthusiasts to meet, exchange ideas and work together. MANT, through its members from various fields of science, organizes conferences, youth forums, summer space camps, issues periodicals, releases media material and holds lectures about space research and connected scientific fields.

The organization of the H-SPACE conference series started in 2015, at a time of growing opportunities arising from ESA recently granting membership to Hungary and the need for a joint presentation of space activities pursued at BME. The selection of the date of the event pays tribute to the successful deployment to orbit and mission of the first Hungarian satellite, the Masat-1, which has been launched on February 13, 2012.

The main topic of this year's conference was "Space research for society on every scale". The agenda of the conference addressed scientific, technological and educational issues of space research and space activities. The conference was open for both local and international professionals and provides an opportunity to showcase Hungarian scientific, technological, educational and outreach activities, related to space.

The Organizing Committee had internationally recognized members: Prof. József Ádám, Dr. Tibor Bálint, Ferenc Horvai, Prof. János Lichtenberger, Dr. Lóránt Földváry, Prof. László Pap, Prof. Gábor Stépán, Dr. Szabolcs Rózsa We are grateful for their contributions to the success of the conference.

Due to the generous support of our partners, the conference had no registration fee. We had more than 200 registered participants from 11 countries. The conference had four main sections: Science and Technology I-III and Education and Outreach. Following the success of last year's poster session, we organized a poster session with 12 great presentation.

We published a book of abstracts for the conference. During the conference, we had 1 keynote lecture, 3 long talks and 26 technical presentations from which 11 authors have submitted a full paper. These papers are included in this proceedings.

Dr. Kálmán Kovács
chair
Director of EIT BME

Dr. László Bacsárdi
co-chair
Vice President of MANT

Final Conference Program

February 15-16, 2018
Budapest,
BME building 'I', Hall IB 026
Address: Magyar tudósok krt. 2., Budapest, H-1117, Hungary

In this program, the affiliation of the first author is listed.

February 15, Thursday

14:00-14:20 Opening

János Józsa, Rector of Budapest University of Technology and Economics (BME)
András Pócza, Head of Department, Department for ICT Regulation and, Management Ministry of National Development
János Solymosi, President of Hungarian Astronautical Society

14:20- 15:20 Long talks, Section of Science and Technology I
Chair: Kálmán Kovács

Estimation of Clear Sky Level for Satellite Propagation Measurements
Bernard Adjei-Frimpong, László Csurgai-Horvath
Department of Broadband Infocommunications and Electromagnetic Theory, BME, Hungary

Participating in NASA-ESA Cassini Mission at Wigner RCP, former KFKI RMKI
Pál Gábor Vizi, Károly Szegő, Sándor Szalai, János Nagy
Wigner Research Centre for Physics, HAS, Hungary

Opportunities of 3D printing in the emerging field of Space Chemistry
Dorottya Milánkovich, Ferenc Darvas
Innostudio Inc. Hungary

15:20-15:40 One minute madness

Chair: László Bacsárdi

Analyzing deformation above gas reservoir using multi-temporal InSAR
Bence Ambrus, Szabolcs Rózsa
Department of Geodesy and Surveying, BME, Hungary

Analyzing the Effects of Atmospheric Factors in Earth-space and Space-Earth Quantum Communication Channels
András Kiss, László Bacsárdi
Institute of Informatics and Economics, University of Sopron, Hungary

Citizen Science - An idea to integrate science into our digitized world
Peter Pusztai
Hungarian Astronautical Society, Hungary

Fifteen years in service for the society – the story of the Hungarian space web portal Űrvilág
Sándor Frey, László Bacsárdi
Űrvilág space portal, Hungary

Human Spaceflight: music effects in space confined environments
Luis Luque Alvarez
Széchenyi István University, Hungary

New methodologies for Big Data in space researches
Gergely Bencsik, Zoltán Pödör, László Bacsárdi
Institute of Informatics and Economics, University of Sopron, Hungary

Preparing a Lunar Rover Mission in the Framework of Analog Planetary Research
Koppány Juhász, Mátyás Hazadi, Tibor Pacher, Miklós Pathy
PuliSpace Technologies Ltd., Hungary

Recent trends in light pollution measured from space in Hungary
Kornél Kolláth, Kai Pong Tong, Zoltán Kolláth
Hungarian Meteorological Service, Hungary

Sensors of Swarm Stream as Technology Research on Nano Scale
Pál Gábor Vizi
Wigner Research Centre for Physics, HAS, Hungary

Sentinel-1 PSI Analysis of Greater Budapest Region
Péter Farkas, Gyula Grenerczy
Geo-Sentinel Ltd., Hungary

Simulation of different quantum error correction codes in free-space channels
Attila Iván, László Bacsárdi
Department of Networked Systems and Services, Hungary

Simulations of Single Event Effects in microelectronics caused by the lunar surface radiation environment
Dávid Lucsányi, Viktor Nagy, Vendel László, Miklós Pathy, Mátyás Hazadi
PuliSpace Technologies Ltd., Hungary

15:40-16:40: Poster session with coffee break

16:40-18:10: Technical presentations, Section of Science and Technology II

Chair: László Csurgai-Horváth

Optical transfer in space communication
Andrea Farkasvölgyi, István Frigyes
Department of Broadband Infocommunications and Electromagnetic Theory, BME, Hungary

Quantum Key Distribution in Space – A security review
Tamás Bisztray
Eötvös Loránd University, Hungary

Comparing Calculated and Measured Losses in QuESS's Quantum Channel
Máté Galambos, László Bacsárdi
Department of Networked Systems and Services, Hungary

Monitoring the movement of geodetic network in Thailand during 2013-2017 by GNSS
Nateepat Srivarom, Weng Jingnong, Serm Chinnarat
Beihang University, China

Tomographic Reconstruction of Atmospheric Water Vapour Using Simulated GNSS Data in Hungar
Yuxiang Yan, Wusheng Hu, Szabolcs Rózsa
Southeast University, China

Assessment of GNSS positioning under extreme weather conditions for safety-of-life application
Szabolcs Rózsa, Bence Ambrus, Ildikó Juni
Department of Geodesy and Surveying, BME, Hungary

February 16, 2018, Friday

9:30-9:40 Opening of the second day
László Jakab, Dean of Faculty of Electrical Engineering and Informatics, BME
László Bacsárdi, Secretary General of Hungarian Astronautical Society

9:40-10:10 Keynote speaker
New perspectives in the Russian-Hungarian space connections
János Lichtenberger, Csaba Ferencz
Eötvös Loránd University, Hungary

10:10-11:00 Technical presentations, Section of Science and Technology III

Chair: Sándor Frey

Validation tests for the recently upgraded Thermo-Vacuum Chamber in the Laboratory of the Space Dosimetry Research Group
Anna Baranyai, Balázs Zábori, Attila Hirn
Centre for Energy Research, HAS, Hungary

*Comparison of the predicted depressed sta*te of crew members with the results of their subjective psychological test at Concordia research station
Gábor Kiss, Klára Vicsi
Department of Telecommunications and Media Informatics, BME, Hungary

Activity of the ESA National Technology Transfer Office: Space technologies in everyday life
Zsuzsanna Tandi, Károly Szegő
Wigner Research Centre for Physics, HAS, Hungary

11:00- 11:20 Coffee break

11:20-12:35: Section of Education/Outreach

Chair: János Lichtenberger

Expanding the Space of Space learning
Maria Messina, Giorgio Garagnani, Rosa Tagliamonte, Sabrina Ricci
Italian Space Agency, Italy

Hungarian Astro Pi experiments on the ISS
Florián Vámosi, Péter Pósa
Mihály Táncsics Grammar School of Kaposvár, Hungary

Solar Physics in the high school - Study of the sunspots
Mária Pető
Székely Mikó High School, Romania

ESERO Romania: Using Space as a Gateway to STEM
Virgiliu Pop
Romanian Space Agency, Romania

Filling the Gap in the ESA Space Technology Education
Levente Dudás, András Gschwindt
Department of Broadband Infocommunications and Electromagnetic Theory, BME, Hungary

12:35 Closing remarks
Kálmán Kovács, Director of Federated Innovation and Knowledge Centre, BME

Content

We have published a separate book of abstracts contains all of the abstracts accepted for the conference. During the conference, we had 1 keynote lecture, 3 long talks and 26 technical presentations from which 11 authors have submitted a full paper. These papers are included in this proceedings as it was submitted by their authors. We have not edited their text or corrected misspellings.

Andrea Farkasvölgyi and István Frigyes, *“Optical transfer in space communication”*

HSPACE2018-FP-26

Máté Galambos and László Bacsárdi, *“Comparing Calculated and Measured Losses in QuESS’s Quantum Channel”*

HSPACE2018-FP-30

Comparison of the predicted depressed state of crew members with the results of their subjective psychological test at Concordia research station

Gábor Kiss, András Módos, Klára Vicsi
Department of Telecommunications and Media Informatics
Budapest University of Technology and Economics
Budapest, Hungary
kiss.gabor@tmit.bme.hu, modos.andras7@gmail.com, vicsi@tmit.bme.hu

Bea Ehmann, László Balázs
Institute of Cognitive Neuroscience and Psychology
Research Centre for Natural Sciences, Hungarian Academy of Sciences
Budapest, Hungary
ehmann.bea@ttk.mta.hu, balazs.laszlo@ttk.mta.hu

Abstract—**In this study the predicted depressed state of examined subjects is compared with the results of their subjective psychological test. This work has been completed under an ESA project, titled the "Psychological Status Monitoring by Computerized Analysis of Language phenomena (COALA-Phonetics)". One aim of this project is to monitor the psychological status of the researchers at the Concordia research station at Antarctica, especially to detect depression based on speech processing. Speech samples were collected from each crew member once a week. Along with recordings, the crew members completed a Positive and Negative Affect Schedule (PANAS) self-report questionnaire once a month. The severity level of the depressed state of crew members were predicted on the base of their speech samples by our automatic prediction system. The system predicts the Beck Depression Inventory score (BDI), what generally is used in in psychiatric practice. From the results of the PANAS questionnaire, EMOC score was calculated which characterizes the positive attitudes of the examined subject. These two descriptors (BDI and EMOC scores) were compared and the cognitive condition of the crew members was deduced based on the analyzation. A weak negative correlation was found between the BDI and EMOC scores, and the crew members seemed to adapt well to the extreme conditions at Concordia research station throughout the examined time.**

Keywords—depression, SVR, speech processing, follow-up status monitoring, PANAS

I. Introduction

In this study, the comparison of predicted depressed state of examined subjects detecting their speech with the results of their subjective psychological test is presented.

Concordia research station is located inside the Antarctic at 3233 m above sea level and 1100 km far away from the coast. French and Italian research organizations jointly operate at the research station. From November to February more than hundred people live and work in the research station, but in the rest of the year only 10-15 crew members are serving here. The circumstances in this time makes the crew face serious challenges. The crew members are almost separated from the outside world, they live and work in a small research station and other circumstances are extreme too, like the outside temperature, and the lack of sunshine, thus the circumstances are similar as in a space mission. These conditions may have a serious impact on subjects and may cause many cognitive problems such as depression, anxiety, and other mental disorders.

The European Space Agency (ESA) examines the cognitive condition of the crew members in the so-called "Cognipole" project, in which the crew is voluntarily involved. Within this project, we make follow-up examinations of the cognitive condition of crew members especially for their depressed state, titled the "Psychological Status Monitoring by Computerized Analysis of Language phenomena (COALA-Phonetics)".

Depression is a psychiatric disorder. Several events can cause depressed state in the life of a person, like stressful events, persistent sadness, and difficulties in the daily duties and so on [1]. The World Health Organization (WHO) "Depression the publication of Global Public Health Concern" stated that there were 350 million people suffering from depression in 2012 [2]. The WHO predicts that by 2030 unipolar depression will be among the top three most serious diseases worldwide, alongside HIV/AIDS and heart disease [3].

As a result of depression, the ability of a person may be impaired. With increasing depression severity, the risk of suicide also increases [4].

Previous studies proved that speech is an appropriate indicator of depression and there are already good results either with depressed state (non-depressed/depressed or non-depressed/mild depression/moderate depression/severe depression) classification [5], [6], [7], or predicting the severity of depression with regression method [8], [9], [10] based on speech processing.

The crew members of Concordia research station were kindly asked to read a short text in their mother tongue ("The North Wind and the Sun") every week and record it with an

The research was supported by European Space Agency COALA project: Psychological Status Monitoring by Computerized Analysis of Language phenomena (COALA) (AO-11-Concordia).

audio-video recording program. The recordings were analyzed, and their depressed state was determined.

Beside the audio recordings, the researchers completed "Positive and Negative Affect Schedule" (PANAS) [11] questionnaires every third week.

The paper is structured as follows. In Section 2, the description of the used database is given. Section 3 describes the methods used during the investigation. Section 4 contains the results of our predicting system and the evaluation of the PANAS questionnaire compared to each other. Section 5 gives some conclusions.

II. Database

During the examined period, 357 audio recordings have been recorded by crew members that were suitable for analysis and 166 PANAS questionnaires have been completed (Table 1). In fact, there were more audio recordings, but for a variety of reasons, not all were suitable for speech processing. The following reasons have arisen: more than one subject talked during the recording, the examined subject did not read the entire text, a loud machine rumbled in the background.

TABLE I. THE MAIN DESCRIPTORS OF THE USED DATABASE

Examined Subjects	Number of audio recordings	Number of PANAS samples
11 (8 French 3 Italian)	357	166

It is important to note that in most cases the recording of audio samples and the completion of PANAS questionnaires were not done on the same day.

III. Methods

A. Beck Depression Inventory

To indicate the severity of depression the well-known and widely accepted Beck Depression Inventory II (BDI) test [12] was used.

The BDI scales the severity of depression into a 0-63 scale, where 0 is the absolute non depressed state while 63 is the most severe depressed state. The following grouping is used for the BDI scale: 0-13 non depressed, 14-19 mild depression, 20-28 moderate depression, 29-63 severe depression. It is important to note that the BDI scale is not necessary linear, so for example, 15 BDI score does not indicate three times more severe depressed state than 5 BDI score.

B. Positive and Negative Affect Schedule

The Positive and Negative Affect Schedule (PANAS) [11] is a self-report questionnaire that consists of two 10-item scales to measure both positive and negative affect (Table 2). For each item, the examined subjects have to assign a number from 1 to 5 based on how much they feel it real for themselves, where 1 means totally not, while 5 is the totally true.

TABLE II. PANAS ITEMS GROUPED BY POSITIVE AND NEGATIVE AFFECTS

Positive affect	Negative affect
Attentive	Hostile
Active	Irritable
Alert	Ashamed
Excited	Guilty
Enthusiastic	Distressed
Determined	Upset
Inspired	Scared
Proud	Afraid
Interested	Jittery
Strong	Nervous

C. Predicting the severity of depression

To predict the severity of depression, our previously developed system was used [10], [13], [14]. The dataflow diagram of the used system can be seen in Fig 1.

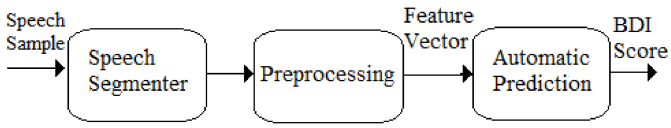


Fig. 1. The Dataflow diagram of the automatic predction system

The system processes and evaluates a speech sample in three steps. In the first step, the speech sample is segmented into phoneme like units automatically using an automatic speech segmenter [15]. Our previous studies showed that using phoneme segmentation before parameter extraction improves the precision of the prediction of depressed state. In the second step, the system extracts the following low level descriptors (LLDs): fundamental frequency and intensity from the whole speech parts, jitter, shimmer, first and second formant values and their bandwidths, mel-filtered band energy values from the same vowel. From the values of the LLDs the system prepares the appropriate feature vector using statistical functions as mean, variance and percentile range. In the third step, the system predicts the severity of depression (using BDI score) from the feature vector using regression method. For the regression method, Support Vector Regression (SVR) [16] was used which was implemented with LIBSVM [17]. The predicting system mean error is 7,05 in BDI [10].

D. EMOC score

From the 20 items of the PANAS questionnaire one characteristic was calculated name EMOC score. The EMOC calculation was done with the following formula (Eq 1):

$$EMOC = \frac{\sum positive\ affects\ scores}{\sum(positive\ and\ negative\ affects\ scores)} \quad (1)$$

The EMOC score describes the subject positive attitude, 0 implies a totally negative attitude (or at least not positive at all) while 1 implies a totally positive attitude (or at least not negative at all). It can be said that if the EMOC score for a subject is above 0.5, then the subject is rather positively affected, while if it is below 0.5, then the subject is rather negatively affected. This EMOC score was used by Ehmann and Balázs in their previous work [18], where they compared the PANAS results and the predicted emotion state derived from the verbal contents of the crew members' diary recordings at Concordia research station.

E. Examined time period

The examination and analyzation of the BDI and EMOC scores were evaluated from the middle of February to the beginning of November according to the start and the end of isolation mentioned in the introduction. The examined time period was divided into four almost equal length of quarters Q1, Q2, Q3 and Q4 according to the work of Ehmann and Balázs [18]. The exact starting and ending date of each quarter is shown in Table 3.

TABLE III. THE STARTING AND ENDING DATES OF EACH QUARTER

	STARTING DATE	ENDING DATE
Q1	2013.02.13	2013.04.19
Q2	2013.04.20	2014.06.23
Q3	2013.06.24	2013.08.27
Q4	2013.08.28	2013.11.05

It was necessary to split the examined period into several parts to allow statistical analyzation to compare the changes of the BDI and EMOC scores in time.

F. Statistical analysis

The mean of BDI and EMOC scores of the whole group were calculated in every quarter, and the mean values were compared using independent sample T-test. 95% significance level was selected for T-test. Besides comparing the mean values, the correlation between BDI and EMOC scores was also examined. For correlation analysis Pearson and Spearman correlation tests were used. As it was mentioned in Section II, the recordings and the completion of PANAS questionnaire were generally not done on the same day, and there were more audio recordings than PANAS results. For the correlation analysis the date of the PANAS results were selected, and the corresponding BDI value was determined by interpolation. Our hypothesis was that with higher value of BDI score, lower value of EMOC score will be measured because depression causes deep sadness for a subject who suffers from it.

Statistical comparisons of the mean values separated for each crew member could not be carried out due to the small number of samples in each quarter for each crew member.

IV. RESULTS

The analysis and comparison of BDI and EMOC scores were carried out in two ways. First, statistical analysis was carried out on the whole group. Then each subjects BDI and EMOC scores were examined separated without using independent sample T-test.

A. Group analyzation

The correlation analysis of the BDI and EMOC scores was evaluated for the whole group. Spearman correlation coefficient was -.155 which was significant at 95% significance level. Pearson correlation coefficient was -.113 which was not significant. Thus, our hypothesis that with the increase of BDI score a decrease of EMOC score can be observed was only partially proved and the correlation is not really remarkable.

Table 4 shows the BDI and EMOC scores of the group in each quarter. The following statistical descriptors were selected: mean, standard deviation (std.), maximum (max.) and minimum (min.).

TABLE IV. THE STATISTICAL ANALYSIS OF BDI AND EMOC SCORES OF THE CREW MEMBERS GORUPED BY QUEARTERS

		Q1	Q2	Q3	Q4	Overall
BDI Scores	**Mean**	1.6	2.6	2.6	2.9	2.5
	Std.	2.2	4.5	3.4	3.4	3.2
	Max.	8	13	15	11	15
	Min.	0	0	0	0	0
EMOC Scores	**Mean**	.72	.74	.72	.72	.72
	Std.	.07	.06	.07	.07	.07
	Max.	.8	.82	.82	.8	.82
	Min.	.55	.55	.49	.5	.5

As we can see from the results (Table 4), the group overall mean BDI score was low (2.5). The lowest mean BDI score was measured in the Q1 (1.6) while the highest mean BDI score was measured in the Q4 (2.9), which is still low compared to the border of the depression which is 14 BDI. The maximum measured BDI score (15) was in Q3. The overall mean EMOC score was (0.72), and it was almost identical during the quarters except for Q2 (0.74). The minimum measured EMOC score (.49) was in Q3 also like the maximum measured BDI score. Based on the examined data, it can be stated that the group was not suffering from depression and their emotional attitude was rather positive and balanced.

Table 5 shows the results of the T-tests. The mean value of BDI and EMOC scores were compared based on the quarters, Q1 was compared to Q2, Q2 was compared to Q3, Q3 was compared to Q4 and Q1 was compared to Q4. The differences of the mean values between the examined quarters are given in the "Diff." row. In the "Sign." row the significance is shown at 95% significance level, if the difference was significant it is marked with "yes" if it was not significant it is marked with "no".

TABLE V. THE RESULTS OF T-TEST FOR THE BDI AND EMOC SCORES GROUPED BY QUARTERS

		Q1-Q2	Q2-Q3	Q3-Q4	Q1-Q4
BDI scores	Diff.	-1.03	-.02	-.31	-1.4
	Sign.	no	no	no	yes
EMOC Scores	Diff	-.018	.018	-.002	-.003
	Sign.	no	no	no	no

There was no significant difference between either consecutive quarters, whether the mean BDI scores or the mean EMOC scores were tested. From the results it can be stated that the biggest difference in the BDI scores was between Q2 and Q1 (1.03 increase), and the mean BDI scores steadily increased in each quarter, however, this increase was not remarkable. When the mean BDI scores of Q1 and Q4 were tested, significant difference (-1.4) was detected, however the mean BDI score of Q4 was still low and non-depressed. There was no remarkable trend in the change of the mean EMOC scores.

B. Separate subject analyzation

Table 6 shows the mean value of the BDI and EMOC scores separately for each crew member grouped by the quarters. The 11 crew member was labeled from subject 1 to subject 11. Spearman and Pearson correlation analysis was carried out separately for each crew member either.

From the results of the separate subject analysis (Table 6), it can be seen that the two highest mean BDI scores were measured for subject 3 and subject 10. The maximum BDI score (15) and the minimum EMOC score (.49) which was mentioned in the section before, was measured in case of subject 10 in the third quarter (Q3). While there is no significant change in EMOC scores in case of subject 3, there is a significant decrease in EMOC scores in case of subject 10. Based on further examination, it can be observed that subject 10 has one of the lowest mean EMOC scores, as he is the only subject where an almost continuous and remarkable decrease in EMOC scores can be observed and the correlation coefficients were the most significant in case of this subject as well (-.495 Spearman correlation coefficient, and -.365 Pearson correlation coefficient). From these results it can be stated that maybe subject 10 was suffering from some kind of bad mood or from mild depression in the third and fourth quarters (Q3 and Q4). The other examined crew members were healthy and non-depressed based on our study.

TABLE VI. THE USED DATABASE MAIN DESCRIPTIVES

		Q1	Q2	Q3	Q4
Subj. 1	BDI	0	0	0	1.2
	EMOC	.77	.73	.74	.76
Subj. 2	BDI	0	0	0	1
	EMOC	.65	.78	.74	.71
Subj. 3	BDI	2.7	8.3	8.2	9.8
	EMOC	.76	.78	.75	.74
Subj. 4	BDI	2.8	5	3.8	3.8
	EMOC	.71	.69	.71	.69
Subj. 5	BDI	2.5	4.7	1.7	0
	EMOC	.69	.69	.6	.69
Subj. 6	BDI	0.5	0	0	0
	EMOC	.77	.75	.75	.75
Subj. 7	BDI	2.4	5.3	0	3.7
	EMOC	.73	.75	.73	.74
Subj. 8	BDI	0	0.7	3	2.6
	EMOC	.64	.7	.75	.76
Subj. 9	BDI	5.3	2	3	0.5
	EMOC	.68	.72	.66	.65
Subj. 10	BDI	1	1	6.5	6.2
	EMOC	.76	.69	.61	.63
Subj. 11	BDI	0	1.7	2.5	2.4
	EMOC	.63	.8	.8	.77

V. CONCLUSIONS

In this paper, the depressed state of the crew members of Concordia research station was compared with the results of their subjective self-report psychological test. An automatic predictive system was used to determine the depressed state, based on speech processing. The system output was a BDI score to describe the severity of depressed state of the examined subject. PANAS questionnaire was used for the subjective psychological test. From the results of the PANAS questionnaire, EMOC scores were calculated, which is reflecting the positive or negative attitude of the examined subject. Our hypothesis was that there is a negative correlation between BDI and EMOC scores.

A follow-up study was carried out on the BDI and EMOC scores of the crew members. The investigated time period lasted from the middle of February to the beginning of November, and this period was divided into four quarters. The difference of BDI and EMOC scores for the whole group cumulatively was examined in each quarter. Further analyzation of the BDI and EMOC scores was carried out separately for each crew member.

The correlation of BDI and EMOC scores was also analyzed with Spearman and Pearson tests.

As a result of the examination (Table 4), it can be stated that the group as a whole did not suffer from depression and had a rather positive attitude throughout the whole examined period (2.5 mean BDI score and .72 mean EMOC score) and in each quarter either (1.6-2.9 mean BDI scores and .72-.74 mean EMOC scores). There was no significant change in the BDI and EMOC scores in consecutive quarters. A higher BDI score (15 BDI) was measured for only one crew member (subject 10), which may indicate a mild depressed state. However, in the examined quarter (Q3), the mean BDI score (6.5 BDI) of subject 10 remained below the border of mild depression (14 BDI). In the case of subject 10, with the increase in BDI scores, a decrease in EMOC scores was observed from .76 to .61-.63.

For these reasons, it can be stated that the group as a whole has adapted well to the extreme circumstances and isolation at Concordia research station.

Based on the correlation analysis weak negative correlation was found between the BDI and EMOC scores (-.155 Spearman correlation, and -.113 Pearson correlation). Thus, our hypothesis was proofed, however, the correlation is really weak and only the Spearman correlation proved to be significant. Low correlation coefficients may have many reasons. One of the main problem was that there was no significant change in either BDI or EMOC scores during the examined time period. The correlation analysis could be distorted by both the natural bias of the BDI prediction and by the well-known bias of the completion of the PANAS questionnaire, for example in the case of self- completion, people are inclined to fill out the questionnaire further positively even if there is a slight negative change in their attitudes. This presumption is supported by the fact that for subject 10 there was a significantly stronger correlation between BDI and EMOC scores (-.495 Spearman correlation, and -.365 Pearson correlation).

It would be important to carry out the study, for another group in which more depressed subjects could be found.

ACKNOWLEDGMENT

The research was supported by European Space Agency COALA project: Psychological Status Monitoring by Computerized Analysis of Language phenomena (COALA) (AO-11-Concordia).

REFERENCES

[1] Schumann, I., Schneider, A., Kantert, C., Lo¨we, B., Linde, K., 2012. “Physicians’ attitudes, diagnostic process and barriers regarding depression diagnosis in primary care: a systematic review of qualitative studies.” Fam. Pract. 29, 255–263.

[2] Marcus, M., Yasamy, M. T., van Ommeren, M., Chisholm, D., & Saxena, S. (2012).” Depression: A global public health concern”. WHO Department of Mental Health and Substance Abuse, 1, 6-8.

[3] Alghowinem, S., Goecke, R., Wagner, M., Epps, J., Breakspear, M., & Parker, G. (2013, May). “Detecting depression: a comparison between spontaneous and read speech.” In 2013 IEEE International Conference on Acoustics, Speech and Signal Processing (pp. 7547-7551). IEEE.

[4] Brendel, R.W., Wei, M., Lagomasino, I.T., Perlis, R.H., Stern, T.A., 2010. “Care of the suicidal patient.” Massachusetts General Hospital Handbook of General Hospital Psychiatry, 6th ed. W.B. Saunders, Saint Louis, pp. 541–554.

[5] Kiss, G., Tulics, M. G., Sztahó, D., Esposito, A., & Vicsi, K., “Language independent detection possibilities of depression by speech,” Recent Advances in Nonlinear Speech Processing, pp. 103-114. Springer International Publishing., 2016

[6] Alghowinem, S., Goecke, R., Epps, J., Wagner, M. and Cohn, J., “Cross-Cultural Depression Recognition from Vocal Biomarkers,” Interspeech 2016, pp. 1943-1947, 2016

[7] Liu, Z., Hu, B., Yan, L., Wang, T., Liu, F., Li, X., & Kang, H., “Detection of depression in speech,” Affective Computing and Intelligent Interaction (ACII), 2015 International Conference on, IEEE, pp. 743-747, 2015

[8] Williamson, J. R., Quatieri, T. F., Helfer, B. S., Horwitz, R., Yu, B., & Mehta, D. D., “Vocal biomarkers of depression based on motor incoordination,” In Proceedings of the 3rd ACM international workshop on Audio/visual emotion challenge, ACM, pp. 41-48, 2013

[9] Cummins, N., Sethu, V., Epps, J., Schnieder, S., & Krajewski, J., “Analysis of acoustic space variability in speech affected by depression,” Speech Communication, 75:27-49, 2015

[10] Kiss, G. and Vicsi, K., 2017. “Mono-and multi-lingual depression prediction based on speech processing.” International Journal of Speech Technology, 20(4), pp.919-935.

[11] Crawford, J.R. and Henry, J.D., 2004. “The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample.” British journal of clinical psychology, 43(3), pp.245-265.

[12] Beck, A.T., Steer, R.A., Ball, R., Ranieri, W.F., “Comparison of beck depression inventories-ia and-ii in psychiatric outpatients,” J. Pers. Assess. 67, 588–597, 1996

[13] Kiss, G. and Vicsi, K., 2017. “Follow-up Psychological Status Monitoring of the Crew Members of Concordia Research Station at Antarctica Based on their Speech.” In Selected papers of 3rd International Conference on Research, Technology and Education of Space (p. 37).

[14] Kiss, G. and Vicsi, K., 2015. “Seasonal affective disorder speech detection on the base of acoustic phonetic speech parameters.” Acta Universitatis Sapientiae Electrical and Mechanical Engineering, 7, pp.62-79.

[15] Kiss, G., Sztahó, D. and Vicsi, K., 2013. “Language independent automatic speech segmentation into phoneme-like units on the base of acoustic distinctive features.” In Cognitive Infocommunications (CogInfoCom), 2013 IEEE 4th International Conference on (pp. 579-582). IEEE.

[16] Smola, A., & Vapnik, V. (1997). “Support vector regression machines.” Advances in neural information processing systems, 9, 155-161.

[17] Chang, C. C., & Lin, C. J. (2011). “LIBSVM: a library for support vector machines.” ACM Transactions on Intelligent Systems and Technology (TIST), 2(3), 27.

[18] Ehmann, B., Balazs, L. 2015 “Concordia antarctica winteroverers: psychological content analysis of weekly video diaries.” In: IAA-HIS-15 Abstract Book. Prague: p. 79.

Estimation of Clear Sky Level for Satellite Propagation Measurements

Bernard Adjei-Frimpong
Department of Broadband Infocommunications and Electromagnetic Theory,
Budapest University of Technology and Economics
Budapest, Hungary
bernard.frimpong@hvt.bme.hu

Laszlo Csurgai-Horvath
Department of Broadband Infocommunications and Electromagnetic Theory,
Budapest University of Technology and Economics
Budapest, Hungary
laszlo.csurgai@hvt.bme.hu

***Abstract*—The European Space Agency launched a communication satellite called 'Alphasat' in 2013, with two experimental beacons to carry out a scientific experiment by measurement at frequencies of 19.7GHz and 39.4GHz respectively. Propagation through the atmosphere at these frequencies is affected by the presence of atmospheric gases and other particles like water vapour, rain and ice drops. Rain attenuation is the most significant parameter which degrades the performance of the links by absorbing and scattering radio waves. Rain rate is the main parameter used to predict of rain attenuation. Rainfall statistical data are measured and recorded over integration time for the period in which data are collected. The prediction methods require minutes of integration time rain intensity.**

In our institute, at the Department of Broadband Infocommunications and Electromagnetic Theory we have set up a ground station to carry out propagation measurements in the Ka/Q band. The station receives signal from the satellite to characterize the satellite-Earth propagation channel. The beacon receiver station has been operating since 2014, collecting signal power data, and also records relevant meteorological data as well. The main goal of long-term propagation measurements is to improve the existing attenuation models that are published in the relevant ITU-R recommendations.

In this paper the key data processing procedures are discussed and exemplified by their application to one year of measurements. In the first phase data pre-processing is performed and the measured received signal power is converted to attenuation. The reference level (clear sky level) is a critical parameter during this process that can be selected as an average signal level or on an event by- event basis.

In our paper we are testing different threshold selection methods and during the conversion procedure calculate the RMSE error to evaluate the quality of the data pre-processing. The attenuation statistics obtained from measured time series are compared with models predictions from the ITU-R to assess their usefulness and precision. An appropriate threshold-selection is supported by comparison with the probability of rain at the specific geographical location as it is given in ITU-R.

Keywords—satellite propagation, data conversion, attenuation statistics

I. Introduction

One of the major challenges, affecting propagating characteristics on terrestrial and satellite communication links at microwave and millimetre wave frequencies are the significance of rain attenuation of electromagnetic waves. Rain attenuation effect, greatly influences the propagation loss experienced by terrestrial communication links, from the transmitter to receiver. The attenuation by rain depends on the temperature, distribution size, terminal velocity and shape of the raindrops.

The rain attenuation can be measured quite accurately by means of satellite beacon signals and radiometers. However, since propagation experiments are carried out only in few places across the world and for a limited number of frequencies and link geometry, their results cannot be directly applied to all sites. For this reason, several attenuation models based on physical facts and using available meteorological data have been developed to provide adequate inputs for system margin calculations in all regions of the world.

The Radio communication Agency of the International Telecommunication Union (ITU-R) provides these set of models which are largely derived from measured data and uses rain intensity and rain height as the main input parameters [2]. The accurate estimation of the prevision of the rain intensity values at any site are needed for a correct terrestrial and satellite radio links design.

In this paper, the main goal of long-term propagation measurements is to improve the existing attenuation models that are published in the relevant ITU-R recommendations. In this case the processing procedures are discussed and exemplified by their application to the one full year of measurements. In the first phase data pre-processing is performed and the measured received signal power is converted to attenuation. The reference level (clear sky level) is a critical parameter during this process that can be selected as an average signal level or on an event by- event basis.

These are scientific propagation measurements basically in both Ka-and Q-bands, and it is based on the unmodulated beacon signal transmitting from the satellite. Our institution the Budapest University of Technology and Economics has set up a receiver station where analysis is carried in relation to this research.

The organization of this paper is as follows. Section II gives a description of equipments used at the receiver station for measurement and the development of a method for predicting rain attenuation. Section III describes the effects of rain attenuation for high frequencies in Ka/Q-band satellite communications links and, the method applied to predict rain rate and attenuation is described together with the data processing technique. Section IV analyses the prediction results of the proposed method, which are then compared with the measured data and the models in recommendation ITU-R P.837[3] and recommendation ITU-R P.618 [2] for rain rate and rain propagation attenuation respectively. Finally, we conclude the paper.

II. RECIEVER STATION SET-UP

Alphasat, is an European satellite launched in 2013 with two beacons for wave propagation characterization in the Ka (19.701GHz) and Q (39.403GHz) band respectively. This beacon receiver station is located on top of the department's building at BME, N47.48° latitudes and E19.06° longitudes at a height of 120m [1]. The building blocks of the receiver station is a modified terrestrial microwave radio equipment with several hardware and firmware modifications. Both the Ka and the Q-band receivers are based on identical outdoor unit (ODU) construction; the difference is only the frequency of the locally synthesized signals to provide an identical 140MHz IF frequency. As the orbit of Alphasat is low-inclination geosynchronous a tracking system is also operated in order to eliminate the daily variation of the received signal power. Figure 1 is a display of high performance antennas with tracking system.

The ODU is a double conversion heterodyne receiver with synthesized local signal sources. Its original noise figure has been reduced from 5dB to 3dB and in order to generate a stable and jitter-free down-converted intermediate frequency (IF) signal, the oscillator block in the ODU is also changed. The reference oscillator of the synthesizers is now designed to achieve a high stability, low phase noise OCXO with less than ± 1.0 ppb/day stability. The down-converted, filtered (bandwidth=100kHz) and amplified IF signals are connected with a low attenuation coaxial cable to the indoor unit (IDU) and the calibrated gain of the ODU is 100dB.

Figure 1. High performance antennas with tracking system

The indoor unit is based on a modified I-Q demodulator that processes the incoming IF signal. The 140 MHz IF signal is under sampled with 80MHz analog/digital converter unit. The role of the quadrature digital downconverter (QDDC) module is to convert down the sampled signal into baseband quadrature component signals. The baseband signals (I, Q) are decimated (512) and filtered by CIC and FIR filters.

The ODU also contains an internal temperature sensor with 1°C accuracy. This sensor is used for the temperature-compensation of the ODU's amplifier circuits. During the calibration of the ODU in a thermal-chamber the temperature-dependency of the complete receiver chain was determined. The firmware has a built-in compensation table; therefore, the result is a temperature-independent, high accuracy level measurement. The temperature-compensated values are averaged and fed to a fine gain control unit that ensures the nominal 100dB ODU gain.

The filtered and decimated signal is processed by an 8192 point FFT where the beacon signal can be detected as the highest amplitude spectral component. The carrier amplitude measurement is performed within 1 second and the final data is forwarded after a logarithmic conversion to the data collecting system. The resolution of the received power is 0.2dBm. By taking into account the speed of A/D conversion, the decimation and the FFT buffer size, the system bandwidth is 80MHz/512/8192=19.07Hz.

III. ITU-R ESTIMATION

ITU-R 618: Basically used for comparing the measured rain attenuation with the ITU-R predictions, this model is a step by step procedure for the calculating rain attenuation cumulative function for satellite link. The ITU –R provides the most accurate statistical estimate of attenuation on slant paths. This model provides a global rain statistic by dividing the earth into five regions and assigning a rain rate to each region with the probability of the rain rate being exceeded. It can also be used for frequencies from 4GHz-55GHz and 0.01-5% percentage probability range. The model uses the rain rate at 0.001% probability level for the estimation of attenuation and then applies an adjustment factor to predict rain fade depth for other possibilities. Attenuation predictions requires first the estimation of a surface rain rate distribution and second the prediction of the radio wave attenuation value distribution, given by that the rain rate distribution. The model is derived based on log normal distribution, using similarity, principles. Inhomogeneities in rain, in both horizontal and vertical direction are accounted for in the prediction. The limit of the model is the data for years of measurements taken at the station and not all stations filled with the one-minute integration time requirement. In Figure 2 is the diagram of the parameters for rain height calculation.

Recommendation ITU-R P.837 contains maps of meteorological parameters that have been obtained using the European Centre for Medium-Range Weather Forecast (ECMWF) ERA-40 re-analysis database, which are recommended for the prediction of rainfall rate statistics with a 1-min integration time, when local measurements are missing. Rainfall rate statistics with a 1-min integration time are required for the prediction of rain attenuation in terrestrial and satellite links. Data of long-term measurements of rainfall rate may be available from local sources, but only with higher integration times. This Recommendation provides a method for the conversion of rainfall rate statistics with a higher integration time to rainfall rate statistics with a 1-min integration time.

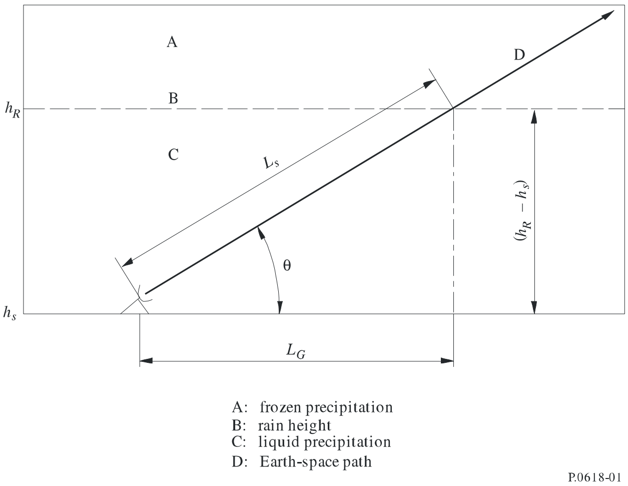


Figure 2. Rain height calculation based on ITU-R [2]

Calculations can be made for Link Availability (%) for all frequency bands, to take into account link budgets, transmit power, receive sensitivity, antenna gain, target availability and other factors. Typical Link Availability Targets are 99.99%, 99.999% and higher.

A. *Data Processing*

The beacon receiver stations (at our station at BME as well) usually record the received signal's power. In order to get attenuation statistics, the received signal (power) should be converted to attenuation. This could be done by applying different methods, but they may influence the precision of the attenuation statistics estimation as well. Therefore, key issue is the process of determining the clear sky level, as the reference level. Due to lack of a radiometer (as it is also at BME) the simplest method to apply is the long-term median or mean value of the received power time series as reference level. To take into account the long-term signal variations a more effective method is used to select manually the individual rain events.

As a first step in the data processing, invalid measurements are removed from the received signal of both attenuation and weather data using a combination of automatic and semi-automatic procedures. After the filtering the 0 dB reference level is identified by using a few minutes of data before and after each event and interpolating between them. This procedure, in combination with the lack of a radiometer, does not allow complete separation of cloud attenuation from rain so there will be some cloud attenuation included in the data. However, the highest cloud attenuation predicted by the ITU-R [2] (at the 1 % exceedance level) is 0.5 dB, thus the contribution should be limited. Next, attenuation events are manually identified and selected for processing. The root mean square error of the signal during clear sky conditions were calculated and the results verified with the models of ITU-R. The set of measurements studied in this paper covers the entire years of 2016.

IV. ANALYSIS OF CLEAR SKY ESTIMATION

One important parameter is the R_{001} value used for characterization of a given geographical location. According to the ITU regulations its value is 35mm/h for Budapest location. However, this value may change during different time in years according to the local weather conditions. This could be one of the reasons why the measured and modelled curves are not exactly covering each other. To determine the clear sky level, the measured values are subtracted from the median (clear sky) received power and then calculated over an entire year. The attenuation events are mainly caused by rainy periods. The Complementary Cumulative Distribution Function (CCDF) of rain attenuation provides the probability of exceeding at different attenuation levels. The monthly distributions reveal how the rain events can significantly influence the actual weather conditions

In Figure 3 is displayed the Complementary Cumulative Distribution Function (CCDF) of the measured attenuation for Ka and Q-band together with the distribution curves predicted by the ITU-R P.618 recommendation for an entire year of 2016 for median estimate of the clear sky level.

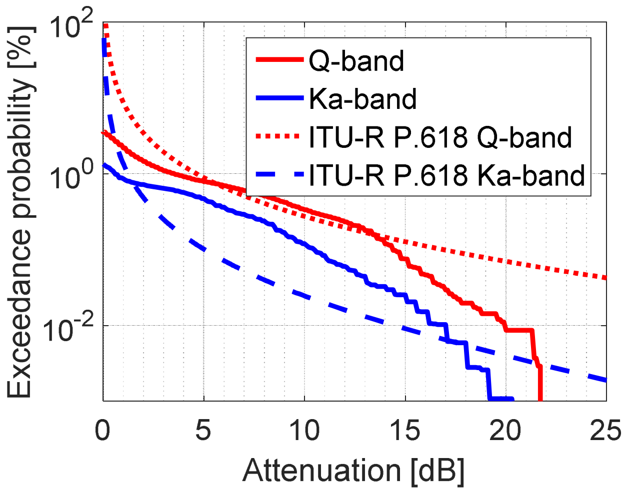


Figure 3. CCDF for Ka and Q band, compared with the ITU-R, clear sky level calculated with median

In order to estimate and enhance the clear sky level, of the error between measurements and the ITU-R model, the root mean square error (RMSE) has been applied. Therefore, we calculate the RMSE between the measured and the predicted attenuation values as the square root of the expected value of the power of differences between the measured and modelled values. Figure 4 and Figure 5 displays the RMSE for the Ka and Q band respectively.

The measured values are again subtracted from the mean (clear level sky) received power and has been calculated over an entire year. And the resulting graphs displayed in Figure 7 and Figure 8. It can be deduced that there are no significant changes comparing to the previous one displayed by the median. This also the same for CCDF displayed in Figure 6.

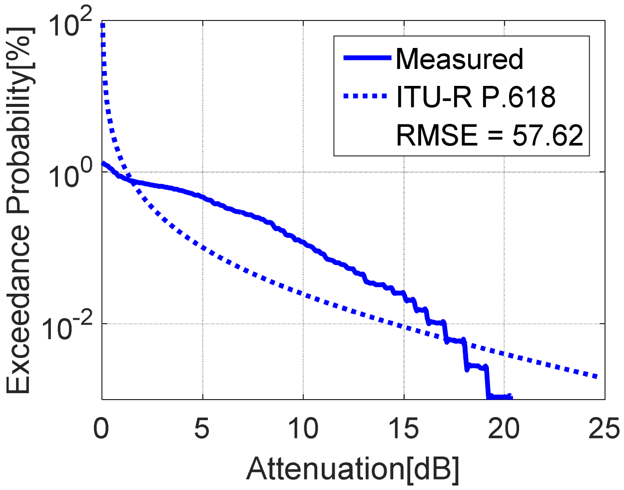


Figure 4. RMSE for Ka-band, clear sky level calculated with median

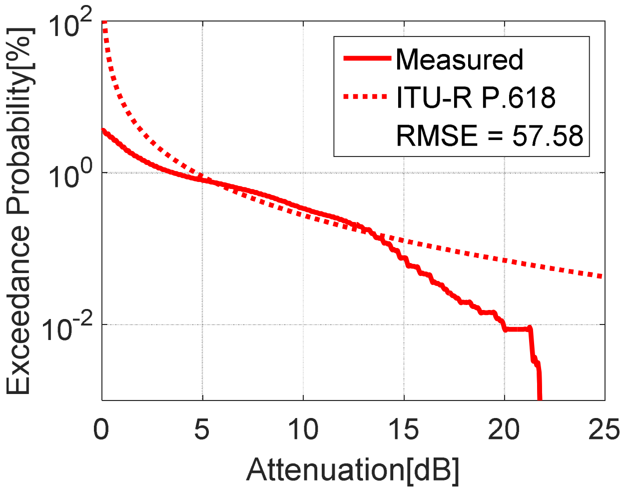


Figure 5. RMSE for Q-band, clear sky level calculated with median

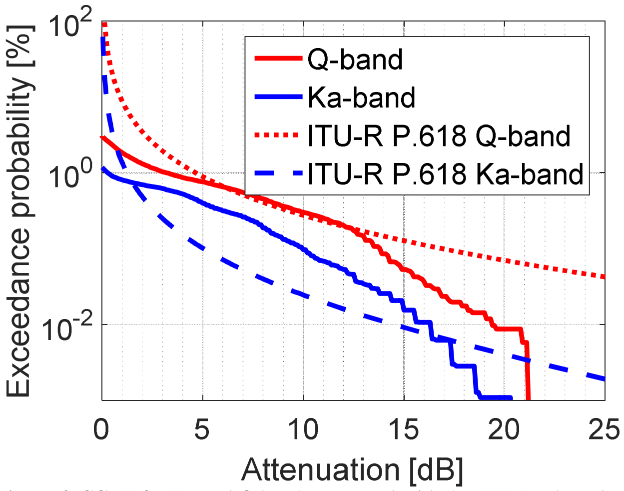


Figure 6. CCDF for Ka and Q band, compared with the ITU-R, clear sky level calculated with mean

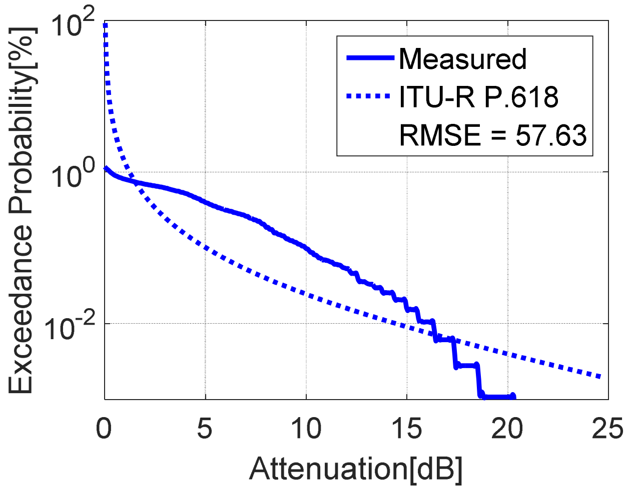


Figure 7. RMSE for Ka-band, clear sky level calculated with mean

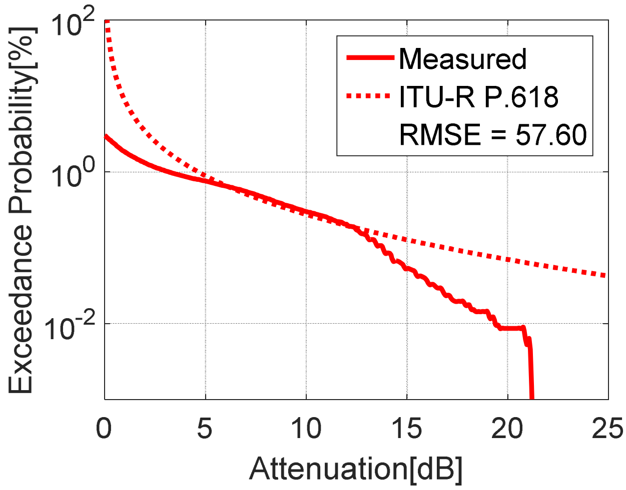


Figure 8. RMSE for Q-band, clear sky level calculated with mean

The rain events are then selected manually selected to estimate the clear sky level from the median and the mean already displayed above. The following analysis depicts the selection of the rainy periods manually and represents, the entire year of 2016 for the Q and Ka-band of the selected events for the channel. When we apply the manually selected events and calculates the attenuation statistics (attenuation CCDF), we obtain a better approximation of the ITU-R curve, can be observed comparing with Figure 3 - Figure 8. The result is depicted in Figure 9. for the Ka-band and Q-bands respectively for CCDF. Then Figure 10 and Figure 11 are depicting the roots mean square value for the manually selected events.

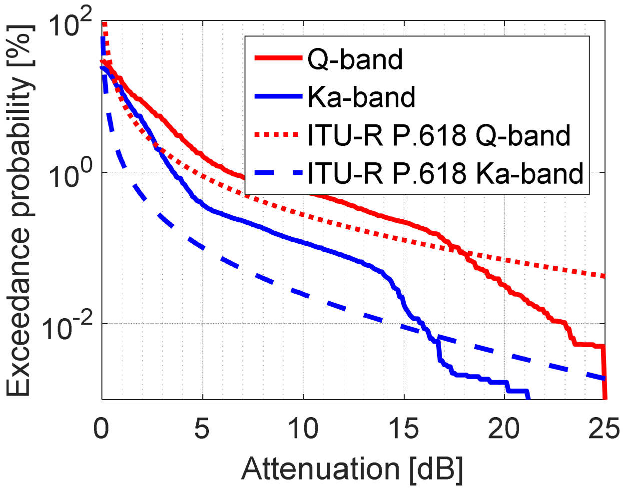


Figure 9. CCDF for Ka and Q band, manually selected compared with the ITU-R, clear sky level

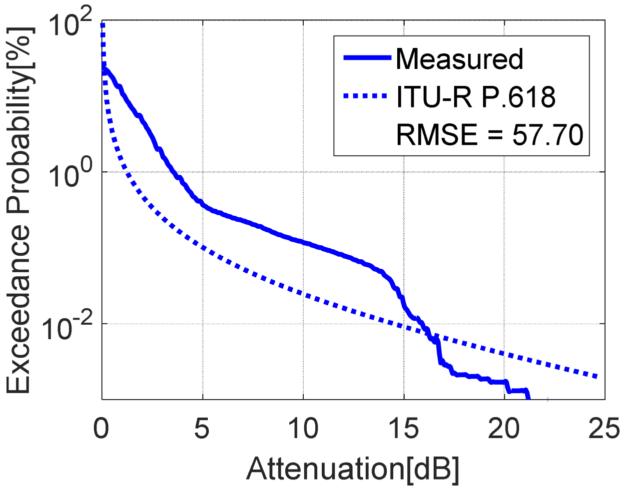


Figure 10. RMSE for Ka-band, clear sky level for manually selected events

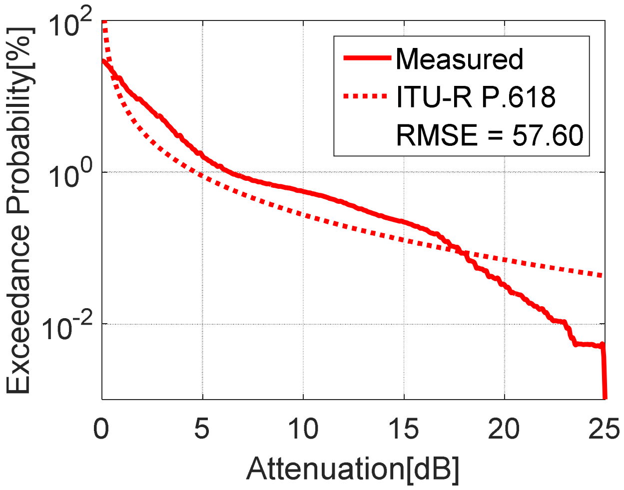


Figure 11. RMSE for Q-band, clear sky level for manually selected events

CONCLUSION

In this paper we have demonstrated how to convert the received power time series to attenuation time series, and it was further demonstrated that by selecting manually the rain events we achieve better approximation of the statistics provided by ITU-R. We calculated RMSE errors for the comparison and to prove the results that were obtained.

Future work will be to finish the manual event selection for a longer, and this may provide the most accurate rain attenuation statistics for the geographical location of the receiver station.

REFERENCES

[1] Csurgai-Horváth L. et. al., "The Aldo Paraboni Scientific Experiment: Ka/Q Band Receiver Station in Hungary", In Proc. 9th European Conference on Antennas and Propagation, Lisbon, Portugal, 12-17 April 2015J.

[2] ITU-R P.618-12, Propagation data and prediction methods required for the design of earth-space telecommu-nication systems, International Telecommunication Union, Geneva, Switzerland, 2015

[3] ITU-R P.837-7, Characteristics of precipitation for propagation modeling, International Telecommunication Union, Geneva, Switzerland, 2017.

[4] Recommendation ITU-R P.1511-1, Topography for Earth-space propagation modelling, ITU, 2015K. Elissa, "Title of paper if known," unpublished.

[5] Recommendation ITU-R P.678-3, Characterization of the variability of propagation phenomena and estimation of the risk associated with propagation margin, ITU, 2015.

[6] Riera J.M. et. al.," Alphasat Propagation Experiment in Madrid: Quality Assessment of the Measurements", In Proc. 9th European Conference on Antennas and Propagation, Lisbon, Portugal, 12-17 April 201

Citizen Science
An idea to integrate science into our digitized world

Pusztai Péter Pál

Szombathely, HUNGARY
pusztai.peter.pal@gmail.com

While the transmission of the information is getting more and more accelerated nowadays, we should thinking "out of the box" about the biggest milestones of the scientific era, to rate and explain and go more further in every aspect of the present and future of our lives, including the space research as the tomorrow's biggest challenge of the mankind. While we getting more and more theoretical and practical experience about our environment up and below the horizon, we should spread the knowledge for everyone who feel enough motivation to help our mission to explore our planet in various ways or be adventurous to discover unknown depth of the void between the stars and planets far away. We should start a long-term project, controlled and supported by the local schools and universities as resource centers for everyone, who wants to take part in it, to help the science in every way, as an innovative and creative citizen. To help this task we should make DIY small kits to which are contains quite cheap and easily available parts to assemble by everyone without age or exact qualification limit or global location to reproduce or observe the experiments in real time even at home. The results what we get from these actions makes the sampling spectrum more wider and diverged fort he scientists. With the help of the volunteer civilians we can organize smaller research groups to methodize these amount of data, remain in contact with the main institute's experts, manage workshops while they supervise, operate with the apportioned assembling kits. It allows to the smaller, and almost unreachable areas to join to an international project what was impossible before and make their new possibilities to catch up with the another parts of the globe. These movements in the future maybe let us to make a "KISS"-like cubesat constellation which can be very important and life-saving option in a global emergency situation-like the latest hurricane events, when all the communication channels were blocked or destroyed by the heavy storm -from any location from the Earth we can use it as a standby communication channel to help the work of the aid organizations and the lifeguards in the devastated zones.

Keywords: civilian, citizen, school, global, emergency, cubesat

[1] INTRODUCTION

The world is changing not just day to day, but from second to second in every details of our lives: the transmission of information has an unbelievable speed, so it's not easy to catch up with the latest trends and be up to date.

The modern citizen has various digital platforms and ways to react to the world's calling: on the road, at home or between ocean and the land -we can do all this actions above simultaneously. Sometimes it's a big struggle to keep up with expectations to be as responsive and communicative in every ways what the technology offers-but the engineers and the developers try to make the user experience more barrier- free, and more efficient in every aspect.

More and more portable electric device appears nowadays and to be honest: expect from these gadgets primary telecommunication function, they show and teach us to make and consume contents in every subject all we can imagine- to share our experiences and opinions, to methodize them into topics and to upload them to a digital storage cloud from every corner of the world- thereby to be a part of big community despite the limits of time and space.

[2] DIGITAL DEPRIVATION:

A. Behind the rush of daily information: finding the right one

We can read, watch or save articles in different topics for our personal research and be inspired to make our ideas come true as the previous ones in the past, who spend hours and days in the library hall behind the books and lecture notes while planning their new breakthrough-today we just need to type few buzzwords and after some scroll on the display screen we can get to the required information instantly within minute, anytime, anywhere.

But we should have to cope with one necessary problem: the quality of this collected content sometimes as diverse as many sources we use- sometimes it cause that we not get reasonable, proper facts and it can lead to misunderstanding and the loss of the interest at first difficulties. It's not easy to be determinated and have enough willpower which insist from the first to the last step while we looking for the answers in the deepest-darkest and the furthest places up and below the horizon.

B. Coping with what the harsh reality offers, and believe

Thanks to speed of nowadays communication channels, people easily get the latest news and statements about our civilization's daily problems, the latest reports of our every day's conflicts with all the possible changes we want to make and with all the difficulties we have to face. Sometimes the mistakes and the tragedies of the mankind overshadows every good things which are counts, and these kind of impressions put a bad mark on our everyday life, and how we see our world's future.

Despite of all the concerns and the baneful guesses, the scientific work- which are affected and influenced at the same time because of these events -getting more and more important: while the top of the headlines often ruled by the distressing facts, the scientist's latest breakthroughs and inventions give us hope to make a better tomorrow for ourselves.

C. Making a decision to be a part of the change

One of the most complex questions is what makes the person to take the first move to start thinking "out of the box"-what kind of influences can make a sparkle nowadays people's mind to be enough desperate to break their obsolete habits and give up their convenient bounds and dedicated to new, more incredible and adventurous one: the conquest of known and the unknown universe, the biggest challenge of the mankind today.

[3] STEP BY STEP

Between the studies and specializations there is one, which can make permeable way to connect the different researcher's work for a groundbreaking collaboration which accepts the knowledge, the skills and experts from every parts of today's science, to extend the borders what we can reach by bare hands alone, but hand in hand they create a new scientific field, the space science, which become one of the most evolving part of the technical industries of today-and a powerful and inspiring theme in every part of our life, from the culture, through the futuristic fashion, design, to the everyday news.

A. From fiction to reality-the source of inspiration

The use of the space technology isn't a just an imaginary concept which is only found in the science-fiction novels and movies; today- from sunrise to sunset -it's a part of our lives. We get versatile and innovative textures, innovative methods what we use regularly and we take all of their advantages in every way. The new discoveries shows us inconceivable perspectives, unbelievable sizes of the hidden universe, both of the amazing and the frightening side of these phenomenons.

These kind of incredible successes makes many of us to feel as enthusiastic as a young themselves, when we open our mind to meet the reality for the first time: it's the era of why's and how's -we draw up tons of questions; maybe some of them never be answered, but the passion is, what makes us to take it to the furthest to get it, and experience and carry the most powerful influences a lifetime along and share with each other our views.

Returning to the one of our main questions about the origin of the first impression of the individual to make a new habit and be engaged to the scientific work-how to make it a routine-like skill, how to learn and practice it in the everyday presence of the space-science?

B. Knowledge in our pocket

If we examine the evolving communication process from an other viewpoint, we can interpret it as an attempt to create an unusual database which is very useful for everyone.
The traditional library and this virtual environment share many similarities, but the way to access to the storage to get this unlimited, specifically categorized information is more easier through the modern, digital platforms.

The practical way of learning basic skills is changed in the modern world because of the presence of the digital devices, but the comprehension method is became more detailed by the help of these: the instantly available audiovisual tutorials, the easily operable interface and the problem-free accessibility to the main modules is absolutely competitive beside what the real life is offering us as experiences on its great and simple way.
Today is almost impossible to make ourselves to be independent of these electronic gadgets, but from an other viewpoint we can use them as a portable, scientific data recording-processing and streaming equipment all in one, which can fit in our bag and makes an entertaining and faithful company in our observing journey.

Nobody is born with the interest coming from an inner urge, but, first, just raise our heads up to the big blueness above.

C. Inspiring initiatives

This idea to make people look up the sky again like the ancient times is not a breakthrough idea of today: without the religious overhears, many applications available to the smart devices to keep in touch with atmosphere's changes instead of the daily weather-forecast.
There is some example from the latest, quite interesting projects:

- The "Stellarium" is a free, open -source computer-based planetarium-simulation program. It allows a realistic, 3- dimensional experience, like an outdoor observing, through a binoculars or telescope. After typing the local geographic coordinates, it shows the exact position of the stars, planets, satellites and meteors above us in present time or in a time-lapse video. (1)

- The NASA is announced a citizen-science project earlier for the self-candidates to help the scientist: the Kepler space-telescope has collected an enormous amount of data from the deep-space during the years, but to process all of these raw visual information, the scientist asked help from the citizens. Kepler data for all the stars are processed at NASA Ames Research Center.
  The NASA has given a permission to access the Kepler's data for "planet hunting" -there is a website where we can learn the method by a simple tutorial and after that we can start looking for new planets, with a little luck, the hard work will show a return. We can use individual filters and own photometry technique and other forms of analysis to succeed in our search.

  The Planet Hunters is a part of the Zooinverse, which is a collection of web-based citizen science projects that use the efforts of volunteers to help researchers deal with the flood of data that confronts them. (2),(3)

- On Aug. 21. 2017, a total solar eclipse occured across the entire continental of the United States. It crossed the country from Oregon to South Carolina over the course of an hour and a half, 14 states experienced night-like darkness for approximately two minutes in the middle of the day.

  “No matter where you are in North America, whether it’s cloudy, clear or rainy, NASA wants as many people as possible to help with this citizen science project,” said Kristen Weaver, deputy coordinator for the project. “We want to inspire a million eclipse viewers to become eclipse scientists.”
  NASA invited eclipse viewers around the United States to participate in a nationwide science experiment by collecting cloud and air temperature data and reporting it via their phones.
  The Global Learning and Observations to Benefit the Environment, or GLOBE, Program is a NASA-supported research and education program that encourages students and citizen scientists to collect and analyze environmental observations. GLOBE Observer is a free, easy-to-use app that guides citizen scientists through data collection. In order to participate, we had to download the GLOBE Observer application and register to become a citizen scientist. The application will instruct the user on how to make the observations. And after all we needed to obtain a thermometer to measure air temperature.(4)

These examples above show us that it isn't hard to find a project to join if we have the all the conditions and tools in our hands to make a simplest observations for the scientists.

D. Additional kits for everyone

We should make and small "do-it-yourself" kits for everyone which are contains simple, replaceable and easily affordable parts to assemble and reproduce or observe the experiments even at home. It's a very entertaining and surprising thing to realize the small, but phenomenal things behind the classic theories about what runs the world ahead- there are different experiments to explore motion, heat, sound, electricity, magnetism and light in safe conditions.

All these examples illustrate that the "citizen science" attitude is one of the biggest trends what can make influence our society- but these results could be useless and ineffective without the help of the organization work of the research centers, universities and people, who spread the word.

[4]. EXAMINING AND LEARNING: THE OPEN INSTITUTE SYSTEM

The next step is to make people learn about what they have observed, to develop themselves to find connections between the nature's beautiful plays and look behind the curtains of the scientists work.

A. The audience

The participation of the local institutes and schools should make an offer for the citizens to make an active community with the help of the technology and make everyday science interesting and sharing the knowledge with everyone with no matter of age, gender or education level.

The latest one is outstanding from the another two- earlier before and unfortunately, nowadays- not everybody has a chance to attend to school, finish a university or get a major degree in a scientific subject, but shares the interest many ways in a special topic and follows the latest researches, even has a good idea to improve the results of it, even they're belongs to the younger or the older generation who wants to ask for a word, a chance to meet their destiny to make the new head-turning discoveries of the tomorrow.

B. Creative commissions, competitions

The institutes, museums and schools should make public science fairs, where the local professors, and experts can hold open classes for the curious ones, make workshops to try new experiments and examine and rate the results of the self-made observations of the volunteers, too.

One of the most interesting projects is the making of a small satellite which can fit in a soda can, but contains the most important, working parts of a normal satellite. It can measure, collect data as the other ones in space and it's a big challenge to make the lightest, the smallest devices which meets the requirements and can land safely after the launch. These Cansat competitions are suitable for the these workshops and the smaller research groups can work together for the same goal. (5)

C. The power of the community

If we can establish a fully functioning, complex resource centers connected with each other every other part of the globe, more people will visit these events for a long-lasting experience, and for the joy of discovering something new - these little, positive confirmations make the susceptible mind to want more and more and take part and continue the long-term projects, to help the science in every way, as an innovative and creative citizen.

The meetings and projects should evolve a stable cooperation with each other, despite of geographic location or economic situation- the scientists will lead and help us to discover the living universe around us and teach to take care of our environment as long as we can.

[5] THE NECESSITY OF THE CITIZEN SCIENCE

Beyond the educational and social benefits of citizen science,(environment protection, scientifically enlightened citizens open places for educational meetings, the hard work of the volunteers) everyday life can produce strange, critic situations, where we can use the learned information and instructions, instead of waiting hopelessly for the light in the sudden darkness.

Despite of every actions what we made to keep our planet calculable and safe place, there are many things which can them collapse every time without a warning sign- it can happened by an unpredictable space weather- condition, like an enormous solar flare which can cause that all the electric devices will become inoperable within seconds, but it's hopefully very uncommon event, but we have to prepare for this case, because most of everyday objects is operating with this energy source.

A. The pioneer candidates

It's seems strange for the first hear, but there is an amateur radio club for the primary students and they have group projects in very uncommon theme: imaginative, real-world, role-play scenarios designed to challenge students which are preparing them to emergency situations and the possible ways to solve them: a shipwreck or a plane crash situation moves the imagination of the kids and offers many creative ways to get help, with the use of supervised radio transmitters and beacons. (6)

It looks like a childish pastime, but it's very important proposal for all of us, what we should do a situation like this?
A severe storm or a natural disaster makes almost the same circumstances, when the communication channels almost are blocked or destroyed by the unstoppable power of the nature. Through these citizen science projects we can prepare almost the worst: if a small part of the population volunteer to acquire the basic skills how to use or build, eventually maintain a radio station in nationwide alert situation they can ask for aid, coordinate and help the lifeguards to locate the most devastated zones as soon as possible.

B. The help of emergency satellites

To use this lifesaving option completely, we have to mention the first a groundbreaking movement: The International Cospas-Sarsat Programme. It is a treaty-based, nonprofit, intergovernmental, humanitarian cooperative of 44 nations and agencies dedicated to detecting and locating radio beacons activated by persons, aircraft or vessels in distress, and forwarding this alert information to authorities that can take action for rescue. The system utilizes a network of satellites that provide coverage anywhere on Earth. Distress alerts are detected, located and forwarded to over 200 countries and territories at no cost to beacon owners or the receiving government agencies. Beacon models are subjected to a rigorous testing procedure by Cospas-Sarsat to ensure that they will operate under a variety of extreme conditions. Once a beacon model successfully has passed this procedure it is known as a Cospas-Sarsat type-approved 406-MHz distress beacon. (7)

The one problem is with the Sarsat system is that their dedicated 406 MHz frequency is does not permitted by the local authorities in every country in the world, but in an emergency situation can rewrite all the rules and permit some actions in order to restore the communication channels. Beside of the greatness of this emergency satellite constellation system we need a backup constellation also, and a peer-to-peer like local radio system beside them to communicate between the damaged areas if there anybody is alive and answer before the help comes.

[6] SUMMARY AND CONCLUSIONS

The citizen science is not as complicated as we thought before, and it can be applied in every possible situations beside of saving lives; the first steps are the most difficult, but after we pick up the thread, it can show us a different way to think about the science in general, to search another possibilities if every door is closed and find new challenges around us and through the mysterious dome above.

REFERENCES

[1] Stellarium Official Homepage :http://stellarium.org/hu/

[2] Planet Hunters Official Homepage: https://www.planethunters.org/#/

[3] NASA Citizen Science :https://www.nasa.gov/kepler/education/citizen

[4] NASA Invites You to Become a Citizen Scientist During US Total Solar Eclipse : https://www.nasa.gov/feature/goddard/2017/nasa-invites-you-to-become-a-citizen-scientist-during-us-total-solar-eclipse

[5] What is a Cansat?, Cansat webpage_ , http://www.esa.int/Education/CanSat/What_is_a_CanSat

[6] School Amateur Radio Club Network :http://sarcnet.org/missions.html

[7] COSPAS- SARSAT Satellite System for Search and Rescue http://www.sarsat.noaa.gov/satellites1.html

Participating in NASA-ESA Cassini/Huygens Mission at Wigner RCP, former KFKI RMKI

Mission to Saturn – the Hungarian Contribution

Pál Gábor VIZI**, Károly SZEGŐ, Sándor SZALAI, János Zoltán NAGY
Department of Space Physics and Space Technology
Wigner RCP of Hungarian Academy of Sciences, Hungary
BUDAPEST, Hungary
*vizi.pal.gabor@wigner.mta.hu

***Abstract*—Cassini-Huygens a NASA - ESA mission developed from 1991, launched in 1997, arrived to Saturn in 2004 and it had been measured on orbit until 15th of September of 2017. Cassini had 12 experiments. Our engineering participation was in CAPS (Cassini Plasma Spectrometer) and MAG (Magnetometer) developing EGSEs (Electrical Ground Supported Experiments).**

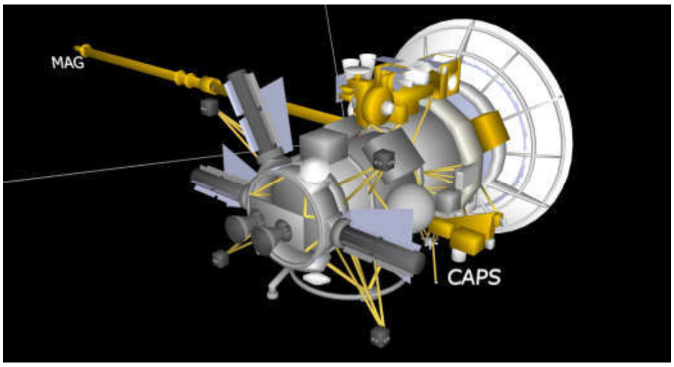
Keywords — Cassini; Saturn; Titan; Plasma; Magnetosphere; NASA; ESA; Wigner; RMKI

I. Introduction

The Cassini-Huygens mission was the biggest and longest International space mission until now. The developing of the NASA - ESA common mission has started in 1991, the launch was in 1997 and the space probe have arrived to Saturn in 2004. Since that year it had been measured on orbit and the mission ended in 15th of September of 2017. [1]

Cassini had 12 experiments on the board. Our engineering participation was in Cassini Plasma Spectrometer (CAPS) and Magnetometer (MAG). Our engineers participated in developing of Electrical Ground Supported Equipment (EGSE) for both experiments.

Fig. 1. The Cassini Spacecraft with MAG



II. The Cassini-Huygens Mission

The Cassini Orbiter's mission consisted of delivering a probe - called Huygens and provided by ESA - to Titan and after this event the Cassini orbiter remained in orbit around Saturn for detailed studies of the planet, it's rings and satellites.

Cassini – Huygens mission had set several records. Longest orbital survey of an outer planet, heaviest spacecraft to reach the outer solar system, Huygens lander became the first probe to land on a remote moon, Titan, setting a new record for the most remote planetary landing in the process, it measured to be the thickest atmosphere on a moon and a record for the Longest river system photographed on another world was set (rivers of liquid methane), in 2005 it spotted the solar system's Largest erupting ice plumes pouring from the frozen ocean moon Enceladus, and later flew straight through them, in July 2013 take the first image to show Saturn, Earth, Mars and Venus in one shot – as tiny specks of light behind Saturn's beautiful rings. [2]

The principal objectives were to determine the three-dimensional structure and dynamic behavior of the rings; to study the composition of the surfaces of satellites and the geological history of each object; to reveal the nature and origin of the dark material on Iapetus' leading hemisphere; to measure the three-dimensional and dynamic properties of the magnetosphere; to determine the dynamic activities of Saturn's atmosphere at cloud level; to study the variability of Titan's clouds and hazes in time; and to characterize Titan's surface on a regional scale.

Twelve science instruments are carried by the orbiter. Cassini Plasma Spectrometer (CAPS); Cosmic Dust Analyzer (CDA); Composite Infrared Spectrometer (CIRS); Ion and Neutral Mass Spectrometer (INMS); Imaging Science Subsystem (ISS); Dual Technique Magnetometer (MAG); Magnetospheric Imaging Instrument (MIMI); Cassini Radar (RADAR); Radio and Plasma Wave Science instrument (RPWS); Radio Science (RSS); Ultraviolet Imaging Spectrograph (UVIS); Visible and Infrared Mapping Spectrometer (VIMS).

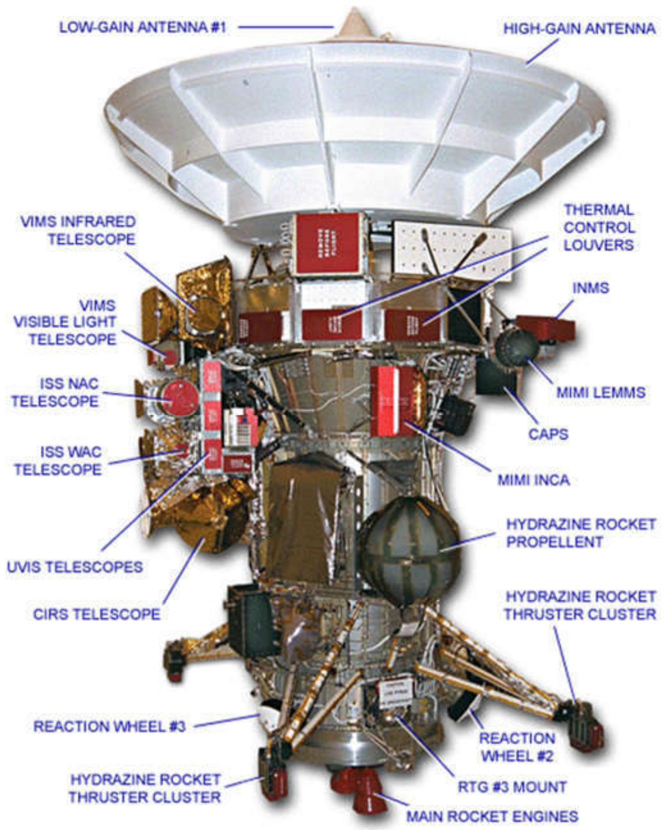


Fig. 2. The Cassini Spacecraft with CAPS in middle right.

Fig. 3. International participation in Cassini-Huygens Mission on the official postcard of mission.

III. Hungarian Contribution

Our human resources participated in the development of the Cassini Plasma Spectrometer (CAPS) and of the Dual Technique Magnetometer (MAG) instruments. In both cases, the orbiter simulators (as EGSEs) were developed by our team members, as employees of KFKI RMKI (present name is Wigner Research Centre of Physics.

Fig. 4. The Cassini-Huygens Mission DVD with flags of contributor states and in data files the names and signatures of participant scientists and enthusiast fans fitted on the surface of both the probe and the Huygens lander. The Hungarian flag is the third at the upper left section.

A. *Technology of Cassini Plasma Spectrometer (CAPS)*

CAPS includes an ion mass spectrometer (IMS) providing species-resolved measurements of the flux of positive atomic and molecular ions as a function of energy/charge vs. aperture entry direction; an ion beam spectrometer (IBS) that measures the flux of positive ions of all species as a function of energy/charge and entry direction; and also an electron spectrometer (ELS) to measure the flux of electrons as a function of energy/charge and entry direction.

When particles approached the CAPS, they could travel into one of three sensors: the electron sensor, the ion mass spectrometer, or the ion beam sensor. All three sensors measured the particle's kinetic energy (a result of its mass and speed), and the direction the particle was traveling. But the ion mass spectrometer also measured the particle's mass. [3]

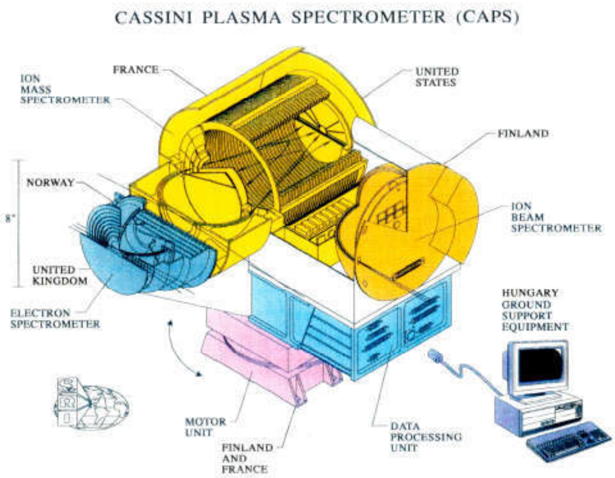


Fig. 5. Cassini Plasma Spectrometer (CAPS) parts and contributors

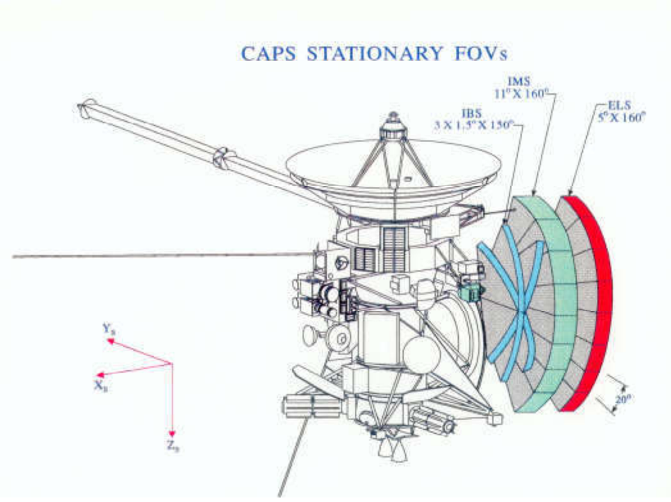


Fig. 6. Stationary Field of View (FOV) of Cassini Plasma Spectrometer (CAPS)

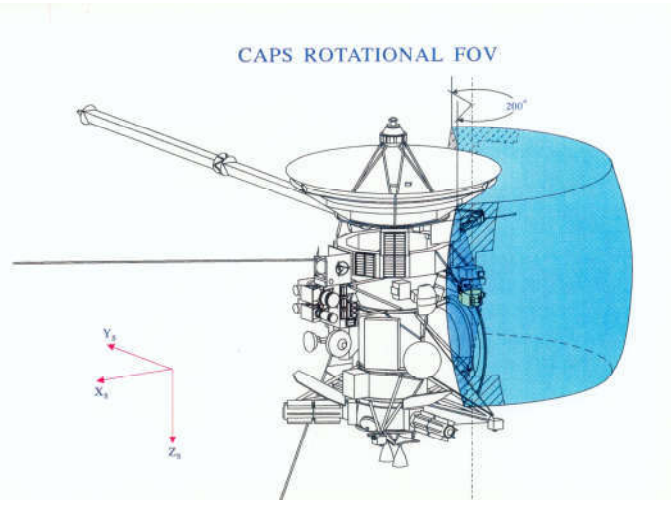


Fig. 7. Rotational Field of View (FOV) of Cassini Plasma Spectrometer (CAPS)

B. *Technology of Dual Technique Magnetometer (MAG)*

The Dual Technique Magnetometer (MAG) is a direct sensing Instrument that measures the strength and direction of the magnetic fields around Saturn. The magnetic fields are generated partly by the intensely hot molten core at Saturn's center. Measuring the magnetic field is one of the ways to probe the core, even though it is far too hot and deep for an actual visit. Magnetometers are direct sensing instruments that detect and measure the strength of magnetic fields in the vicinity of the spacecraft. MAG consists of a vector/scalar helium magnetometer sensor, a flux-gate magnetometer sensor, a data processing unit, and three power supplies, plus operating software and electronics associated with the sensors. [4]

C. *Technical development for CAPS EGSEs and for flying experiment MAG*

Several circuits and programs were designed in our Department of Space Technology during the rest of developing of Cassini EGSEs, e.g. software for Cassini CAPS EGSE, Temperature Acquisition Subsystem Simulator for Eight Channels (TASS), Mil1553 Serial Interface Bus Monitor (SIB Monitor) and the power system for flying experiment of MAG.

1) *Engineers and programmers*

Engineers and programmers are the follows at the Department of Space Technology involved in the mission:

Károly SZEGŐ Organizing the Science and HW SW designing as director of the Institute.

Sándor SZALAI: Organizing the project for hardware and software designs and program development for flying board and EGSE models.

János NAGY: Plan and schematics of TASS

György KORGA: Circuit plan and schematics of the SIB Monitor MIL1553 Serial Interface Bus Monitor card.

Pál Gábor VIZI: CAD-CAM system designs, CAD PCB plans for EGSE cards e.g. SIB MIL1553 Serial bus, and organizing the manufacturing. System engineer of the CAPS EGSEs, e.g. Sun IPX.

István HERNYES: Circuit plans and schematics of voltages switching modules for MAG

Irina GLADKIH, Lajos FÖLDY, László NAGY: EGSE software design for CAPS EGSEs.

2) *Software for Cassini CAPS EGSE*

Program for downloading and displaying the Scientific Data stored by Cassini CAPS EGSE. The science and housekeeping telemetry data was stored on hard disk. The visualization part of the EGSE retrieved this data and displayed it graphically. Users could select data according to time, sensor (ELS, IBS or IMS) and sensor mode. Multiple windows could be created with several plot types (time series, contour, spectrum) to allow comparison of different measurements. Graphics could be saved to Postscript files.

3) *Mil1553 Serial Interface Bus Monitor*

To develop an electrical circuit was mainly manual work before nineties, but design with CAD-CAM systems were introduced at that time and those circuits were developed first as pioneer work resulting a reliable design process.

Fig8.. The Mil1553 Serial Interface Bus Monitor (SIB Monitor) developed with new CAD-CAM system of nineties as pioneer work resulting a reliable design process.

Serial Interface Bus Monitor Mil1553 standard (SIB Monitor) card boards were used to communicate and test in communications between probe and its telecommunication system to Earth and between all electrical circuits of experiments on the board of the Cassini space probe.

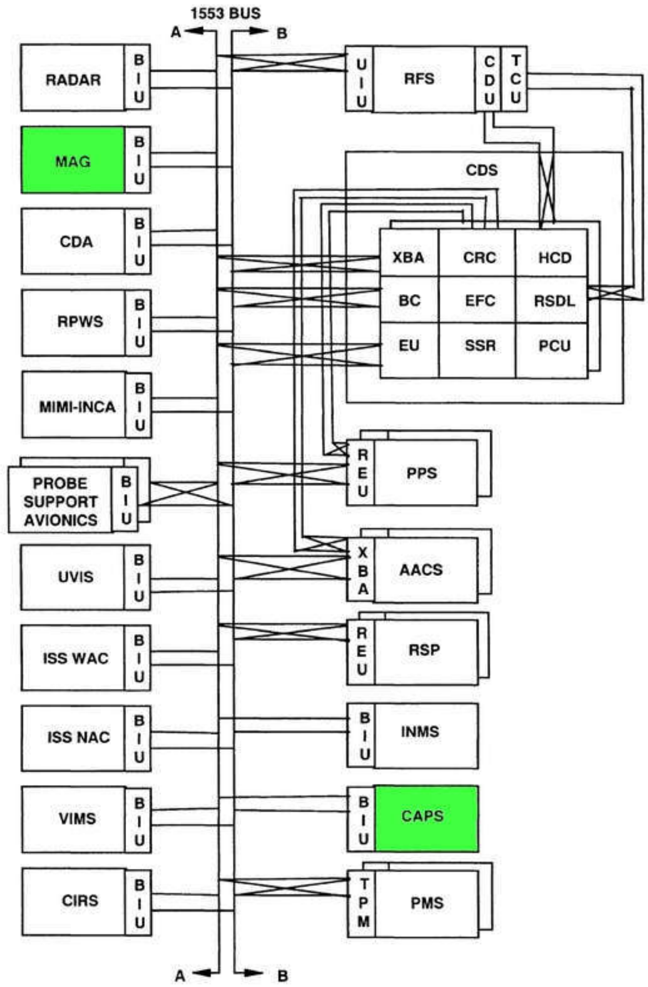
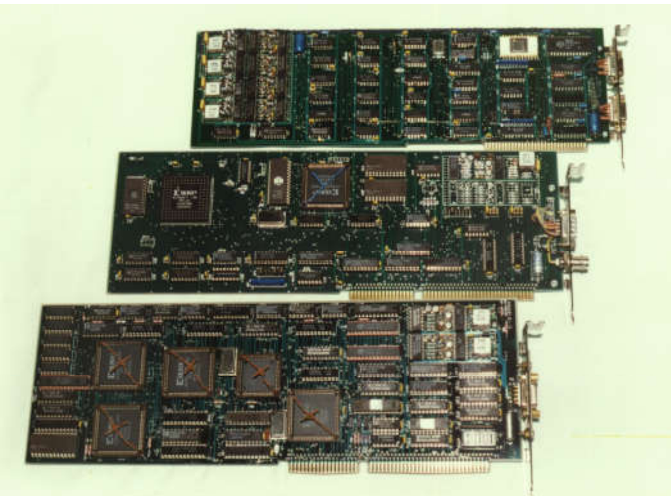


Fig. 9. Cassini Spacecraft Information System based on MIL1553 bus [5]



10. Fig. Serial of versions of Mil1552 cards for Cassini EGSEs

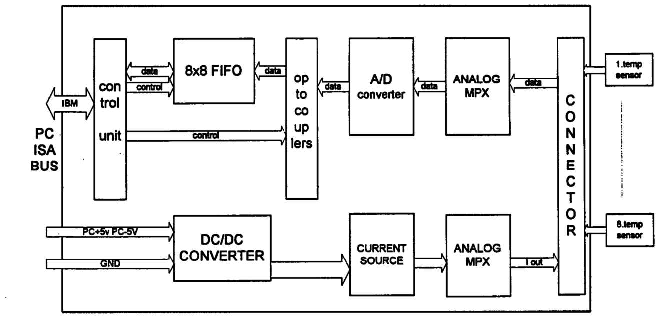


Fig. 11. Blok diagram of the Eight Cannel Temperature Meter (TASS)

4) Temperature Acquisition Subsystem Simulator for Eight Channels (TASS).

PC plug in EGSE card named Temperature Acquisition Subsystem Simulator for Eight Channels (TASS) can measure eight platina temperature sensors. It is developed according to the requirements of the Cassini experiment. The card switches 2.25 mA onto the eight resistors in consecutive steps. The value of the resistors measured can be between 343 and 695.6 in the possible temperature range, and so the range is between O.77V and 1.56V. Voltages are accepted and converted into digital values. The analogue inputs are isolated by DC-DC converters and optocouplers from the computer interface of the card.

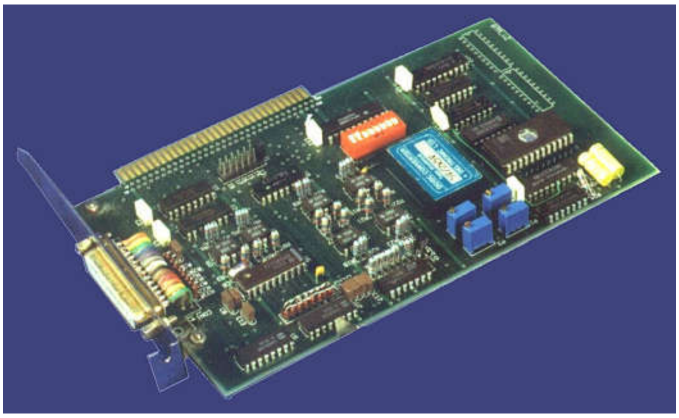
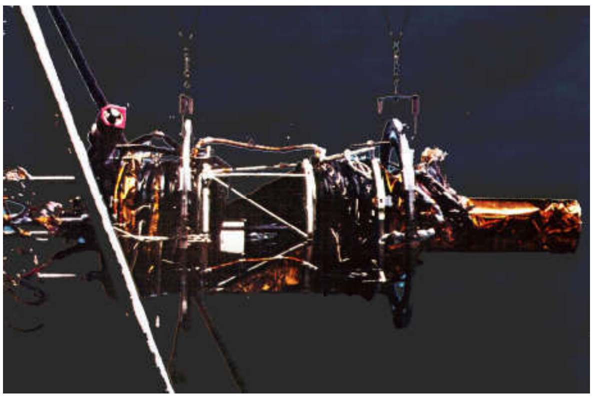


Fig. 12. Temperature Acquisition Subsystem Simulator for Eight Channels (TASS) for Cassini Experiments



13. Fig. The Magnetometer (MAG)

14. Fig. Cassini probe passing the plums of Enceladus at its southern pole

D. Space physics of CAPS, MAG and all Cassini Mission

Our physicist — Károly SZEGŐ, Zoltán NÉMETH, Zsófia BEBESI, Géza ERDŐS, Lajos FÖLD, Antal JUHÁSZ, Katalin LUKÁCS, Andrea OPITZ — connected to the analysis of the results of the experiments and have several results they published, e.g. the exploration of the variable plasma environment of Titan, to investigate the similarities and differences between the processes that lead to the induced magnetospheres around Titan and around similar non-magnetic bodies; and to identify the major physical clues of those processes.

Topics are the follows:

Ion distributions of different Kronian plasma regions;

Location of the magnetodisk in the night side outer magnetosphere of Saturn near equinox based on ion densities;

Time-reversed particle dynamics calculation with field line tracing at Titan - an update

Investigation of Titan's ion environment during plasma sheet type encounters

Location of the magnetodisk in the outer magnetosphere of Saturn based on ion densities

Analysis of energetic electron drop-outs in the upper atmosphere of Titan during flybys in the dayside magnetosphere of Saturn

Exploration of the magnetodisk of Saturn around equinox

On the structure of Titan's tail

Energetic electron absorption in the upper atmosphere of Titan. etz.

IV. Conclusions

The aim of the Cassini mission was to study the planet Saturn, its satellites and very complex plasma environment. One of the main objectives was the investigation of the moon Titan which is unique among the numerous satellites in the Solar System. Scientists and engineers of our institute participating in the Cassini mission enriched our understanding about Saturn's magnetosphere and the moon Titan with new elements. Our Institute contributed to the building of plasma Cassini Plasma Spectrometer(CAPS) and Magnetometer (MAG) instruments to ensure the electrical ground support equipment which simulated the Cassini space probe interfaces. The joined work with the big community of NASA-ESA Cassini-Huygens Mission ensured us to reach the scientific data immediately and we were able to publish the analyzed results right away because of EGSEs were provided by our Institute for the Cassini mission.

References

[1] Cassini spacecraft sets records, Guiness World Records http://www.guinnessworldrecords.com/news/2017/9/cassini-spacecraft-sets-record-for-longest-orbital-survey-of-an-outer-planet-494695

[2] S. Szalai et al.: Missions, The Cassini mission, http://www.sgf.hu

[3] Young DT, Szego K, Szalai S, et al, „Cassini Plasma Spectrometer Investigation", Measurement Techniques in Space Plasmas: Particles. 355 p. Washington: American Geophysical Union, 1998. pp. 237-242. (Geophysical monograph; 102.) (ISBN:0-87590-085-2)

[4] Kellock S, Austin P, Balogh A, Gerlach B, Marquedant R, Musmann G, Smith E, Southwood D, Szalai S, "Cassini dual technique magnetometer instrument (MAG)" PROCEEDINGS OF SPIE - THE INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING 2803: pp. 141-152. (1996)

Curt Henry: An Introduction to the Design of the Cassini Spacecraft, Space Science Reviews, July 2002 pp. 129-153. DOI: 10.1023/A:1023696808894

Hungarian Astro Pi experiments on the ISS

UltimaSpace

Florian Vamosi, Peter Posa
Student Science Laboratory
Mihaly Tancsics Grammar School of Kaposvar
Kaposvar, Hungary
ceo@ultimatemedia.hu, coo@ultimatemedia.hu

***Abstract*— The First European Astro Pi mission was launched by ESA and The Raspberry Pi Foundation in 2016 [1]. Teams of students from all ESA member states could join the competition to design and code their space experiments that could be selected to run on the ISS. We were the only Hungarian team whose code was selected to run on the ISS. Our main goal was to find the weakest points of the Earth's magnetic field. The data was returned to the ground and visualized on a geochart. The chart shows the 100 weakest points in the Earth's magnetic field. This year we are planning on measuring the light pollution over Europe with the Astro Pi's Infrared camera, the use of which was prohibited last year. Our main goal is to see whether we can distinguish dark sky protection areas like the "Zselic Park of Stars International Dark Sky Park" and the "Møn and Nyord International Dark Sky Community". We will also try to visualize the color difference between the new LED lights and the old incandescent on a color diagram.**

Keywords*— *education, Astro Pi, space experiments, research-based teaching, space generation

I. Introduction

The First European Astro Pi mission was launched by ESA and The Raspberry Pi Foundation in 2016 following the success of the UK Astro Pi mission in 2015 [1]. The UK mission's goal was to get more students involved in programming by giving them a chance to get their coded experiments up in space. The selected experiments were run on the Astro Pi computers aboard the ISS.

A. *What Is an Astro Pi?*

An Astro Pi is a small computer enclosed in a flight case, with many different sensors that can be used to collect data. Each Astro Pi on the ISS has a camera module; Ed has a visible camera and Izzy has an infrared camera. They are based on the very popular Raspberry Pi mini PC [2]. Ed and Izzy have been sent to the station in 2015 for the UK challenge and Tim Peake was the British astronaut who deployed them.

II. Our Involvement

We are members of a team of Student Scientists from Kaposvar, Hungary. We are students of the Mihaly Tancsics Grammar School of Kaposvar. We do our research at the Student Science Laboratory of the institution.

We first heard about the UK mission in July 2016, when on vacation in Great Britain. We bought the then current issue of the Mag Pi magazine and read about the mission there. After our vacation, in October 2016 we saw the announcement of the European Astro Pi mission in the Raspberry Pi Weekly newsletter. We were excited and jumped on the opportunity immediately.

We had to submit our initial idea by the end of October. Our idea was to find out if the region of the "South Atlantic Anomaly" can be detected with a magnetometer. In December we received an Astro Pi hardware kit and a letter in the mail, saying we have been selected for Phase 2 of the competition, which is writing the code and submitting it for judging.

In the second phase we had two missions, we had to write code to sense the presence of crew members in the Columbus module of the station in addition to our own experiment.

A. *Our code had to comply with numerous rules:*

- At least one sensor per mission has to be used;
- The LED matrix has to be used;
- Data has to be collected and stored with a timestamp for later analysis on the ground;
- Codes must be written in Python 3.4 or 2.7;
- The total time of execution for both the primary and secondary missions combined cannot be more than 3 hours.
- Considering the busy schedules of the astronauts, the Astro Pi on the ISS will be controlled from the ground without the involvement of the crew. For this reason:
- Astronaut interaction with the Astro Pi trough the joystick and the buttons cannot be considered in your mission design and execution code;
- The Astro Pi cameras cannot be used;
- The Astro Pi cannot be moved from and around its fixed position in Columbus.

B. *Our Experiment*

Our code detected the presence of crew members by using the temperature sensor of the Astro Pi. We have used 2 weeks of prerecorded data to set up a baseline temperature above which a crew member must be present.

The second part of the mission was to gather data for our experiment. Our experiment's main goal was to find the weakest points of the Earth's magnetic field. We did this by collecting magnetometer readings along with latitude and longitude information of the space station. We used the PyEphem ephemeris module to calculate the position of the ISS above the Earth's surface using the TLE (two-line element set) provided by ESA containing the orbital elements of the station. We collected all the data in a CSV (comma-separated values) file for later analysis on the ground.

We had to submit our experiment for judging by the end of February 2017. After the submission we have received a letter saying "Congratulations! Your code has been qualified to fly and run on the International Space Station.". Our code could run aboard the ISS for 3 hours.

We have received our CSV file with the collected data on 17 May 2017. After receiving the data, we have made a visualization of our measurements on our website [3]. The visualization is a Google Geochart showing the 100 lowest measured magnetic field strengths as data points on the world map. When you hover over the data points you can see the exact values in microteslas.

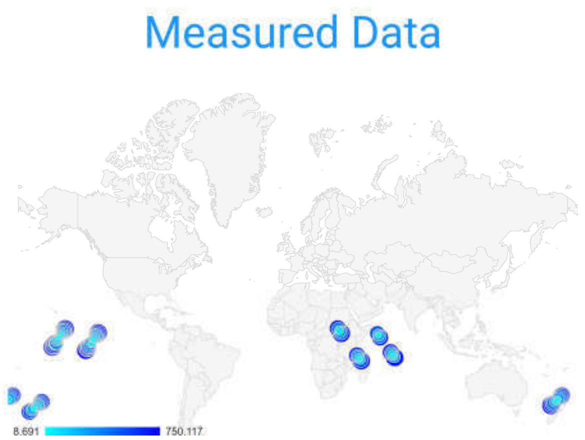


Fig. 1. Measured Data Geochart

Our code can be found on our GitHub repository [4].

III. This Year's Mission

The Second European Astro Pi Mission was Announced by ESA and The Raspberry Pi Foundation in October 2017. This time around students could compete in two categories Mission Zero and Mission Space lab, 0-14 and 15-19 years old respectively.

Teams in mission zero had to use the online Astro Pi Sense Hat web emulator to code a greeting message and ambient air temperature display for the crew, that would be guaranteed to run in space.

We are participating in Mission Space lab. This Mission has two Themes, Life in space and life on Earth. Teams that chose to investigate 'Life in space' will have to make use of the Astro Pi Ed, which is located in the Columbus module and features a visible camera, to run their investigation.

Teams that choose to investigate 'Life on Earth' will have to make use of the Astro Pi Izzy, also featuring an infrared camera and located at one of the ISS windows, looking down to Earth [5].

IV. Our Involvement This year

We chose the theme of 'Life on Earth' and we have submitted our experiment involving light pollution of large cities in Europe.

We would like to measure the level of light pollution over populated areas of the world and compare it to scarcely or non-populated areas light pollution levels. Our main goal is to see whether we can distinguish dark sky protection areas like the "Zselic Park of Stars International Dark Sky Park" [6] and the "Møn and Nyord International Dark Sky Community" [7]. We also intend to detect the percentage of LED streetlights compared to traditional incandescent. Our results would be a world map showing the lowest and highest light pollution areas and a graph showing the percentage of LED lights in our observed regions. Our observation prioritizes Europe, but is not limited to it, so we would need to conduct the experiment when the ISS flies above Europe at night.

We are planning on using the camera of Astro Pi Izzy to capture blue filtered infrared shots of the earth. From the pictures we can determine light pollution levels. Because of the blue filter we can easily distinguish the color of street lights. We then would calculate the location of the ISS when the picture is taken with the python module pyEphem. The filenames, location, and timestamp would be logged in a csv file. We would use ground analysis to determine the light pollution levels and the color of street lights across the world.

As of now we know that it is not possible to specify when the experiment runs, so we might not get a good coverage of Europe. If we get selected we will only have two orbits to capture pictures, so we will not be able to make a global map of light pollution, but hopefully we will be able to distinguish dark sky protection areas from large cities anywhere it happens to be nighttime when our experiment runs even if it is daytime in Europe.

So far, our idea has been selected for phase 2, consisting of writing and submitting the code to be evaluated by a panel of judges. This means that we are in the process of writing the code now and we will have to submit it on 7 February 2018.

After the evaluation process our code might be selected to run in space.

If our experiment runs in space, this year's challenge also includes analyzing the flight data and submitting the results which will be judged, and a final winner will be chosen.

V. Astro Pi's Place in Education

The best way to teach students is to show them how to learn. The Astro Pi Mission gives a great opportunity for students to learn about space and the importance of coding and logic at the same time. It makes students solve their own problems and answer their own questions. Therefore, combines the greatest of skills needed in real life.

Learning programming is a necessity for today's scientists. The reason behind this, is that a programmer doesn't understand the science behind a piece of software needed for scientific research. This makes it a lot harder to write efficient and usable code. It is a lot easier for everyone to code their own experiment than it is to explain the experiment to a programmer, who doesn't have any scientific background.

For this purpose, most of all universities teach science students programming. In Hungarian High Schools unfortunately this is not the case. Astro Pi however brings scientific programming to the High School level in a very exemplary way. For this reason, Astro Pi needs to be supported.

References

[1] Astro Pi Website, http://astro-pi.org

[2] Raspberry Pi Website, http://raspberrypi.org

[3] UltimaSpace Website, http://ultima.space

[4] UltimaSpace GitHub, https://github.com/ultimatecompany/ultimaspace-anpd

[5] Astro Pi 2017-18, http://www.esa.int/Education/AstroPI/The_2017-2018_European_Astro_Pi_Challenge_begins

[6] Zselic Starry Sky Park on the IDA's website, http://darksky.org/idsp/parks/zselic

[7] Møn and Nyord International Dark Sky Community and International Dark Sky Park on the IDA's website, http://darksky.org/idsp/parks/monandnyordpark

Expanding the Space of Space learning

*Maria Messina**
Education Activities Unit
maria.messina@est.asi.it

*Giorgio Garagnani**
STG Unit
giorgio.garagnani@est.asi.it

*Rosa Tagliamonte**
Education Activities Unit
rosa.tagliamonte@est.asi.it

*Sabrina Ricci**
Education Activities Unit
sabrina.ricci@asi.it

*Italian Space Agency,
Rome, Italy

***Abstract*— The importance of having the same education program around the world is not prosaic. A multi-speed space race, in which the influence of Member States varies, could have weakened proficiency related to a common space science standard.**

It is clear how important a common level of learning is within the Space sector, especially given the use of it to assure national development and peaceful uses.

For that reason, during the UNISPACE 1968, State delegates endorsed creation of a specific space science programme and just like that, United Space Programme on Space Application was adopted providing training courses and long-term fellowship opportunities under institution cooperation's.

In support of this initiative, United Nation General Assembly adopted resolutions 45/72 and 50/27, conscious of the need to increase growth of space technologies and benefits derived therefrom.

These decisions are especially important to progress of education systems for the sake of greater legal certainty – taking particular account of the interest of development countries.

International effort to establish Regional Centre for Space Science and Technology Education, affiliated to the United Nations, have been realized with the aim to get higher and immediate results to promote a cross border educational activity.

Based on a specific assessment process, a UN commission of experts has identified the following nations that would hosted Regional Centers: India (1995), Morocco (1998), Nigeria (1998), Mexico and Brazil (2003), Jordan (2012) and finally China in 2014.

Furthermore, in order to have a common level of learning in the Space sector it is important to start from formal education in the school. In our knowledge-based society many studies have highlighted an alarming decline in young people's interest for key science studies and mathematics. The international science education community mostly agrees on the importance to adopt pedagogical practices on inquiry-based methods are more effective to reverse this trend. A motivating context for teaching and learning STEM is important to engage students in their study and to pursue a career in these fields, in the space domain in particular. In this sense space science is a very good context for learning STEM and a useful tool to help attract the interest of students. Space is able to turn on the imagination and promotes curiosity.

Keywords*— *education program, space sector, common standard, knowledge-based society.

I. Introduction

What do we mean when we refer to "learning"?

According to the Oxford English Dictionary, "to learn" means "to gain knowledge or skill by studying, from experience, from being taught, etc.". And it is not fortuitously that the concept itself refers to a growth process inherent in the different meanings that the term "gain" can have, that's to say: to achieve, to reach, to look forward…

So "to learn" is exactly this: achieving new experiences, reaching new goals, maybe unconceivable before, and having the chance to look forward with new eyes…new views. Hence, "to learn" means to improve himself and the others, in one word: to grow.

"Expanding the space of space learning" therefore it was not the choice of a random title: it is not only a pun, a play with words, but it represents the real wish to combine two concepts that, from a semantic point of view, could establish contrariwise reciprocal relationships.

Space is vacuum, is void, but it is also time break and place in between. Space is that "Outer space-including the Moon and the other celestial bodies", where the International Community, with 1967 OST Treaty chose to set down peace prospects and development possibilities for the benefit of humanity, in order to cooperate and overcome a political context dominated by the Cold War and by a new arms race.

And it is exactly from that vision we were inspired in writing this small project: to reflect on the opportunity to encourage new spaces of growth in order to support students and young professional education, the education of the ones who wish to grow with the purpose of improving themselves and of getting their environment better, in the name of the scientific progress and international cooperation.

II. THE INTERNATIONAL SCENARIO

On the international scenario, UNISPACE +50 is going to celebrate, this year, the 50 years anniversary from the first United Nation Conference on the Exploration and Peaceful Uses of Outer Space. Already in 1968, the member States underlined the importance to undertake measures addressed to decrease the gap with the developing countries, applying in this respect, technological innovations in space field.

Speaking of which, the opening Statement by the Chairman at the 53rd meeting of the Committee, on 15 October 1968: *"We must now beer in mind, however, that the Conference was not a final, but, on the contrary, a first step in our efforts to bring the practical benefits of space exploration to all nation, regardless of their degree of technical and economic development, in order to alleviate some of the economic and social problems which they face today."* [1]

And still, a reference to the note by Secretary – General during the same session: *"Special emphasis was laid in discussion at the Conference on the need to provide to developing countries meaningful information on space applications as well as the need to give them facilities for training and education in space science, technology and applications"*. [2].

Every action in this direction, starts from a necessary change: to educate, even before instructing, the less developed countries consciousness to the scientific progress culture.
So, now as it was then, the idea that all this can be realized profiting from the most modern technological applications, is not only desirable but also possible.

In support of this initiative and on the basis of a previous Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space recommendation, the United Nations General Assembly promoted the elaboration of the United Nations Programme on Space Application (PSA), an *ad hoc* project conceived to get the new space technologies handy and comprehensible, by encouraging the social progress of the underdeveloped regions.

With the following creation of the Regional Centre for Space Science and Technology Education [3] , affiliated to the United Nations PSA, it became real the wish to get functional to everybody, all the advantages this kind of innovation might have offered even in other environments, promoting the improvement of life conditions, referring to health, urbanization and welfare *tout court*.
From that moment, the actors of the education process themselves, could directly benefit of the proliferation of research opportunities in specific working areas, such as remote sensing, meteorology, satellite communications, biodiversity.

Fifty years later, the goal to encourage the space culture diffusion, by promoting the immediacy of data access, also to protect an innovation from equal opportunities, became as never before a priority, in order to develop specific research instruments that simplify education processes in the areas of space science and exploration, mainly for the developing countries.

III. THE NATIONAL EFFORT IN ORDER TO SUPPORT THE SPACE CULTURE DIFFUSION

In the same view, the Italian Space Agency, acts in order to promote the scientific research and its applications – art. 2 a) of Italian Space Agency Statute - encouraging the space culture diffusion and divulgation also thanks to scholarships and research grants on the basis of *ad hoc* Agreement or Memorandum, with secondary and high schools, Universities and highly specialized national and international Centers.

Italian Space Agency is therefore engaged in supporting education projects able to respond to the new market challenges, aiming at developing skills and expertise necessary to accomplish the future space missions.

The participation of University and high level Research Centers represents an influential orientation in the view of strengthen collaborations addressed to outstanding results responding to a theoretical ideal of internationality.

In this purview, we can consider all the collaboration activities on common interests, with important Italian education centers, such as: "*Sapienza University of Rome*", *"Politecnico di Milano", "Società Italiana per l'Organizzazione Internazionale (SIOI), "Tor Vergata" University of Rome, "Politecnico di Torino"*.

The support to the above initiatives is translated also in financing specific Master and Specialization Courses based on evaluations linked to general criteria such as:

- National and international prestige of the proposing entity;
- Quality and professionalism of the teachers and professors;
- The possibility to undertake a stage at the end of the course.

In the goal of spreading the scientific and technological research in the space and aerospace field, carrying out synergies between enterprises and academies aims to stimulate innovative didactic methods, which point to highlight the central position of the learning in the competences valorization of everyone.

IV. SCIENCE EDUCATION FOR SCHOOL

Moreover, in order to have a common level of learning in the Space sector is important to start from formal education in the school. In our knowledge-based society, many studies have highlighted an alarming decline in young people's interest for key science studies and mathematics. The international science education community mostly agrees on the importance to adopt pedagogical practices on inquiry-based methods, more effective to reverse this trend. A motivating context for teaching and learning STEM (Science, Technology, Engineering, Mathematics) is important to engage students in their study and to pursue a career in these fields, in the space domain in particular. In this sense space science is a very good context for learning STEM and a useful tool to help attract the interest of students. Space is able to turn on the imagination and promotes curiosity. The potential of using space as a teaching and learning context for STEM subjects, in field of formal primary and secondary school education, is exploited with success from many space agencies all over the world. In effect, there is NO STEM curricular subject that:

- is not covered by a space discipline;
- cannot be linked to a space example;
- cannot be linked to a space mission;
- cannot be linked to a career in the space sector.

Schools are one of the most important target for space agencies. In Italy, Italian Space Agency has always been a reference point for scientific training, in the dissemination of aerospace culture and in the promotion of educational initiatives and projects for schools. To high schools ASI offers educational programmes like *Lessons on the International Space Station* (LISS): it was the main educational activity organized by ASI for Futura Mission with the Italian astronaut Samantha Cristoforetti . The program involved 5 Universities and 5 high schools in Italy. The focus of the activity was a course dedicated to human space exploration and was associated with high school didactic program. In order to demonstrate the effect of space flight, Universities worked with high school students so as to implement an experiment, that illustrated the effect of microgravity even if in simulation. The activity is based on students' lab experiments in cell and plant biology and is aimed at understanding the differences between Earth and Space based measurements and results. The evolution of the LISS is *Explora*, one of the education programme of the Vita Mission with the Italian astronaut Paolo Nespoli. In general, the goal of activities for high school is to introduce students to activities that will take place in universities. To promoting links between space and schools, ASI organizes events, competitions, communication contest, in flight call with the Italian astronauts aboard the International Space Station. Furthermore, ASI takes part to the European Space Education Resource Office (ESERO): ESA's main project in the field of primary and secondary education in order to support the specific national STEM education objectives, needs and priorities, and to be represented in existing national networks in ESA Member State.

The objective of these activities and projects is two-fold: to attract the attention of young students and to create didactic tools (e-books, video games, comics, puzzle, etc.) useful for teachers and families. The initiatives follow an innovative didactic concept which, in the logic of edutainment, "teach while entertaining". ASI is looking to the new generations of students, investing in their potential. Special care is given to the relationship with teachers, encouraging training in space themes by producing and distributing teaching support materials or the attendance in conferences and workshops. Educational activities aims at enabling capacity building in the teacher communities and at designing and promoting the use of resources and activities that make use of space as a context for the teaching and learning of STEM-related disciplines in order to motivate and enable young people to enhance their literacy and competence in sciences and technology and inspire them to consider pursuing a career in the STEM field. For the Italian Space Agency, the co-operation with NASA, ESA and other Space Agencies is essential to exploit synergies of objectives and resources, that maximize sustainability and distribution of capabilities.

"Education is not the filling of a pail but the lighting of a fire".

William Butler Yeats

REFERENCES

[1] United Nations, General Assembly – Report of the committee on the peaceful uses of the outer space, 23 Sess, Agenda item 24, A/7285 (1968), available from unoosa.org.

[2] A/7285.

[3] UNOOSA, Capacity-Building in Space Science and Technology: Regional Centres for Space Science and Technology Education, affiliated to the United Nations." ST/SPACE/41. New York: United Nations. 2008.

[4] European commission, 2007, *Science Education NOW: A Renewed Pedagogy for the Future of Europe (Rapporto Rocard*), Office for Officil Publications of the European Communities, Luxemburg.

[5] European commission, 2015*, Science education for Responsible Citizenship,* Publications Office of the European Union, Luxembourg.

Quantum Key Distribution in Space -A security review

Tamás Bisztray
Faculty of Informatics
Eötvös Loránd Tudományegyetem
Budapest, Hungary
Email: t.bisztray@gmail.com

***Abstract*—In this paper after an introduction on the technology and the driving forces behind it, we look at the recent achievements in free space quantum key distribution (QKD) and where it has evolved. Meanwhile we examine the security aspects entanglement based and prepare and measure protocols, with a strong focus on the difference between theoretical and practical security. Lastly, we discuss possible attacks on free space QKD systems.**

I. Introduction

The ability to securely transmit information is an essential requirement in the information age we are living in. With the rapid development of quantum computers, it is safe to assume that the method how we send secret information will change in the near future. Quantum computer based algorithms are proven to break the current public key exchange methods that are used to establish a common secret between the communicating parties. Even if new classical algorithms are invented, they always rely on the assumption that a certain hard problem is not possible to break. These assumptions are directly linked to the computing power of the adversary. But with a better breaking algorithm or a stronger then expected computer these might not hold in the future. A permanent solution for this problem is to turn to quantum physics namely, quantum key distribution (QKD). Here, instead of a hard mathematical problem, the security relies on no assumption regarding the adversary's power, only that the laws of physics are true. This method comes as a replacement for the public key exchange. A big difference in between QKD and the conventional key exchange methods is that traditional information exchange can be tapped, recorded and this leaves the possibility that some day it can be deciphered. QKD however cannot be recorded as an efficient and stable way to store light is not yet invented. But secure QKD protocols were designed such that even someone with quantum memory, or with arbitrary computing power will not be able to learn the shared secret. These are mathematically provable claims. The only problem is that the physical implementation of these QKD devices are not as perfect as the security proofs would require. This often opens up the possibility to physical attacks, where the attacker either tries to exploit an imperfection, or causes the device to malfunction so he can carry out an attack. How to identify and avoid these attacks will be discussed in the coming sections.

II. Information transmission methods

Definition: The simplest quantum system can be described as a two-dimensional complex valued vector in a two-dimensional Hilbert space. This is called a qubit and a physical example can be a photon or an electron. [1]

A qubit in an arbitrary state can be written as the linear combination of the two basis vectors in the two-dimensional Hilbert space $|\psi\rangle = a|0\rangle + b|1\rangle$ where $a, b \in \mathbb{C}$ are the probability amplitudes. A column vector will be denoted by $|.\rangle$. The corresponding row vector is $\langle.|$ where $|.\rangle$= $(\langle.|)^{\dagger}$. This state is called a superposition and unlike a classical bit that always have a defined value, and measuring it just reveals this fact, a superposition is neither in any of the states with certain probability, and it will only take on a value when we measure it. If we would like to know what is the probability that $|\psi\rangle$ is in one of the basis states after a measurement, we simply need to square the probability amplitude belonging to that state. Therefore, the probability amplitudes must satisfy $|a|^2 + |b|^2 = 1$. If we represent this in a coordinate system we can say that the $|0\rangle$ component is the x axis and $|1\rangle$ corresponds to the y axis. Then we can represent the polarization of an arbitrary photon with a unit length vector that is angle θ to the horizontal x axis. $|\theta\rangle = a|0\rangle + b|1\rangle$. If $a$and b are the coordinates it is easy to see that $a = cos\theta$ and $b = sin\theta$. We can make a vector orthogonal to $|\theta\rangle$, lets name it $|\psi\rangle = \left(\frac{-sin\theta}{cos\theta}\right)$. Now we can introduce the "braket" operation for $|\theta\rangle$ and $|\psi\rangle$: $\langle\theta|\psi\rangle$. This operation has which describes what is the probability for a photon prepared in ψ state being measured in θ. In case of orthogonal states it is 0. In general for arbitrary states its

$$| \langle\beta \mid \alpha\rangle |^2 = \left[(cos\beta \; sin\beta)\begin{pmatrix} cos\alpha \\ sin\alpha \end{pmatrix}\right]^2 =$$

$$(cos\beta cos\alpha + sin\beta sin\alpha)^2 = cos^2(\alpha - \beta)$$

where $(\alpha - \beta)$ is the angle difference in the reference frame.

A. Prepare and measure

The simplest and most widespread protocol that is used today is the so called BB84. The steps for establishing the common secret is the following. [1] [2]

1) Alice sends a random bit sequence encoded in the polarization degree of freedom of photons. The four states are: vertical, horizontal, diagonal, anti-diagonal.
2) Bob randomly measures either in the rectilinear or in the diagonal base (obtains the raw key)
3) Bob tells Alice which base he used for each event
4) Alice tells him which ones are correct
5) They discard all results that are from incompatible bases
6) A binary string is obtained (shifted key) according to the encoding scheme: $\longleftrightarrow = \nearrow = 0$, $\updownarrow = \nwarrow = 1$

From the perspective of security there are two important laws that this protocol relies on. The first is the no cloning theorem, which ensures that quantum states cannot be copied. The second is that only one property can be measured at a time and it is not possible to measure for the rectilinear and the diagonal polarization at the same time. Further, when a measurement is performed it magnifies the probability amplitude of the outcome state to be 1. If a second measurement is done it will be on this new state, all information about the previous one is lost.

B. Entanglement

States that can be produced from individual lower dimensional states by means of tensor product are called product states. [1], [3]An example can be the following:

$$|\varphi_1\rangle = \frac{|0\rangle + |1\rangle}{\sqrt{2}}, \; |\varphi_2\rangle = \frac{1}{2}|0\rangle + \frac{\sqrt{3}}{2}|1\rangle$$

$$|\varphi_1\rangle \otimes |\varphi_2\rangle = \frac{1}{2\sqrt{2}}|00\rangle + \frac{\sqrt{3}}{2\sqrt{2}}|01\rangle + \frac{1}{2\sqrt{2}}|10\rangle + \frac{\sqrt{3}}{2\sqrt{2}}|11\rangle$$

This works back and forth as we can factor the second term to get the individual qubits. The question is can we do this for all joint states? It turns out that we can not. Lets consider the following special state called a Bell state:

$$|\varphi\rangle = \frac{1}{\sqrt{2}}|00\rangle + \frac{1}{\sqrt{2}}|11\rangle$$

If we want to work our way back to the individual qubit states we can calculate the coefficients for the following tensor product

$$(\alpha_0 |0\rangle + \alpha_1 |1\rangle) \otimes (\beta_0 |0\rangle + \beta_1 |1\rangle) =$$

$$= \alpha_0\beta_0 |00\rangle + \alpha_0\beta_1 |01\rangle + \alpha_1\beta_0 |10\rangle + \alpha_1\beta_1 |11\rangle$$

Here $\alpha_0\beta_0 = \alpha_1\beta_1 = \frac{1}{\sqrt{2}}$ and $\alpha_1\beta_0 = \alpha_0\beta_1 = 0$ which is a contradiction. $|\varphi\rangle = \frac{1}{\sqrt{2}}|00\rangle + \frac{1}{\sqrt{2}}|11\rangle$ is called an entangled state. There are interesting experimental results connected to such states. If we perform a measurement on the first qubit we obtain either $|0\rangle$ or $|1\rangle$ in this case with probability $\frac{1}{2}$. But whatever result we get with the first measurement if we perform the same measurement on the second qubit it will give the same result with probability 1. Experiments show that even if entangled qubits are sent to two distant location and a measurement is performed on one of them and we perform the other measurement faster than light could reach from one qubit to the other, we will always find the second one in the same state. At first this seams like to be in contradiction with Einstein's theory of relativity. Therefore Einstein was not pleased with these results. He called it "spooky action at distance", and claimed that each of these particles contain hidden variables that encode how they behave in certain situations. This makes it look like that each particle should contain huge amount of hidden information which seems problematic and in fact it can be proved that it is not the case. In quantum communication we can exploit this property of entangled pairs to use it for device independent quantum key distribution.

This property can be used for QKD. Namely we send one half of the pair to Alice and the other to Bob. When they perform the same measurement they will get the same outcome. If the entangled pair is generated at the transmitter side then the security proof is analogous to the BB84 protocol, however there is another interesting property. When we examine the measurement results for incompatible bases we can see that the results correlate more than measuring independent photons would allow. With this test called the CHSH inequality it can be checked whether the photons were indeed entangled.

III. The road to space

The first quantum key distribution experiment was performed in 1991 in a laboratory with a 32.5 cm free space channel [4]. The authors used the BB84 protocol and the information was encoded in polarization. On the transmitter side Alice used Pockels Cells −(an optical component that can change the light's polarization direction as a function of applied voltage)− to alternate between the different base states −horizontal, vertical, left circular, right circular polarization. Although the experiment was successful the apparatus had a serious flaw which was recognized by the authors: "Indeed, the largest piece in the prototype was the power supply needed to feed in the order of one thousand volts to Pockels cells, used to turn photon polarization. But power supplies make noise, and not the same noise for the different voltages needed for different polarizations. So, we could literally hear the photons as they flew, and zeroes and ones made different noises." This problem perfectly demonstrates the gap between theory and its realization. Another important factor is that security proofs rely on the indivisibility of single photons and the no cloning theorem. But in practice it is difficult to produce single photon pulses on a regular bases. If μ denotes the average photon number than the probability that the attacker can split the pulse is $\frac{\mu^2}{2}$, if $\mu \ll 1$. For this reason $\mu = 0.1$ was used in the experiment. The protocol and the privacy amplification steps should recover from the probabilistic success of the eavesdropper performing the attack. [5]

The first outdoor environment experiment was performed in 1996 over 75 m [6]. Here instead of the right and left circular polarization states the diagonal base were used alongside the rectilinear. This was achieved by adding a second Pockels cell. From the first experiment we learned that it is very important that the attacker should not be able to eavesdrop on the noise of the Pockels cell so the physical devices should be able to hide this from a potential attacker, otherwise by learning the applied voltages they can easily acquire the secret key.

The first real long distance free space QKD transmission was conducted in 2002 over a 9.81 km distance both under daytime and nighttime conditions [7]. Because of the excess background noise coming from the sun and the difference in the atmospheric transmission efficiency, the daytime average photon number was higher then during the nighttime conditions ($0.2 < \mu < 0.8$ vs $0.1 < \mu < 0.2$). This means that the attacker can learn a higher amount of partial information by performing a photon number splitting attack (PNS). Therefore, the privacy amplification step should mitigate that probabilistic knowledge to a negligible level. Another significant difference is that instead of one, four temperature−controlled diode lasers were used. This eliminated the need of Pockels cells since each laser beam is now polarized by default to represent a state either in the rectilinear or diagonal basis. To determine which laser should fire a cryptographic monolithic randomizer generates two random bits. The true randomness of this RNG (random number generator) is the hearth of the security. Nearly all secret key based cryptographic protocols rely on the assumptions that the key is true random and that its confidentiality is not compromised. If the random number generation is done incorrectly than the security is compromised from the start. The other important factor is that since now we have four instead lasers, the attacker should not be able to determine by any means which one has fired. If that could be performer than the key exchange becomes nothing more than sending key bits unencrypted in a public channel which is needless to say compromises confidentiality.

A big milestone in free space QKD was the realization of an experiment that exceeded all previous ones in terms of transmission distance [8]. It was performed 2400 m above sea level using polarization entangled photons over a 144 km long free space path. Entanglement based communication has the advantage that from the violation of the Bell inequality we can check whether the received photons were indeed entangled or they were manipulated by an adversary [9]. Over such distances the transmission efficiency suffers a significant attenuation by diffraction and absorption. The atmospheric losses together with other factors such as detection efficiency and attenuation by imperfections is physical components, resulted in a 25 dB total attenuation, with 25% single photon detector efficiency which is equivalent to a 6 dB attenuation. It is important to keep in mind that in case of entanglement detection what we need is a coincident detection of a pair. So in reality this results in a $\sim$6% detection efficiency which is a significant disadvantage comparing it to prepare and measure protocols. With this the achieved key rate was $\sim$2.3 bit/s which is far from sufficient for feeding a modern crypto system, but in case of a satellite transmission where the minimal distance is 400 km the atmospheric thickness decreases as we get farther from the surface, therefore it is one order of magnitude less then in this experiment. In this setup the entangled pair is generated at Alice's side and one half travels to Bob while the other is detected locally. But this violates the locality loophole since there is no delay on Alice's pair and it is detected while Bob's half is just meters away.

Other experiments such as an aircraft–to–ground downlink [10] or moving truck to ground station uplink [11] transmissions were performed to sort out the challenges like tracking inaccuracy or errors introduced by the movement of the equipment.

The big breakthrough in free space QKD came when the first successful experiment was conducted in 2016 with satellite named Micius [12]. By pursuing a global quantum encryption network, one has to realize the limitations regarding terrestrial QKD [13] [14] [15]. This is that the transmission distance is limited by the exponential reduction of transmission efficiency introduced by the attenuation of fiber and terrestrial free space links. In empty space this is negligible. Here the transmission distance varied between satellite altitudes of 500 and 1200 km. Using the BB84 decoy state protocol a key rate of 40.2 kbits/s was achieved at 530 km altitude.

IV. Attacking strategies and security

At the current state of technology the implementation will introduce several challenges where an attacker could obtain information on the key and remain undetected. In classical communication security critical parts can be separated and they are not directly connected to the environment, therefore the adversary cannot reach them physically. In quantum communication the system is directly connected to environment via an optical or free space channel and this opens the opportunity to attacks.

A. Intercept and resend

This is the most basic type of attack and it's independent of the physical apparatus. The attacker blocks the communication channel and measures the traveling photons (either all or a subset). Then she sends her measurement results to Bob. Since this attack doesn't depend on the device it has to be answered in a protocol level. The attacker won't be able to stay unnoticed if a large portion of the qubits are intercepted. Since Bob usually guesses right 50% of the time and in these cases will know Alice's bit exactly. Otherwise there is a 50% chance getting the correct result from the wrong measurement. In the end he should see a 25% error rate in the raw key. But after shifting when they only keep results where they used the same measurement, no errors should be present, so if Eve was actively intercepting her presence will be discovered and the key bits are discarded. They problem is that even on idle there will be errors introduced by the channel. The first task is to determine the error rate that is present without an attacker. This is not an easy task in case of free space QKD since QBER can fluctuate depending on the weather or the night and day cycle or even the moon cycle. If the allowed QBER is not determined properly it can cause denial of service, or could allow the attacker to perform an attack and remain unnoticed if the threshold is set too high [16].

B. Photon number splitting

If only weak single photon signals are transmitted the no cloning theorem prevents the attacker to obtain useful information on the key unnoticed. But the single photon sources are not perfect and sometimes with small probability they send stronger pulses containing 2 or more photons. In this case the attacker can learn these key bit values by measuring a half of the pulse and letting the other half go to Bob. If the attacker has quantum memory she can store the intercepted photons until the measurement bases are announced. Otherwise she needs to perform a measurement immediately, but this means that only 50% of the time she will get the correct result [16].

C. Trojan horse

Also known as light injection attack. Here Eve tries to get information on what basis choice Alice has for photon polarization at each step. Therefore she send bright light pulses on the optical fibre to Alice's or Bob's direction and analyses the back-reflection. From the back-reflection of the single photon detectors Eve is able to tell Bobs base choices and with that she can compromise the security of the system. The other method is that Alice is targeted and Eve can tell what bases she used for encoding the key bit and if she can intercept the photon before it reaches Bob she can perform the right measurement and perform an intercept-resend attack without introducing any additional QBER. The remedy for this attack is to install wavelength filters however, various wavelengths can be used [17].

D. Wavelength control / laser diode side channel

In free space QKD the information is usually encoded in polarization. This can be either done by modulating a single laser diode or by using a separate laser for each of the states. The latter is commonly used because it is easier to operate it with higher speeds. To maintain security the lasers need to be hand picket and adjusted so that their spatial, spectral and temporal modes are not distinguishable. Furthermore the lasers need to be temperature cooled and their output must be filtered. In an experiment [x] researchers showed that shooting a strong laser polarized in one of the states can tune the individual lasers in Alice's possession to output different wavelength. Since each laser diode is equipped with a polarizer, it will either reflect or let through some of the light coming from Eve's laser. After this Eve can easily distinguish the signals by a wavelength division multiplexer to send signals to one of Eve's four laser diodes −same model as Alice's−which then forwards the information to Bob. With this attack Eve can learn the full secret key without introducing any errors. To prevent this attack Alice must use narrow band-pass filter and isolators. These however might be damaged by a strong laser that so a laser monitoring unit must be used to detect Eve's attempt. This attack threatens all free space QKD systems where separate laser diodes are used for the individual states [18].

E. Laser damage

To prevent trojan horse and wavelength control attacks different QKD implementations use various countermeasures such as spectral filters, optical isolators, wavelength filters and pulse−energy monitoring detectors. The latter is calibrated such a way that a portion of the incoming light is fed to this detector such that if extra energy is injected an alarm goes off. Eve can work her way around this countermeasure by shooting a strong laser signal on the communication channel that damages this detector fully or partially and as a result it looses sensitivity which opens up the system for trojan horse attacks. It is possible to damage the spatial filters or pinholes that are put to protect the lenses from angles that could be used by Eve. Laser damage can melt this part of the device and open up a bigger hole but leave all other parts undamaged [19].

F. Blinding

This attack family targets the single photon detectors on the receiver side. Detectors are usually operated in a gated mode where there is a short time window where the detection can happen. After detection there is a so called dead time for the detector, where it is insensitive. To reduce the probability of dark counts, when the detector fires even without an incoming photon due to background noise, the gating is done in a periodic way synchronized with the transmitter side. The attackers goal in this scenario is to send dim light pulses into the system in one of the base states around the time Bob has his detection window open. The pulse can blind the detectors with certain probability except the one that is orthogonal to that state making them blind. If Alice and Bob will use this detection event Eve can know that it could be detected only by detectors not blinded. With this tactic she can learn significant information about the secret key without introducing alarming amount of error to the system. This attack basically creates a detector efficiency mismatch that is predictable for the adversary [20].

G. Fake state attack

This is a special type of intercept and resend attack where Eve doesn't try to resend a "copy" of Alice's qubit but create a signal where the time shift is set in such a way that it can be detected by Bob only if he is choosing the base that Eve wants him to. If he uses the wrong detector it gets blinded by the incoming signal and Bob can't detect anything. This attack is usually combined with a blinding attack or it is using detector efficiency mismatch. Bob will choose the right bases approximately 50% of the time. If Eve guessed Alice's choice than Bob will have the correct result. Otherwise she introduces only as much error as Bob would do under normal circumstances [21].

V. Conclusion

QKD is rapidly developing however the current state of technology makes its implementation challenging. Each time a prototype is developed, its security should be carefully tested against all possible attacks. The same is true when a device is deployed especially for free space QKD. For a new setup distance, weather condition, altitude, components are different and the system need to be fine tuned to achieve the desired security.

Acknowledgment

The research is connected to COST Action CA15220 Quantum Technologies in Space.

References

[1] S. Imre and F. Balázs. Quantum Computing and Communications – An Engineering Approach. Wiley, 2004

[2] C. H. Bennett and G. Brassard, "Quantum cryptography: Public key distribution and coin tossing," in Proceedings of the IEEE International Conference on Computers, Systems and Signal Processing. Bangalore, India: IEEE, 1984

[3] M. A. Nielsen and I. L. Chuang. Quantum Computation and Quantum Information: 10th Anniversary Edition. Cambridge University Press, New York, NY, USA, 10th edition, 2011and Communications – An Engineering Approach. Wiley, 2004

[4] C. H. Bennett, F. Bessette, G. Brassard, L. Salvail and John Smolin, "Experimental Quantum Cryptography", Journal of Cryptology, 1992, volume 5, pages 3-28.

[5] G. Brassard, ""Brief history of quantum cryptography: A personal perspective"", Proceedings of IEEE Information Theory Workshop on Theory and Practice in Information Theoretic Security, Awaji Island, Japan, pp. 19 23, October 2005

[6] B. C. Jacobs and J. D. Franson, "Quantum cryptography in free space", Opt. Lett. 21, 1854-1856 (1996), https://doi.org/10.1364/OL.21.001854

[7] J. Richard at al. "Practical free-space quantum key distribution over 10 km in daylight and at night", Physics Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

[8] R. Ursin at al. "Free-Space distribution of entanglement and single photons over 144 km", 2006

[9] A. Korsos, L. Bacsardi, Zs. Kis, "An analysis of entanglement-based solutions on Earth-satellite channel", H-SPACE 2017, Budapest, Hungary, 2017.

[10] F. Moll, S. Nauerth at al. "Communication system technology for demonstration of BB84 quantum key distribution in optical aircraft downlinks". DOI: 10.1117/12.929739, 2012

[11] J-P. Bourgoin, at al. "Free-space quantum key distribution to a moving receiver", Opt. Express 23, 33437-33447 2015

[12] S-K Liao at al. "Satellite-to-ground quantum key distribution", Nature 10.1038/nature23655, 2017

[13] L. Bacsardi, ?On the Way to Quantum-Based Satellite Communication?, IEEE Comm. Mag.51:(08) pp. 50-55., 2013

[14] L. Bacsardi, ?Satellite Communication Over Quantum Channel?, Acta Astronautica 61:(1-6) pp. 151-159., 2007)

[15] A. Kiss and L. Bacsardi, ?Analyzing a Satellite-based Quantum Key Distribution Network?, Global Space Application Conference, Paris, France, 2014

[16] R. Aggarwal, H. Sharma, D. Gupta, "Analysis of Various Attacks over BB84 Quantum Key Distribution Protocol", International Journal of Computer Applications (0975 – 8887) Volume 20– No.8, April 2011

[17] S. Sajeed, C. Minshull, N. Jain, and V. Makarov, "Invisible Trojan-horse attack"

[18] Min Soo Lee, at al. , "Free-space QKD system hacking by wavelength control using an external laser", Opt. Express 25, 11124-11131 (2017)

[19] V. Makarov, at al. "Creation of backdoors in quantum communications via laser damage", Phys. Rev. A 94, 030302 (2016)

[20] H. Weier at al., "Quantum eavesdropping without interception: an attack exploiting the dead time of single-photon detectors", Henning Weier et al 2011 New J. Phys. 13 073024, https://doi.org/10.1088/1367-2630/13/7/073024

[21] V. Makarov and D. R. Hjelme, "Faked states attack on quantum cryptosystems", J. Mod. Opt. 52, 691 (2005)

Recent trends in light pollution measured from space in Hungary

Kornél Kolláth
Hungarian Meteorological Service, Hungary
kollath.k@met.hu

Kai Pong Tong, Zoltán Kolláth
Eötvös Loránd University, Savaria Campus
Szombathely, Hungary

***Abstract*—For mapping and monitoring the changes in light pollution one of the convenient ways is to measure the radiances from space. VIIRS sensor onboard the Suomi NPP satellite is capable to measure visual radiances (VIIRS Day/Night band in 0.5–0.9 micrometre wavelength range). Our attention is to detect changes in the satellite based radiances and mapping its spatial distribution in Hungary. The monthly cloud-free composite images available from Earth Observation Group, NOAA were used. We find around 3% increase in the spatial coverage of radiance values above 5 nW/cm²/sr, and around 20% increase above 40–50 nW/cm²/sr based on the ratio of the two-year averages of 2014–2015 and 2016–2017.**

***Keywords*—light pollution; sustainable lighting; remote sensing; VIIRS; Day/Night band**

I. Introduction

Unnecessary, misdirected or intrusive use of artificial outdoor lighting, called light pollution is a rapidly growing environmental problem. There are growing interests in light pollution among scientific community in different disciplines, like socio-economic activity, health care, ecology, astronomy, air chemistry, meteorology. Light pollution alters the natural night sky, adversely affects the environment, wildlife and humans as well. Sources come from public lightings, buildings, advertising boards, sporting venues, ornamental lightings, factories, etc.

Ground and satellite-based remote sensing of artificial light is necessary for monitoring the problem and its effects. Day/Night Band (DNB) radiometer onboard the Suomi National Polar-orbiting Partnership satellite provides calibrated measurements of visual radiances at night which is a unique instrument of this type [8]. It has a visible/near-infrared sensor with 500–900 nm band pass and able to measure extremely dim lights.

Recently, Kyba et al. carried out studies about changes in lights at the national and global level [5]. They found that global light emissions are increasing at a rate of 2.2% per year. They also explored the changes in Germany in a more detailed regional way [7]. Interpreting the light pollution trends from DNB data the most important complication comes from the fact that the sensor spectral response differs from the human eye. In many countries transitions from high pressure sodium to LED street lighting are taking place. White LEDs usually have a blue peak in 400–500 nm, but it is outside of the DNB sensitivity range. Nevertheless, the observed increase in DNB radiance generally suggest increases in total visible light emission and so light pollution, but a decrease in DNB radiance could be a consequence just from a transition to LED alone.

Our aim is to analyse distribution and map changes in DNB radiance values in Hungary from 2014 till 2017, especially since public street lightings has been replaced in several towns in this period, but also the country experienced significant increase in building industry.

II. Data and Methodology

Next to the individual VIIRS DNB measurements NOAA produces a VIIRS night-time lights product on a monthly basis. They filter out low-quality data and extraneous features unrelated to lightings. Only moonless cases are involved without clouds based on filtering algorithms. The details can be found in [1]. These so-called cloud free composites are available in geotiff format in 15 arc-second geographic grids from Earth Observation Group, NOAA National Geophysical Data Center at https://www.ngdc.noaa.gov/eog/viirs.html. Note that the original resolution of the data is 0.75 km × 0.75 km (~0.56 km²). The nominal minimum detection in-band radiance for the DNB is 3 nW/cm²/sr, the noise floor is 0.05 nW/cm²/sr. The system currently performing above 9 signal-to-noise ratio (SNR=9), so the DNB values much less than the nominal detection limit could serve valuable information.

For our study data from September 2012 till December 2017 were used. There were missing data from May 2013 till August 2013. We analysed pixel values within Hungary and calculated the area extent above specific DNB thresholds. Time series of monthly data can be seen in Fig 1. and 2.

To have an overview of probably significant changes two years averages were compared and visualized its spatial distribution. Winter month were not considered, because snow as a high albedo surface can significantly alter the results. Also

The research was supported by EFOP-3.6.2-16-2017-00014

because of obvious quality problem November 2015 monthly data were excluded from the comparison analysis.

III. Results

Table 1. shows the area extent (km²) of the pixel values above specific thresholds (from 1 to 50 nW/cm²/sr) in the 2014-2015 and 2016-2017 two years averages. Based on the ratio of the two measurements, percentages were calculated as a rate of change. The DNB values higher than 1 nW/cm²/sr in around 11.000 km², and higher than 5 nW/cm²/sr in around 2500 km² which is about 12% and it is 2.5% of the territory of Hungary. The extent in km² increased about 3-8% above these thresholds. The DNB values higher than 50 nW/cm²/sr are covering only about 50-65 km² and the ratio of the two year's averages shows around 23% increase.

TABLE I. Spatial extent (km²) with radiance values above specific thresholds in 2014–2015 and 2016–2017 two-year averages.

Threshold radiance (nW/cm²/sr)	**Area (km²)**		**Change (%)**
	2014–2015	***2016–2017***	
1	10178	11036	8.4
2	5586	5880	5.3
3	3910	4051	3.6
4	3023	3122	3.3
5	2478.0	2552.5	3.0
10	1230.3	1267.5	3.0
20	471.2	501.2	6.4
30	208.6	233.8	12.1
40	100.2	118.6	18.4
50	52.4	64.5	23.2

Figures 3-5 display the positive (colored red) and negative (colored blue) changes in nW/cm²/sr based on the difference between the 2016–2017 and the 2014–2015 year's average values. Gaussian smoothing was applied with sigma=2. In many places (including Budapest) positive values are dominant, but there are towns where the average DNB values are decreased.

IV. Discussion

Interpreting VIIRS DNB observations has several difficulties. Weather conditions, atmospheric transmittance, surface albedo can significantly change the radiance value. The direction from which the satellite see the light source could also have importance. Furthermore, DNB records phenomena not related to electric lighting as well. Atmospheric airglow, biomass burnings, gas-flares, radiance from infrared heating of greenhouses or other strong near-infrared sources in some factories may appear in the DNB images. One of the highest radiance in Hungary can be observed from a greenhouse near the settlement Aba (Fig. 6). The DNB satellite images, and also the monthly cloud free composites may suffer from stray light. In the monthly composite images involved in our study the DNB values seemed to be systematically shifted with some decimals of nW/cm²/sr in one part of the image, especially in summer. The DNB values can change with the seasons as a function of surface albedo, so vegetation and snow cover could affect the brightness [8]. From the time series of DNB values (Figs 4 and 5.) peaks are obvious in winter. Because snow coverage is a very varying parameter in Hungary, winter was better to be excluded from the analysis. From November till February we find errors originates from the cloud detection algorithm. In many cases the effect of fog and low-level clouds could be seen in the composite images. In November 2015, technical problem with the calibration of the instrument lead us to exclude this month from the analysis, as well. We suppose that averaging near two-year periods ensure some robustness in the comparison.

From the spatial distribution of the variations showed in Fig. 3, most of the changes happened in towns. Budapest experienced a significant increase in DNB radiance values. Alterations in many towns, where decrease could be calculated, may be explained with lighting reconstruction and transition to LEDs. These towns are Balmazújváros, Budaörs, Dunaújváros, Érd, Hajdúböszörmény, Kiskunfélegyháza, Mezőkövesd, Orosháza, Pécs, Sárospatak, Sárvár, Szarvas, Szentes, Szolnok, Zalaegerszeg.

The change in the spatial extent of radiance values above 5 nW/cm²/sr (lit area) the trend (3%/2year) is somewhat lower than the global average (2.2%/year) published in [5].

V. Conclusion

In the examined period (2014-2017) DNB radiance values generally increased in Hungary as an average. In this period lighting remodelling happened in several Hungarian cities by replacing the earlier high pressure sodium street lightings to white LEDs. Because of the better shielding of these new luminaries and their different spectra (a peak in the blue range where DNB is "blind") the transition to LED technology alone should decrease the observed DNB radiances. We conclude that newly installed lightings in new places or installation of stronger lights in many places exceed the effect of LED transition in the change of DNB radiance values as an average in the country. It implies that recent trend makes the light pollution significantly worsen in Hungary

References

[1] Christopher D Elvidge, Kimberly Baugh, Mikhail Zhizhin, Feng Chi Hsu and Tilottama Ghosh (2017): VIIRS night-time lights, International Journal of Remote Sensing, 38:21, 5860-5879.

[2] Falchi et al (2016): The new world atlas of artificial night sky brightness, Science Advances, Vol. 2, No. 6.

[3] Kolláth, Z., Dömény, A., K. Kolláth and B. Nagy (2016): Qualifying lighting remodelling in a Hungarian city based on light pollution effects. J. Quant. Spectrosc. Radiat. Transf. 181, 46–51.

[4] Kolláth, Z. and Dömény, A. (2017): Night sky quality monitoring in existing and planned dark sky parks by digital cameras. International Journal of Sustainable Lighting 19. 61-68.

[5] Kyba, C. et al (2017). Artificially lit surface of Earth at night increasing in radiance and extent. Science Advances, 2017; 3 (11): e1701528

[6] Kyba, C. et al (2014). High resolution imagery of Earth at night: new sources, opportunities and challenges. Remote sensing, 7(1), 1-23.

[7] Kyba, C., Kuester, T. and Keuchly, H.U., Changes in outdoor lighting in Germany from 2012-2016. International Journal of Sustainable Lighting 19, 112-123.

[8] N. Levin, Q. Zhang (2017): A global analysis of factors controlling VIIRS nighttime light levels from densely populated areas. Remote Sens. Environ. 190, 366–382.

[9] Miller et al (2013): Illuminating the Capabilities of the Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band, Remote Sens. 5 (12).

[10] Walczak, K., Gyuk, G., Kruger, A., Byers, E., & Huerta, S. (2017): NITESat: A High Resolution, Full-Color, Light Pollution Imaging Satellite Mission. International Journal of Sustainable Lighting, 19(1), 48-55.

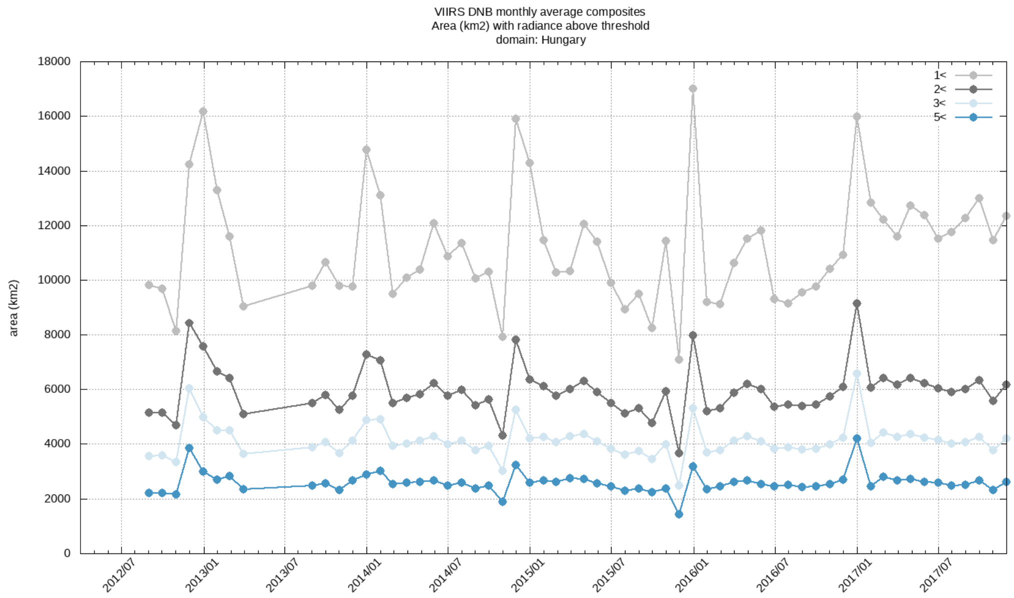


Fig. 1. Time series of the area in Hungary with pixels above given radiance (1,2,3,5 nW/cm^2/sr) thresholds between October 2014 and December 2017. Outstanding values can be seen in some winter months presumably because of measurements with snow on the ground.

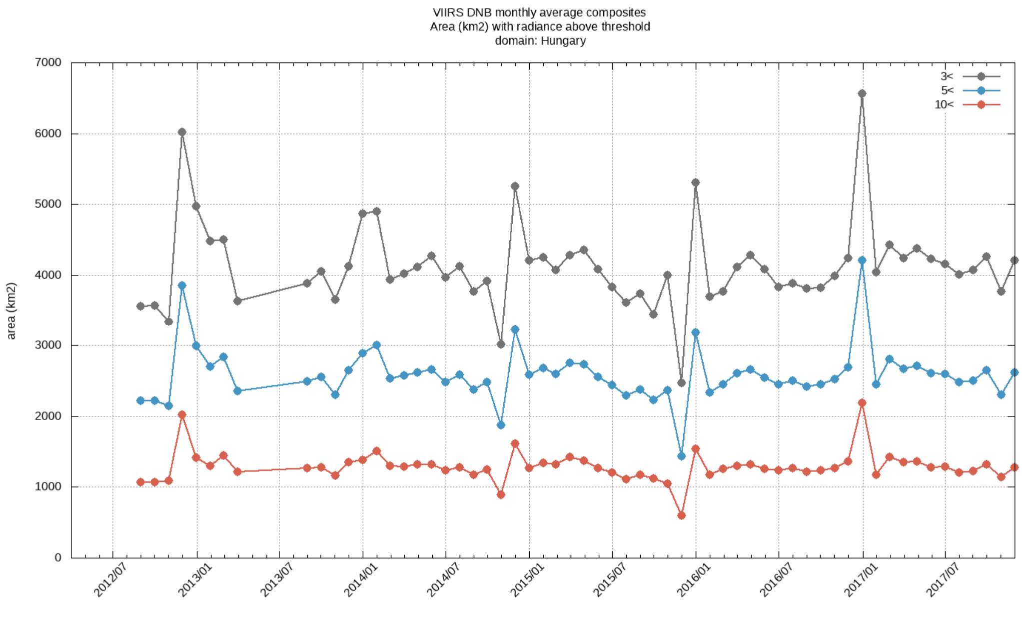


Fig. 2. Time series of the area in Hungary with pixels above given radiance (1,2,3,5 nW/cm^2/sr) thresholds between October 2012 and December 2017. Outstanding values can be seen in some winter months presumably because of measurements with snow on the ground.

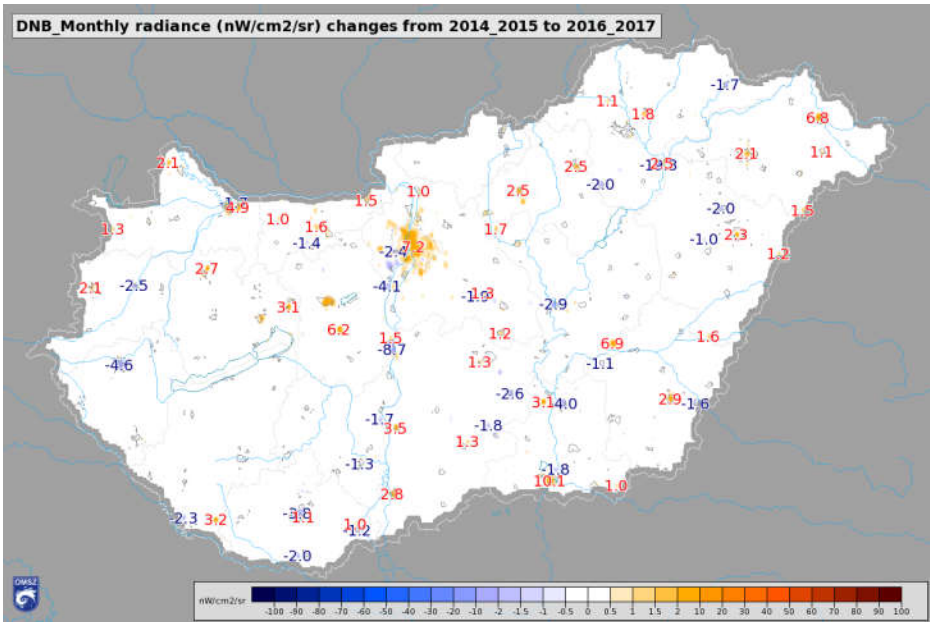


Fig. 3: Spatial distribution of the difference between two year's averages (2016/2017 and 2014/2015) of the composite DNB radiance values with Gaussian smoothing (sigma=2). Maximum and minimum values above 1.0 and below -1.0 are indicated with numbers.

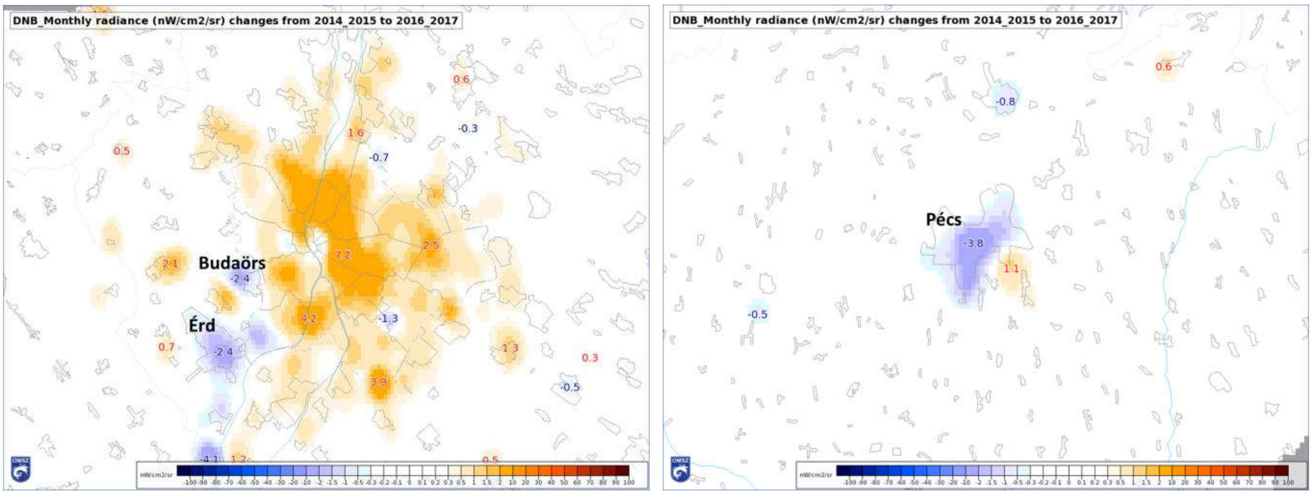


Fig 4-5. Difference between two year's averages (2016/2017 and 2014/2015) of the composite DNB radiance values in Budapest and Pécs and its surroundings. In Budaörs, Érd and Pécs many street lights were replaced to LEDs within this period.

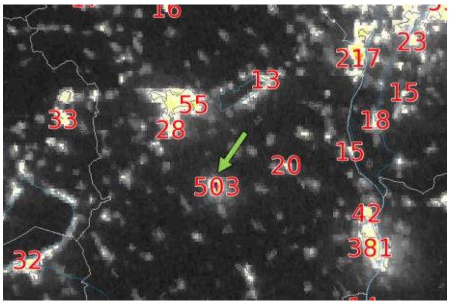


Fig 6. One of the highest radiance values are observed next to the settlement, Aba in Fejér county where a greenhouse is operating with infrared lamps. The example shows the monthly average of 2017 November, when DNB was above 500 $nW/cm^2/sr$.

Analyzing the Effects of Atmospheric Factors in Earth-Space and Space-Earth Quantum Communication Channels

Andras Kiss
Institute of Informatics and Economics
University of Sopron
Sopron, Hungary
kissa@gain.uni-sopron.hu

Laszlo Bacsardi
Institute of Informatics and Economics
University of Sopron
Sopron, Hungary
bacsardi@inf.uni-sopron.hu

***Abstract*—So far 2017 had the most important milestones in satellite-based quantum communication as a video conference between Beijing and Vienna [1] has been held. That was not only a demonstration, but also a real proof of the feasibility of the space-based quantum data transmission. Basically, a satellite-based network is composed of at least one ground station and one satellite. Ground-space, space-ground and space-space channels are used to transmit data between the endpoints of the route in the network [2].This means the different properties of the Earth's atmosphere has been taken into account to determine the performance characteristics of an Earth-space or space-Earth optic channel. All of the atmospheric factors affect the transmittance of the channels and all of the analyzed quantum key distribution (QKD) protocols, including BB84, B92, S09, Gisin take into account the transmittance to determine the Quantum Bit Error Rate (QBER) of the protocol. Here appears the importance of the Earth's atmospheric factors in a quantum-based satellite network. In this paper, our goal is to analyze and evaluate the effects of the atmospheric factors in the mentioned communication channels.**

In September of 2017, we have released the latest version of the Quantum Satellite Communication Simulator, which was developed directly to analyze satellite-based quantum communication channels by various scenarios, taking into account the atmospheric factors of the Earth. In this paper, we analyze the influences of absorption and scattering of the light beam in different climate, season and weather conditions.

Keywords—quantum communications; satellites communication; atmospheric factors

I. THEORETICAL BACKGROUND

In a satellite-based quantum key distribution network we use quantum bit to transfer data from the sender to the receiver. Its unit is the qubit and its value is the arbitrary superposition of 0 and 1. In the communication channel there is a point where we have to do a measurement to determine the value of a qubit. The measurement results 0 or 1 value. Compared the quantum communication channel to the classic communication channel, in case of an eavesdropping attack the attacker automatically changes the quantum state and by this, the opportunity is given to detect the attacker. This is one of the biggest advantages of the quantum communication channel.

Between the communicating participants, including data sending between ground station and satellite or between two satellites, the data is encoded in photon. It is a critical point to transfer the photon from the sender to the receiver with as low loss as possible. That is why it is needed to use laser beam (typically 860 nm or 1060 nm) for the data transmission. Beside the advantages of the optic channel communication we have to take into account the conditions for its operation. Here appears the importance of how atmospheric factors affect the laser beam spread. In this paper we are focusing on the determination of the transmittance by the parameters, which belong to the Earth's atmosphere.

Basically there are two types of channels: Earth-space, space-Earth. In space-space communication the transmittance is obviously different from the case of Earth-space or space-Earth channels, because there is no atmosphere, in which the loss of atmosphere could affect the light beam.

We used the Quantum Satellite Communication Simulator 2.0 to simulate and evaluate the results of the Earth-space and space-Earth channels in function of different parameters, which are part of the Earth's atmosphere.

II. DETERMINATION OF TRANSMITTANCE

A. Static loss

Basically, there are two types of static loss in the atmosphere: scattering factor and absorption factor. Both of them can be originated from molecular or aerosol loss, as it is described in Table 1. The molecular loss means the light is absorbed or scattered by molecules, the aerosol loss means the light is absorbed or scattered by dust motes and water drops.

TABLE I. SCATTERING AND ABSORPTION FACTORS

		Type of loss	
		Scattering	**Absorption**
Reason of loss	**Molecular**	σ_m	k_m
	Aerosol	σ_a	k_a

The sum of the two types of the losses is the attenuation coefficient. It can be different values depending on the height above sea level and the following various ambient factors: Climate, season, weather. It is also needed to take into account the optical length of the light beam in the atmosphere. Fig. 1. shows how the optical length of the light is calculated, where the zenith angle, signed by θ is the bias from the vertical line of the ground station position and the L_i is the thickness of the ith atmospheric layer.

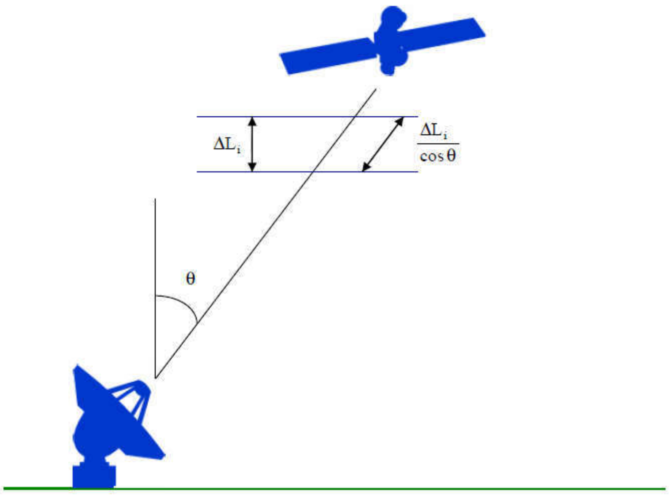


Fig. 1. Determination of the optical length of the light beam

The static loss can be calculated by the following formula [3].

$$\tau_{STAT} = \exp\left(-\sum_i (\sigma_i + k_i) \cdot \frac{\Delta L_i}{\cos\theta}\right)$$

where

- σ is the scattering value of the ith atmospheric layer.
- k is the absorption value of the ith atmospheric layer.
- L is the thickness of the ith atmospheric layer.
- θ is the zenith angle.

B. Turbulence strength

We applied the Hufnagel-Valley model to calculate the turbulence strength in out model [4], which gives an approximate value to the effective turbulence strength. The equation gives the result using the value of height above sea level and the integrated values of average wind speed for different heights.

$$C_n^2 = 0.00594 \cdot \left(\frac{W}{27}\right)^2 \left(h \cdot 10^{-5}\right)^{10} \exp\left(-\frac{h}{1000}\right) +$$
$$+ 2.7 \cdot 10^{-16} \cdot \exp\left(-\frac{h}{1500}\right) + A \cdot \exp\left(-\frac{h}{100}\right)$$

where

- W is the average wind speed integrated on the different heights above sea level.
- h is the height above sea level.
- A is a constant number with $1.7 \cdot 10^{-14}$ value.

C. Beam widening

When the laser beam goes through the turbulent area, the vortexes, which are smaller than the width of the beam, they make the light beam wider [4]. Knowing the turbulence measurable at each heights, we can see how much the beam widens when the effects of the atmosphere is taken into account. The following formula shows how the beam widening is calculated in case of the light beam goes through the atmosphere.

$$\rho = \sqrt{\frac{4L^2}{k^2 D_A^2} + \frac{D_A^2}{4} + \frac{4L^2}{(k \cdot \rho_0)^2}\left(1 - 0.62\left(\frac{\rho_0}{D_A}\right)^{\frac{1}{3}}\right)^{\frac{6}{5}}}$$

where

$$\rho_0 = \left[1.46 k^2 \int_0^L C_n^2(z)\left(1 - \frac{z}{L}\right)^{\frac{5}{3}} dz\right]^{-\frac{3}{5}}$$

where

- L is the channel length.
- D_A is the aperture diameter.
- k is the wave number.
- ρ_0 is the coherence length.
- z is the specified layer in the Earth's atmosphere.

D. Targeting error

We have to take into account the error factors from the sender side. One of these factors is the targeting error. In practice, the value of the targeting error is about 1 micro-radian [5]. It can be calculated by the following formula.

$$\sigma_{TARGET} = L \cdot \sigma_\varphi \cdot 10^{-6}$$

where

- L is the channel length.
- σ_φ is the targeting angular error.

E. Total scattering

In the determination of the total scattering appears the importance of the beam widening and the targeting error. These values are needed to calculate the total scattering by the following formula.

$$\sigma_{SPREAD} = \sqrt{\rho^2 + \sigma_{TARGET}^2}$$

where

- ρ is the beam widening.
- σ_{TARGET} is the targeting error.

F. Dynamic loss

The dynamic loss is as important as the static loss is to calculate the value of the transmittance. Basically the dynamic loss is composed by the total scattering and the mirror radius on the receiver side.

$$\tau_{DYNAMIC} = \exp\left(- \frac{-R_B^2}{2 \cdot \sigma_{SPREAD}^2} \right)$$

where

- R_B^2 is the radius of the mirror on the receiver side.
- σ_{SPREAD} is the total scattering.

G. Transmittance

After determining the values of static loss and dynamic loss, the value of the transmittance can be calculated as a multiplication of these values.

$$\tau = \tau_{STAT} \cdot \tau_{DYNAMIC}$$

where

- τ_{STAT} is the static loss.
- $\tau_{DYNAMIC}$ is the dynamic loss.

III. QUANTUM SATELLITE COMMUNICATION SIMULATOR

The *Determination Of Transmittance* section describes the formulas and parameters, which are needed to use to calculate the transmittance using a lot of physical parameters. The large parameter sets and the complex calculations were the main reason to develop a simulation software. The Quantum Satellite Communication Simulator 2.0 is the latest version of the application. The scenario-based architecture and the user friendly GUI make the usage of the calculations easier and it show all of the important results the user. The cover of the simulator is illustrated in Fig 1.

Fig. 1. Cover of the Quantum Satellite Communication Simulator 2.0

In this paper, we are focusing on the effects on the atmospheric factors of the communication channel. The Calculating by Constant Parameters scenario is the best choice to determine the performance characteristics of the simulated channels. By this scenario we can get all of the necessary and useful information that is needed to take into account to determine the channel transmittance as a final result. The Calculating by Constant Parameters scenario can be seen in Fig. 2.

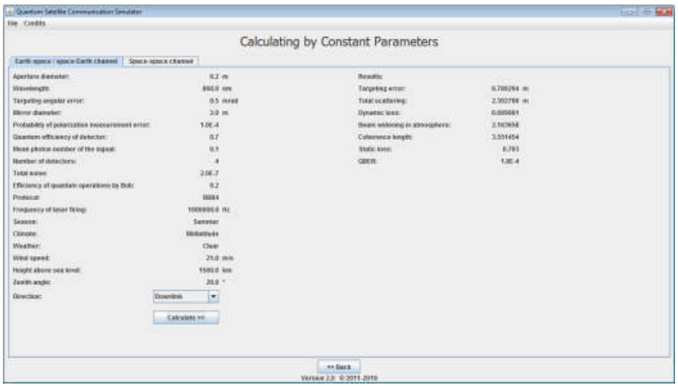


Fig. 2. Calculating by Constant Parameters

This scenario includes the two different calculation methods for Earth-space and space-Earth channel directions. The *Simulation Results* section shows the results about how important it is to handle these directions differently.

IV. SIMULATION RESULTS

In our simulations, we are focusing on the transmittance in function of height above sea level, wind speed and zenith angle. This section also contains charts to compare the different absorption and scattering values in function of the height above the sea level.

In every simulation, if no other parameter is specified, the default values are the following:

- Wavelength: 860 nm

- Aperture diameter: 0.2 m
- Wind speed: 21 m/s
- Zenith angle: 0 °
- Targeting angular error: 0.5 µrad
- Mirror diameter: 2 m
- Channel length: 1000 km
- Climate: midlatitude
- Season: summer
- Weather: clear
- Direction Earth-space

In Fig. 3., the transmittance values of three types of communication channels in function of height above sea level is illustrated. As the chart shows, the longer channel length results lower transmittance. The space-space channel has the higher transmittance due to the lack of atmospheric effects. The chart also shows the importance of the difference between the order of atmosphere and vacuum in an optical path.

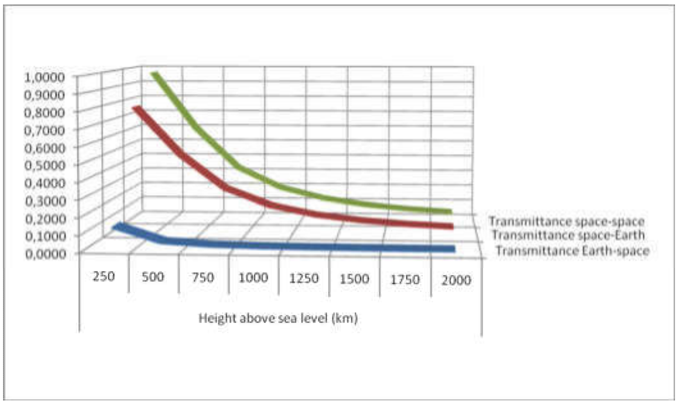


Fig. 3. Transmittance values for different channel directions in function of height above sea level

The aerosol absorption values in case of clear and hazy weather can be seen in Fig 4. in function of height above sea level. These values matter to the attenuation mostly when the light beam goes through the atmosphere below 6 km height above sea level.

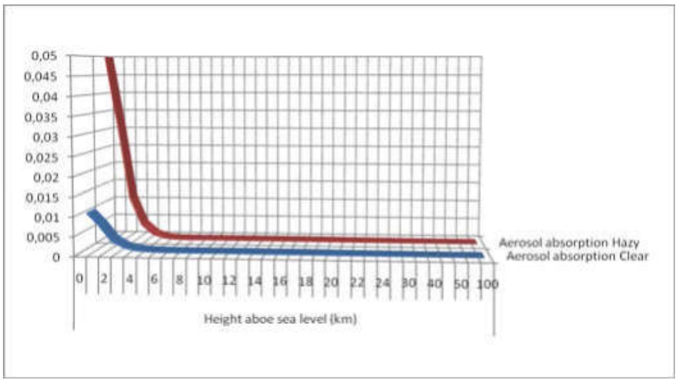


Fig. 4. Aerosol absorption values for clear and hazy weather in function of height above sea level

Molecular scattering values are shown in Fig 5. in case of trope, midlatitude winter and midlatitude summer climate and season in function of height above sea level. It is a negative factor, which means the higher height above the sea level there is, the lower molecular scattering value there is due to the lower air density.

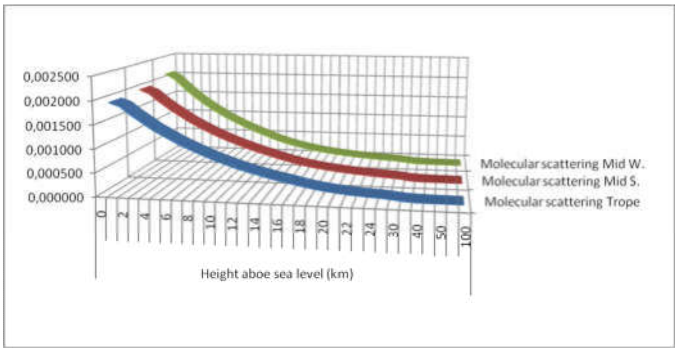


Fig. 5. Molecular scattering values for midlatitude and trope climates in function of height above sea level

The values of transmittance in case of 1000 km long Earth-space channel in function of wind speed is illustrated in Fig. 6.. The higher wind speed results lower transmittance, but as the chart shows in a 10-30 km/h wind speed interval, the difference between the lowest and highest transmittance values is lower than 0.1 %.

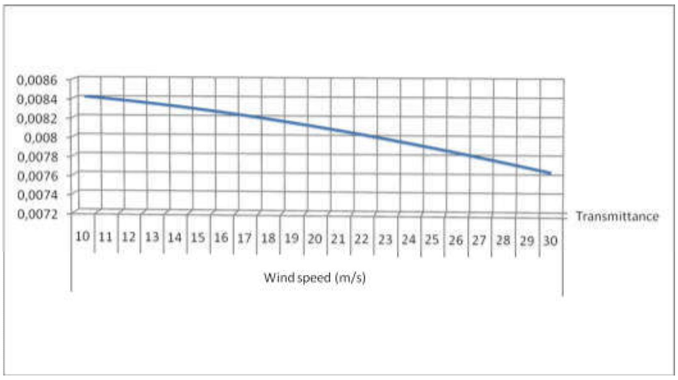


Fig. 6. Transmittance in function of wind speed

The values of transmittance in case of 1000 km long Earth-space channel in function of the zenith angle are shown in Fig 7.. The higher zenith angle results lower transmittance, because in case of higher zenith angle the light beam needs to take longer path through the atmosphere. In our simulation model we set the maximum zenith angle to 70°.

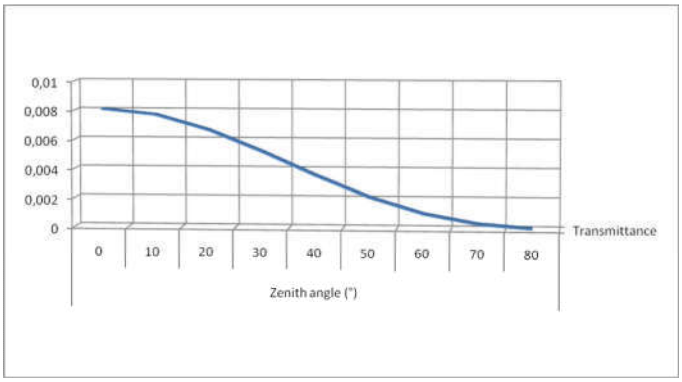


Fig. 7. Transmittance in function of zenith angle

ACKNOWLEDGMENT

The research was supported by the Hungarian Scientific Research Fund – OTKA PD-112529. The research is connected to COST Action CA15220 Quantum Technologies in Space.

REFERENCES

[1] Phys.org https://phys.org/news/2017-09-team-world-space-ground-quantum-network.html (Last retrieved on 12 November 2017)

[2] P.Villoresi et al., "Experimental verification of the feasibility of a quantum channel between space and earth", New Journal of Physics, Vol. 10, No. 3, p. 033038, 2008.

[3] Walter G. Discoll, 'Handbook of Optics', (McGraw-Hill, 1978)

[4] Michael Brass, 'Handbook of Optics, Vol. I. (2nd. Ed.)', (McGraw-Hill, 1995)

[5] Stephen g. Lambert, William L. Casey, 'Laser Communications in Space', (Artech House, 1995)

Optical transfer in space

Andrea Farkasvolgyi
Department of Broadband Infocommunications and Electromagnetic Theory
Budapest University of Technology and Economics
Budapest, Hungary
andrea.farkasvolgyi@hvt.bme.hu

Istvan Frigyes
Department of Broadband Infocommunications and Electromagnetic Theory
Budapest University of Technology and Economics
Budapest, Hungary
frigyes@mht.bme.hu

Abstract— **This paper presents the possibilities of Free Space Optical (FSO) connection in space communication. It summarizes the advantages and disadvantages of optical transmission in case of Near Earth and Deep Space region. It compares available maximum channel parameters of near future space missions. This article discusses the application of multichannel or more precise diversity systems, which we recommend for long distance space communication.**

Keywords— free space optical communication, diversity, correlation problems, hybrid RF/FSO

I. Introduction

In space communications the optical transmission (OT) has been applied for satellite - to - satellite link (SPOT-4 – OPALE, OICET) since the mid - 90s. This first inter – satellite optical communication link was a short distance, non-continuous operational transfer link between ARTEMIS - a geostationary earth orbit satellite (GEOS) for telecommunications – and SPOT-4 - an Earths observation Low Earth Orbit (LEO) satellite. This inter satellite connection was a really high capacity data transfer link. In the earth observation systems, the large amount of data collected by observation equipment is transferred to an earth station through a repeater GEOS satellite.[1],[2]

The FSO connections currently used in space communication are near-Earth's, near space, and deep space communication links. Near - Earth's communication links are ground to-satellite / satellite-to-ground links, inter-satellite links and interorbital link. So these connections are very short distance links (max ~80.000km) as opposed to near space or deep space communication links.

The ITU defines Deep Space [3] as a distance that is larger than 2 million km. Moon - Earth and Sun-Earth communications are interpreted as near space communication. Comparing the near-earth and deep space communication, the extra path loss is minimum 60-70dB, this proportional the square of the link distance. In deep space transmission, the information rate is very low because of high - distance links. This is why relative large transmission power, and virtually error - free transmission is required.[4]

Due to the characteristics of long - distance or deep space communication channel, a powerful and high-security channel is essentially required. In case of near space communication, the channel requirements are high date rate, consequently high bandwidth, and also high security.

Currently operating OT space communication systems include, but are not limited to, OPALS (Optical PAyload for Lasercomm Science), LLCD (Lunar Laser Communications Demonstration), DSOC (Deep Space Optical Communications), LCRD (Laser Communications Relay Demonstration).

II. Advantages and Disadvantages of Free Space Optical Communication

Compared to optical and RF communication, the differences come from different wavelengths. The common wavelength for RF communication is between 30 mm to 3 m, compared to the optical 500 - 1600nm. Therefore, RF wavelength is thousands of times larger than the optical wavelength. Differences due to different wavelengths are as follows.

Advantages of optical communication

(I) High bandwidth: In RF and microwave communication systems, the allowable bandwidth is maximum 20% of the carrier frequency. In optical communication, if the bandwidth is 1% of the carrier frequency, the allowable bandwidth will be 100 THz. This makes the usable bandwidth at an optical frequency in the order of THz which is almost 10^5 times that of a typical RF carrier. This results in high -speed link without atmospheric phenomena, as turbulence and other problems.

(II) Small size and weight: The beam divergence is proportional to λ/D_R, where λ is the carrier wavelength and D_R the aperture diameter. The beam spread offered by the optical carrier is narrower than that of the RF carrier. This leads to an increase in the intensity of the signal at the receiver for a given transmitted power. Since, the optical wavelength is very small, a very high directivity and large antenna gain can be achieved.

(III) Free spectrum utilization: The optical system is free from spectrum licensing till now. This reduces set up and development cost.

(V) High Security: in FSO communication no detection is possible without a professional instrument as result the high directional laser beam with very narrow beam divergence. [4],[5]

Disadvantages of optical communication

Required tight ATP system: The most fundamental disadvantage is the requirement of very tight acquisition, tracking and pointing (ATP) system due to the narrow beam divergence.

Effect of turbulence: FSO communication is dependent on varying atmospheric conditions that can degrade fatally the system performance. Therefore, the negative impact of turbulence must be considered near the Earth's surface, e.g. attenuation of fog, cloud, rain, dust etc.[6]

Sun position: Another limiting factor is the position of the Sun relative to the laser transmitter and receiver. Solar background radiations can increase and that will lead to poor system efficiency.

The disadvantage of using optical transmission in space communications between the ground terminal and spacecraft.

Various factors cause absorption and scattering in FSO system, but the major contribution for atmospheric attenuation is due to fog. During dense fog conditions, when the visibility is even less than 50 m, attenuation can be more than 350 dB/km. Fog can extend vertically up to the height of 400 m above the Earth's surface, so the maximum attenuation due to for is maximum 140dB.

We should mention the powerful effects of the atmospheric turbulence.

Beam wandering which does not occur for downlink channels. However, for uplink at the satellite, it can be as large as several microradians. Beam wander can be mitigated by the use of multiple beams or a fast-tracking transmitter.

Pointing errors cause serious degradation in the communication channel reliability because of off-axis scintillation and increases/deteriorate the outage probability. For downlink aperture averaging will occur for sufficiently large receiver apertures, but for uplink at the satellite it does not occur this is why any receiver at the satellite always behaves like a point receiver.

Due to the presence of turbulence in the atmosphere, the laser beam wavefront arriving at the receiver will be distorted this effect is called angle-of-arrival fluctuation. This will lead to spot motion or image dancing at the focal plane of the receiver. For downlink the rms (root mean square) angle-of-arrival fluctuations are several microradians, and for uplink at the satellite is generally less than 1 mrad.

Beam spreading causes a dilution of the available power for an uplink channel. Beam scintillation leads to redistribution of signal energy resulting in temporal and spatial irradiance fluctuations of the received signal. This intensity fluctuation of the received signal is known as scintillation and is the major cause of degradation in the performance of the FSO system.

Last but not least, the background noise has to be mentioned. The main sources of background noise are: diffused extended background noise from the atmosphere, background noise from the Sun and other stellar (point) objects and scattered light collected by the receiver. The background noise can be controlled by limiting the receiver optical bandwidth. Single optical filter with very narrow bandwidth in the order of approx. 0.05 nm can be used to control the amount of background noise. Some of the design considerations while selecting narrowband optical filter are the angle of arrival of the signal, Doppler shifted line width of the laser and various temporal modes. [5],[7], [8],[13]

Spacecraft to spacecraft link

General, a theoretical analysis of the inter-satellite FSO link is performed for 1000 km distance at 2.5 Gbps in. Although, space FSO links are not subject to atmospheric and weather limitations, however, they are limited by other challenges like PAA (pointing-ahead-angle), doppler shift, acquisition and tracking, background radiations and satellite platform stability.

- Pointing-ahead-angle is relevant in deep space optical link. For deep space optical links, PAA is of the order of hundreds of micro-radians and for inter-satellite/ground-to-satellite links, its value is typically tens of micro-radian.
- Doppler shift: relevant in interorbital links, but not in deep space communication, because of small target motion.
- Background noise source of the sun, when strong background source near the receiver FOV can lead to significant scattering. Degradations caused by radiating celestial bodies other than the Sun are generally negligible except when receiving optics are directly pointing the Sun. The major source of background noise is due to scattering when an optical receiver design has its optics under direct exposure to sunlight. [12],[13]
-

III. Channel Characterization

Near - earth link

The Near-Earth regions are LEO, Medium Earth Orbit (MEO), GEO, and lunar links. About 1–2m diameter ground telescopes are needed to receive the high-rate downlink. Near-Earth links use a laser beacon as a reference for acquisition, tracking, and pointing. The distances and corresponding link delay are relatively short. Link acquisition results in spatial uncertainty. Spiral scans operations have been employed. Both direct and coherent detection links have been demonstrated in space-to-space links and space-to-ground links. Near-Earth links have supported high data rates (> 1 Gb/s) from space-to-ground and 5.6 Gb/s in space-to-space and ground-to-space links. Near-infrared wavelength lasers at discrete wavelengths around 800, 1064, and 1550 nm have been used.

Space-to-space link

In the case of Space-to-space links, there is no negative effect of the atmosphere and weather. Moreover, diffraction-limited single-mode laser beams can be exchanged so that phase coherent techniques (i.e.: heterodyne or homodyne) that deliver high link capacity, without vulnerability to additive background noise (pointing close to the Sun, for example), can be implemented. Indeed the LEO-to-LEO 5.6 Gb/s took advantage of this.

Deep space link

NASA's new deep space project will launch in 2020. It is known as for instance Psyche mission. Psyche is the giant metal asteroid with near circular orbit between Mars and Jupiter.

Goal of this mission is,

(1) to demonstrate at least a 10× enhanced data-return capacity relative to state of the art deep-space telecommunication systems with equivalent mass and power

(2) try to achieve 10 Mb/s from Saturn and 250 kb/s from Neptune by scaling Flight Transceiver to 40cm and 20W

(3) to enable streaming of high-definition video from deep-space and use of high data rate science devices. [9],[10],[11]

TABLE 1.

Mission / instrument	Target	Link	Data rate (Mbps)	Distance (AU)
LLCD (2013)	Moon	Uplink	20	2.7E-3
		Downlink	622	
OPAL (2014)	LEO	Up and Down link	20-100	1.33E-5
LCRD (2019)	GEO/Near earth space	Up and Down link	1200	2.68E-4
DSOC (2020)	Mars/Jupiter	Downlink	250	2E-1
		Downlink	250	5.5E-1
		Uplink	20	2E+0

Table 1. contains the maximum available channel characteristics at different systems and its range in astronomical units (AU). The value of outage probability (Pout) depends on the condition of the atmosphere. Basically, turbulence intensity can be affected the probability of fade. If the receiving unit is provided with tight ATP system and the beam is collimated then transmission channel parameter will be appropriate.[7],[14]-[19]

IV. Using the application of Multiple channels in Space communication

Using MIMO (multiple-input and multiple-output) systems the scintillation can be drastically improved with several multiple beams for uplink or downlink transmission, the scintillation can be reduced by a factor of square root of the antennas number of the ground terminal. Usage of MIMO system the channel capacity can increase with the number of transmitting antennas. In case of SIMO, these systems utilize the receiver diversity. Diversity gain is achieved by averaging over multiple signal paths. The signals can be combined at the receiver using selection combining (SC) or equal gain combining (EGC) or maximal ratio combining (MRC). Implementation of EGC is preferred over MRC due to its simplicity and suitable channel performance. For optical transmission from deep space, multiple receivers can be proposed for secure information transmission, since better channel parameters are available (Pout, BER). The negative effect of atmospheric turbulence can be reduced by installing receivers on high satellite orbit. Probably it would be a feasible signal reception from deep space by multiple simultaneous satellites receiver antennas. In case onboard signal regeneration is available on the satellites, the improved signal can be radiated toward the ground terminal. Unfortunately under special conditions in case of satellite - Earth connection the use of optical links may become very vulnerable. The effect of scintillation or attenuation, caused by the atmosphere degrades fatally the efficiency of the channel. That is why in certain cases an additional radio frequency link may be required by which negative effects of turbulence can be minimized. The biggest problem is that the maximum available bit rate of the RF or microwave link is much smaller than the original optical link. It would be a solution to transmit the optical signal by an inter-satellite-link to an orbital position where atmospheric conditions are appropriate for radiation the optical signal toward the ground terminal. These systems would be a multi-hop communication channel that eliminates the negative effect of atmosphere and ensures the high data-rate and high reliability, uninterrupted space link connection. [22]-[25]

References

[1] T. T. Nielsen and G. Oppenhauser, “In-orbit test result of an operational optical intersatellite link between ARTEMIS and SPOT4, SILEX,” Proc. SPIE, Free Space Laser Comm. Tech. XIV, vol. 4635, 2002.

[2] A. Katsuyoshi, “Overview of the optical inter-orbit communications engineering test satellite (OICETS) project,” J. Nat. Inst. of Info. and Comm. Tech., vol. 59, pp. 5–12, 2012.

[3]https://deepspace.jpl.nasa.gov/dsndocs/810-005/201/201B.pdf

[4] H. Hemmati, Deep Space Optical Communication. John Wiley & Sons, New York, 2006.

[5] H. Kaushal, G Kaddoum, “Optical communication in Space: Challenge and Mitigation Techniques”. IEEE Communication Surveys and Tutorial, 2017

[6] B. Flecker, M. Gebhart, E. Leitgeb, S. S. Muhammad, and C. Chlestil, “Results of attenuation measurements for optical wireless channels under dense fog conditions regarding different wavelengths,” Proc. SPIE, Atmospheric Opt. Model., Measure., and Simula. II, vol. 6303, 2006.

[7] L. C. Andrews and R. L. Phillips, “Laser Beam Propagation through Random Media.”SPIE Press, 2005.

[8] H. Kaushal, V. Kumar, A. Dutta, H. Aennam, H. Aennam, V. Jain, S. Kar, and J. Joseph, “Experimental study on beam wander under varying atmospheric turbulence conditions,” IEEE Photon. Tech. Lett., vol. 23, no. 22, pp. 1691–1693, 2011.

[9] H. Hemmati, A. Biswas, and I. B. Djordjevic, “Deep-space optical communications: Future perspectives and applications,” Proc. IEEE, vol. 99, no. 11, pp. 2020–2039, 2011.

[10] D.M. Boroson ; Chien-Chung Chen ; B. Edwards, "Overview of the Mars laser communications demonstration project" LEOS Summer Topical Meetings, 2005, INSPEC A. Num.: 8715041

[11] K. E. Wilson, “An overview of the GOLD experiment between the ETS-VI satellite and the table mountain facility,” TDA Progress Report 42-124, Comm. Sys. and Research Sec., pp. 9-19, 1996.

[12] G. Baister, K. Kudielka, T. Dreischer, and M. Tüchler, “Results from the DOLCE (deep space optical link communications experiment) project,” Proc. SPIE, Free Space Laser Comm. Tech. XXI, vol. 7199, 2009.

[13] Hemani KaushalVk JainVk JainSubrat KarSubrat Kar, "Ground-to-Satellite Optical Communication Link Performance with Spatial Diversity in Weak Atmospheric Turbulence," Fiber and Integrated Optics, ISSN: 0146-8030 print/1096-4681

[14] D. M. Boroson, A. Biswas, and B. L. Edward, “MLCD: Overview of NASA’s Mars laser communications demonstration system,” Proc. SPIE, Free Space Laser Comm. Tech. XVI, vol. 5338, 2004.

[15] A. Biswas, D. Boroson, and B. Edwards, “Mars laser communication demonstration: What it would have been,” Proc. SPIE, Free Space Laser Comm. Tech. XVIII, vol. 6105, 2006.

[16] https://www.nasa.gov/sites/default/files/atoms/files/fs_dsoc_factsheet_150910.pdf

[17]https://www.nasa.gov/sites/default/files/atoms/files/tglavich_dsoc.pdf

[18] Abhijit Biswas,* Hamid Hemmati, et al., "Deep-space Optical Terminals (DOT) Systems Engineering," IPN Progress Report 42-183, Nov 15, 2010 - https://ipnpr.jpl.nasa.gov/progress_report/42-183/183A.pdf

[19] Donald Cornwell, "Space-Based Laser Communications Break Threshold," Optics and Photonics News 27(5):24 DOI10.1364/OPN.27.5.000024

[20] D. M. Boroson, A. Biswas, and B. L. Edward, “MLCD: Overview of NASA’s Mars laser communications demonstration system,” Proc. SPIE, Free Space Laser Comm. Tech. XVI, vol. 5338, 2004.

[21] A. Biswas, D. Boroson, and B. Edwards, “Mars laser communication demonstration: What it would have been,” Proc. SPIE, Free Space Laser Comm. Tech. XVIII, vol. 6105, 2006.

[22] A. J. Hashmi, A. A. Eftekhar, A. Adibi, and F. Amoozegar, “Analysis of adaptive optics-based telescope arrays in a deep-space inter-planetary optical communications link between Earth and Mars,” Optics Comm. (Elsevier), vol. 333, pp. 120–128, 2014.

[23] V. Weerackody ; A. R. Hammons ; D. J. Tebben, " Multi-Input Multi-Output Free Space Optical Satellite Communication Links," Information Sciences and Systems, 2007. CISS '07. 41st Annual Conference

[24] W. J. Hurd, B. E. MacNeal, G. G. Ortiz, and R. V. Moe et al., “Exo-atmospheric telescopes for deep space optical communications,” in Proc. IEEE Aerosp. Conf., (Big Sky, MT), 2006.

[25] R. J. Cesarone, D. Abraham, S. Shambayati, and J. Rush, “Deep-space optical communications visions, trends, and prospects,” in Proc IEEE Int. Conf. on Space Opt. Sys., (Santa Monica, CA, U S.), 2011.

Comparing Calculated and Measured Losses in QuESS's Quantum Channel

Máté Galambos
Dennis Gabor College
Budapest, Hungary

László Bacsárdi
Department of Networked Systems and Services
Budapest University of Technology and Economics
Budapest, Hungary

***Abstract*—Long distance distribution of quantum states is necessary for quantum communication and large scale quantum experiments. Currently this distance is limited by channel loss. Previous theoretical analysis [1] and proof of concept experiments [2] showed that satellite quantum communication may have lower losses than optical cable based counterparts. Recently the QuESS experiment [3] realized the first satellite-Earth quantum channel. In this paper we compare theoretical predictions of different mathematical models with experimental results regarding channel loss. We examine the HV-5/7 model, HV-Night model and Greenwood model of optical turbulences, the geometric [4] and diffraction [5][6] models of beam wander and beam widening. Furthermore we take into account the effect of atmospheric gases and aerosols as well as the effect of pointing error. We find that theoretical predictions are largely in the same order of magnitude as experimental results. The exception is the diffraction model of beam spreading where our calculations yielded only one tenth of the measured value. Given the ever changing nature of weather conditions and the changing composition of atmospheric aerosols we conclude that calculated and measured losses are in good agreement.**

Keywords—satellite; quantum communication; channel loss; downink;

I. Introduction

Quantum cryptography, quantum teleportation and proposed large scale experiments (such as experiments testing theories about quantum gravity [7][8]) require long distance distribution of quantum bits. These qubits are realized using photons and the distance at which they can be transmitted is limited by optical channel loss – either the loss of an optical cable or losses in free space.

The QuESS (Quantum Experiment at Space Scale) experiment realized the first satellite-Earth quantum channel. The satellite produced entangled photon pars and transmitted them to two ground stations at Lijiang and Delingha China via two downlinks.

In this paper we compare theoretical predictions for channel loss with measured values. This is necessary because theoretical predictions of quantum communication are based on mathematical models describing classical light beams. This approach requires the assumption that properties of the atmosphere are either completely or at the very least largely independent of light intensity and that individual photons behave in a way that is consistent with an infinitesimal part of a classical light beam.

The research was supported by the Hungarian Scientific Research Fund – OTKA PD-112529. The research is connected to COST Action CA15220 Quantum Technologies in Space.

II. Sources of Loss in Satellite-Eatrh Quantum Channels

Free space losses can be induced by multiple causes. In the following section we detail the sources of loss that we have taken into account in our calculations.

A. Pointing Error

Errors in targeting may result in the photon missing the detector and thus contribute to the free space channel loss. In our calculations we used the reported value of the targeting error measured in the QuESS experiment and assumed the reported Gaussian profile of the targeting error.

In the QuESS experiment the detector mirror of the telescope was a Cassegrain reflector [3]. We approximated this in our calculation by assuming that the cross section of the detector is a perfect circle with radius equal to the radius of the primary mirror and disregarded the blind spot created by the secondary mirror.

B. Beam Spreding and Beam Wander

Since the refraction of air is temperature dependent fluctuations of air temperature can deflect and distort light signals. The strength of this effect depends on atmospheric conditions: the optical turbulence strength depends on wind speed, altitude and several other factors such as geographical features. Furthermore diffraction causes a beam to spread even in the vacuum of space.

C. Atmospheric Attenuation

Atmospheric gases and aerosols (solid particles of dust and liquid droplets) absorb and scatter light thus contributing to the channel loss. In our calculations we took a semi-empirical approach. Instead of relying on purely theoretical calculations of molecular extinction we used experimentally measured values [9] of atmospheric transmittance.

This method is not only simple and easy to use it gives us a more realistic picture of the aerosol profile as function of altitude than theoretical models. Since aerosol extinction is typically stronger than molecular extinction [9], we can expect a realistic result even with relatively inaccurate data about molecular extinction.

However in these experiments determining the extinction the wavelength was slightly different than in the QuESS experiment. Since molecular extinction is mostly independent of wavelength (this statement is supported by both experimental data [10] and the theory of Mie-scattering 10]) we approximated molecular extinctions by linear interpolation of measured values. In case of molecular extinction we used the closest available analog which was a measurement performed using GaAs laser.

D. Efficienny of the Detector and the Optical Setup

Losses of the optical setup (due to imperfect detector efficiency, noise and inefficiencies in the photon generation process) are reported in the article detailing the QuESS experiment. We have taken these efficiencies into account in our calculations.

III. Channel Lengths and Elevation Angles in the QuESS Experiment

An important factor in determining the channel loss is the relative position of the ground station and the satellite. The elevation angle as seen from the ground station determines the effective thickness of the atmosphere whereas the distance to the satellite determines the channel length. Therefore both of these parameters are required to estimate the channel loss.

The article describing the results of the QuESS experiment [3] focuses on two geometric arrangements. One is the moment when the communication is established and losses are the highest, and the other is when the overall two-channel length is the shortest and the channel loss is the lowest. In both cases the authors disclose either the channel length or the elevation angle but not both. However one can be calculated from the other.

We used the satellite ground station Earth center triangle to calculate the missing parameters. According to our calculations when communication was established the satellite-Lijiang distance was 1700 km and the elevation angle at Lijiang station was 10° while the satellite-Delingha channel length was 700 km and the elevation angle at Delingha was 43°. The combined two channel length was the shortest when the satellite was 800-800 km from both Lijiang and Delingha stations and could be seen at 36° elevation angle from both ground stations.

IV. Optical Trublulence

In order to model beam spreading and beam wander in the atmosphere we must know the atmospheric turbulence strength parameter (C_n^2). There are several different turbulence profile models to choose from – these are typically curves fitted onto measured data. Since free space quantum communication is carried out during the night (when the background noise is the lowest) we focused on models applicable to nighttime conditions. In our calculations we used three specific models. These are:

- Hufnagel-Valey 5/7 (or HV 5/7) model [11]
- HV-Night model [11]
- Greenwood model [11].

V. Geometric Beam Spreading Model

In this section we compare the calculated beam spreading with the measured values. The far field beam divergence has been reported to be 10 μrad.

To calculate the beam wander we used the geometric approximation [4]. This treats optical turbulence as converging or diverging lenses.

A. HV 5/7 Model

Calculating with the HV 5/7 model the radial beam divergence comes out to be between 3.11 μrad and 3.39 μrad depending on which transmitting telescope of the QuESS satellite was used.

The lower value of the calculated beam spreading angle corresponds to the larger telescope (0.3 m diameter) and the higher beam spreading angle corresponds to the smaller telescope (0.18 m diameter).

However the dependence of beam spreading angle on channel length seems to be negligible (our calculations yielded approximately the same result for each downlink). The most likely explanation for this independence is that beam spreading is comparably small in vacuum. This means that the spot size at the detectors plane is mostly determined by the part of the optical path that is in the atmosphere.

This path length in the atmosphere is a function of the elevation angle. However a lower elevation angle corresponds to a longer link distance if the altitude of the satellite is fixed. The increase of the spot size seems to be almost perfectly cancelled out by the increase of the channel length and therefore the decrease of the angle corresponding to a given spot size.

Comparing the calculated and reported values we can conclude that these values are small – being roughly one third of the reported 10 μrad radial beam divergence.

B. HV Night Model

Using the HV Night model we obtain radial beam divergence angles between 1.07 μrad and 1.17 μrad.

The outcome of the calculation is similar to the previous model: the result is largely unaffected by channel length but depends on transmitter telescope diameter (the smaller beam spreading angle corresponding to the larger telescope).

Comparing measured and calculated values we conclude that the HV night model gives us results that are a magnitude smaller than the reported 10 μrad radial beam divergence.

C. Greenwood Model

Using the Greenwood model we get radial beam divergence angles between 17.84 μrad and 19.43 μrad.

The characteristic is similar to the previous models: the result is largely independent from channel length but depends on transmitter telescope diameter (the smaller beam spreading angle corresponding to the larger telescope).

Comparing the calculated and measured values we conclude that the Greenwood model yields values roughly twice the reported 10 μrad radial beam divergence.

D. Comparing the Different Models

Comparing the measured beam spreading with the calculated values we can conclude that none of the optical turbulence models yields exactly the measured result. However the values obtained from the different models seem to form a range and the experimental value falls within that range.

The experimental value seems to be roughly halfway between values obtained using the Greenwood and HV 5/7 models. Whether that would be the case for future experiments warrants further investigation, however it seems likely that the experimental values in the future will fall somewhere within this calculated range.

In conclusion we suggest performing the calculation using several different optical turbulence profiles for assessing viability or performance of future experiments.

VI. Diffraction Beam Spreading Model

Another alternative to calculating the geometric beam wander model is a diffraction based model [5][6]. In this section we present the results of our calculations using this approximation.

Since the elevation angle in the QuESS experiment was fairly low, we used Fante's approach to calculating the coherence length [5][6].

According to our calculation the beam spreading should be between 0.86-0.87 μrad. This is less than one tenth of the reported 10 μrad.

This result holds regardless of the model used for calculating the optical turbulence strength. The reason for the discrepancy between the measured and calculated value is currently unknown and warrants further investigation.

VII. Channel Loss

Using the value of beam spreading measured in the QuESS experiment we can validate our method of calculating the channel loss. In this section we examine channel loss when the combined two channel length is the longest (maximal loss) and shortest (minimal loss).

The results presented in this section are calculated assuming 50% overall optical efficiencies for the telescopes while the actual value was reported to be somewhere between 45-55%.

A. Maximal Loss

When the communication was established with the satellite the measured two channel loss in the QuESS experiment was reported to be 82 dB.

According to our calculations the loss due to pointing error, beam wander and beam spreading in the satellite-Lijiang channel was 28.54 dB while in the satellite-Delingha channel it was 24.36 dB. The combined two channel loss due to beam spreading and pointing error was 52.9 dB.

According to our calculations the channel loss due to molecular and aerosol extinction had to be between 4.85 dB and 14.72 dB in the satellite-Lijiang channel (depending on weather conditions). In the satellite-Delingha channel the loss had to be between 2.05 dB and 7.68 dB.

Taking into account all factors (including optical and detector inefficiencies) the total combined two channel loss had to be between 68.92 dB (assuming clear weather) and 84.43 dB (assuming hazy weather). These calculated values are in good agreement with the reported 82 dB loss.

B. Minimal Loss

Losses were the lowest when the satellite was closest to the two ground stations. The measured two channel loss in this position is reported to be between 64 dB and 68.5 dB.

According to our calculations the loss due to pointing error, beam spreading and beam widening had to be 22 dB in the satellite-Lijiang channel and 25.52 dB in the satellite-Delingha channel. The combined two channel loss comes out to be 47.53 dB.

According to our calculations the channel loss due to molecular and aerosol extinction had to be between 2.38 dB (assuming clear weather) and 8.91 dB (assuming hazy weather) in both channels.

Taking into account all errors, losses and inefficiencies the combined total two channel loss had to be between 61.41 dB and 74.47 dB. These calculated values are in the same order of magnitude as the measured 64 to 68.5 dB reported in the literature.

VIII. Conclusions

In this paper we compared the measured beam spreading and channel loss of the QuESS satellite experiment with calculated values.

We found that the geometrical optic approximation [4] yields results in the same order of magnitude as the reported value of beam divergence. The exact result depends on the model of optical turbulence strength being used. In our calculations we examined the HV 5/7 [11], HV Night [11] and Greenwood [11] models of optical turbulence and found that the reported value of beam divergence falls within the range of the values calculated using these approximations.

We also examined the diffraction model [5][6] of beam spreading. Our calculations yielded results that are a magnitude smaller than that of the reported values. This relationship holds for all models of optical turbulence strength. The reason for this discrepancy is currently unknown and warrants further investigation.

References

[1] J.P. Bourgoin, et al., “A comprehensive design and performance analysis of low Earth orbit satellite quantum communication.”, New Journal of Physics, 15(2), p.023006, 2013.

[2] A. Zeilinger, “Long-distance quantum cryptography with entangled photons.”, Quantum Communications Realized, vol. 6780, p. 67800B. International Society for Optics and Photonics, 2007.

[3] J. Yin, et al., “Satellite-based entanglement distribution over 1200 kilometers.”, Science, 356(6343), pp.1140-1144. 2017.

[4] J.H. Churnside, and R. J. Lataitis, “Wander of an optical beam in the turbulent atmosphere.”, Applied Optics, 29(7), pp. 926-930, 1990.

[5] H.T. Yura, “Atmospheric turbulence induced laser beam spread.”, Applied optics, 10(12), pp.2771-2773, 1971.

[6] R.L. Fante, “Electromagnetic beam propagation in turbulent media: an update.”, Proceedings of the IEEE, 68(11), pp.1424-1443. 1980.

[7] S.K. Joshi, et al., “Space QUEST mission proposal: experimentally testing decoherence due to gravity.”, arXiv preprint arXiv:1703.08036. 2017.

[8] D. Rideout, et al., Fundamental quantum optics experiments conceivable with satellites—reaching relativistic distances and velocities. Classical and Quantum Gravity, 29(22), p.224011, 2012.

[9] R.A. McClatchey, R.W. Fenn, J.A. Selby, F.E. Volz, and J.S. Garing, “Optical properties of the atmosphere” (No. AFCRL-72-0497). AIR FORCE CAMBRIDGE RESEARCH LABS HANSCOM AFB MA. 1972.

[10] M. Bass, “Handbook of Optics. 2.”, New York : McGraw Hill Professional, ISBN: 978-0-07-163314-7. 2010.

[11] A.K. Majumdar, J.C. Ricklin, “Free-Space Laser Communications Principles and Advances." New York : Springer, ISBN 978-0-387-28652-5. 2008.