

Working Group 4, Milestone M4.1

Long Range Links – Channel Modelling and Transmission Schemes for UV and airborne IR Links



Introduction

The working group 4 (WG4) deals with long-range links mainly focussing on airborne and satellite FSO links. Reporting on channel modelling and transceiver design for UV and airborne IR Links, various STSM reports and internal documents summarizing collaborative work within the working group members have been presented fulfilling the Milestone 4.1. List of input documents and STSMs are below.

Technical details on the activities are detailed in Deliverables 4.1.

Input Documents

The activities for WG4 targeting “Field trial implementation and evaluations” has been presented in terms of various input documents during working group meeting and discussed. Some of the topics that were covered are below.

1. “Error control capability of NB-IoT MCS over satellite links with optical feeder links”, Alexis Dowhuszko, Department of Communications and Networking, Aalto University, Finland.
2. “Airborne and space laser communication ground terminal”, Andris Treijs, HEE Photonic Labs.
3. “Modelling near-Earth FSO channels and atmospheric seeing affected by turbulence and clouds”, Hristo Ivanov, University of Graz.
4. “Resource allocation in a Quantum Key Distribution Network with LEO and GEO trusted-repeaters,” in Proc. Int. Workshop Optical Wireless Comm., pp. 1-6, Sept. 2021, M. Grillo, A. Dowhuszko, M.-A. Khalighi and J. Hämäläinen.
5. “End-to-end error control coding capability of NB-IoT transmissions in a GEO satellite system with time-packed optical feeder link”, Joan Bas and Alexis Dowhuszko.
6. “Modelling near-Earth/deep-space FSO channels and atmospheric seeing affected by turbulence and clouds”, Hristo Ivanov, Erich Leitgeb, Frank Marzano, Pasha Bekhrad.
7. “Optical Wireless Channel Models for High Throughput Satellite Communication Systems”, Dowhuszko Alexis.
8. “Testbed Emulator of Satellite-to-Ground FSO Downlink Affected by Atmospheric Seeing Including Scintillations and Clouds”, Hristov Ivanov.
9. " On Hybrid Optical-Radio Communication Systems for 6G NonTerrestrial Networks", Marc Amay, Joan Bas (CTTC).
10. “Influence of EDFA on the satellite QKD channel Research” – STSM, Ali Khalighi (ECM).
11. “Background optical radiation measurement in Hungary”, Gerhátné Udvary Eszter (TU Budapest).
12. “Adaptive approaches to reduce long-range FSO channel distortions”, Niek Doelman (TNO).

Publications

Some publications related to WG4 Milestone 4.1 are listed below:

- [1] H. Ivanov, F. Marzano, E. Leitgeb, P. Bekhrad, “Testbed Emulator of Satellite-to-Ground FSO Downlink Affected by Atmospheric Seeing Including Scintillations and Clouds,” *Electronics*, vo. 11(7), 2022. <https://doi.org/10.3390/electronics11071102>

- [2] J. Bas and A. Dowhuszko, "On the use of NB-IoT over GEO satellite systems with time-packed optical feeder links for over-the-air firmware/software updates of machine-type terminals," *Sensors*, vol. 21, no. 12, p. 3952, June 2021. Doi: 10.3390/s21123952
- [3] J. Bas and A. Dowhuszko, "End-to-end performance of an uplink NB-IoT transmission relayed on a low-altitude UAV platform with non-orthogonal single-carrier FDMA in the optical wireless backhaul link," *Special Issue on Mobile Networks*, Springer, pp. 1-22, June 2022.
- [4] M. Grillo, A. Dowhuszko, M.-A. Khalighi and J. Hämäläinen, "Resource allocation in a quantum key distribution network with LEO and GEO trusted-repeaters," in *Proc. International Symposium on Wireless Communication Systems*, Belin, Germany, pp. 1-6, September 2021. Doi: 10.1109/ISWCS49558.2021.9562139. (T4.2, T4.3)
- [5] Hristo Ivanov, Erich Leitgeb, "Artificial Generation of Mie Scattering Conditions for FSO Fog Chambers," in *Proc. 13th International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP)*, Porto, Portugal, 2022.
- [6] A. Vavoulas, H. G. Sandalidis, N. D. Chatzidiamantis, Z. Xu and G. K. Karagiannidis, "A Survey on Ultraviolet C-Band (UV-C) Communications," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 3, pp. 2111-2133, thirdquarter 2019, doi: 10.1109/COMST.2019.2898946.
- [7] M. Amay, J. Bas, "On Hybrid Free Space Optic Radio Systems as Enablers of 6G services", In *Proc. Of ICASSP Conference 2023*

Training School

In addition, training school was organized in August 2022 in University of Prague covering the topics on WG3 and WG4. For WG4 following lectures/presentations were provided to educate but also to advertise what fields and topics are currently being investigated in research industries.

1. Free space Optical Communication activities in German Aerospace Center (DLR), Oberpfaffenhofen, Amita Shrestha (DLR)
2. Seminar on Optical Communication for Space, Dr. Dirk Giggenbach (DLR)
3. Embedded Systems Development within the framework of new Space, Dr. Julio Ramirez (DLR)

Short Term Scientific Mission

Moreover, several Short-term scientific missions were also done to maximize the collaborative work between different WG members.

1. "Modelling near-Earth FSO channels and atmospheric seeing affected by turbulence and clouds ", Hristov Ivanov (TU Graz) and Sapienza Universita di Roma. 2nd October -15th October 2021.
2. "Influence of EDFA on the satellite QKD channel Research, Ali Khalighi (ECM) and DLR. August 2022
3. "Development of High-Performance Adaptive Optics Control Algorithms for Free Space Optical Communication ", Joana Torres (DLR) and Instit d'Optique, April 2023 (planned)
4. "Influence of ASE noise from EDFAs on a free space QKD channel", Carlos Guerra Yanez (University of Prague), and DLR. June 2023 (planned)
5. "Emulation and Definition of Continuous Variable QKD systems ", Marc Amay CTU, April-May 2023.



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White Paper Contribution



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Following contribution were done from WG4 to the second white paper:

1. Giulio Cossu, Veronica Spirito, Michail P. Ninos, Ernesto Ciaramella, “Wavelength Division Multiplexing Free Space Optical Links”.
2. Joan Bas, Marc Amay, “Review of Hybrid Optical-Radio Inter-Satellite Links in 6G NTN Including Quantum Security”.
3. Davide Orsucci, Florian Moll, Amita Shrestha, “Review of low-Earth orbit satellite quantum key distribution”.
4. Davide Orsucci, Florian Moll, Amita Shrestha, “Perspectives for global-scale quantum key distribution via uplink to geostationary satellites”.