IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM (B2)
Interactive Presentations - IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM (IP)

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MODELLING AND PERFORMANCE EVALUATION OF SATELLITE LINKS FOR QUANTUM KEY DISTRIBUTION NETWORKS

Abstract

Security is a major concern of digital society, and quantum key distribution (QKD) can contribute with an unconditional secure mechanism for symmetric key distribution. Satellites can overcome the range limit of quantum communications based on fiber networks, so it is expected that quantum enabled satellite links would be an integral part of future quantum communication networks.

This paper presents a modelling and performance evaluation of a satellite based QKD system based on the BB84 protocol with decoy states. The three type of links required to build satellite networks are covered: donwlink (DL) and uplink (UL), for satellite with ground communication, and inter-stellite link (ISL) for satellite to satellite communication. Evaluation of key generation capacity is done at mentioned link levels, considering an scenario of a low Earth orbit (LEO) satellite network. Estimation of secret key length is done per visibility interval and considering finite key statistics, with sample data obtained using orbital propagation; this allows to consider the short times and variability of visibility intervals typical of LEO orbits.

First, the link transmissivity models for UL, DL and ISL are described and analysed. They take into account diffraction losses, atmospheric turbulence and absorption. Next, special attention is given to corrective mechanisms (such as adaptive optics, AO) and losses due to pointing accuracy, the first severely affecting UL, and the second specially relevant for ISL with two satellites contributing to pointing error loss. Lastly, using these analyses we will further evaluate the operation and performance of specific satellite QKD systems in terms of transmissivity, secret key length (SKL) and quantum bit error rate (QBER).

To this end, we will employ the BB84 protocol with two-decoy states implementation and simulate different scenarios, propagating satellite orbits for UL, DL and ISL, and computing the SKL with finite effects. The SKL is optimized as a function of system parameters, as pulse intensity or time window duration, and SKL and QBER statistics are extracted for the different passes as well as one-year averages. The presented results shows the impact of the three different satellite links on key generation, the relevance of compensation techniques and quantify the impact of pointing accuracy. These results may guide in the design and evaluation of future deployments of QKD networks satellite based.