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Feasability study of satellite quantum key distribution with continuous variables

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Abstract

Nowadays, link distance is the main limitation for practical performances of Quantum Key Distribution (QKD) in order to secure the communication between two nodes of a classical or quantum network. In this work, we calculate the probability distribution of a satellite-to-ground QKD based in continuous variables to simulate different satellite passages with realistic experimental parameters. In this way we calculate the key rates for different satellite altitudes and propose the use of the classical beacon for improving the performance in the case of LEO (Low-Earth-Orbit) satellites.

Achievable distance remains one of the main limitations in quantum key distribution (QKD) systems. Satellite communications is one of the most promising technology for establishing a quantum network where the nodes are secure by QKD at a global scale. A decoy-state Discrete-Variable (DV) QKD protocol link of 1200 km has been recently achieved using a low Earth orbit (LEO) satellite [1] proving the feasibility of this approach, but many challenges remain to be solved before QKD over satellite becomes a commercial reality.

Continuous-variable QKD is an alternative to DV-QKD that uses the quantum quadratures of the electromagnetic field to encode the information. One of the reasons why CVQKD is nowadays a very interesting candidate is that most of the components are available off-the-shelf from telecom industry. Additionally, its measurement technique (homodyne or heterodyne detection), acts as a natural filter to undesired components. Although CV-QKD is a mature technology which has been successfully implemented in fiber [2] and in real scenarios [3], satellite communications present new scientific and technological challenges.

The main difference with respect to the fiber case is the attenuation in the channel. In practical scenarios the attenuation will typically exceed 20 dB, but the quadratic increase of the attenuation in vacuum allows communication over higher distances. Another special characteristic of mobile free-space communications is the inevitable variation of the attenuation with time that will be a function of the slant distance between the transmitter and the receiver. Also, as the optics have to be aligned during the communication, the fluctuations due to pointing will introduce a fading effect in the received signal.

In our work we propose a feasibility analysis of CV-QKD considering a satellite-to-ground communication for different satellite perigees using an auxiliary classical beacon to recover the local oscillator phase and estimate the transmittance. For each satellite passage we calculate probability distribution of the transmittance, computing the fading effects considering realistic experimental parameters for the optics and the pointing systems.

We propose a method to measure the fading excess noise in the generated secret key. We show that without further processing no key could be achieved. To solve this problem we classify the received quantum symbols into sets (bins) in function of the transmittance of their corresponding classical beacons. We recalculate the expected excess noise after applying this binning and we show that we can overcome the fading and generate secret key over a passage. As we ascend to MEO orbits we show that the effect of fading is reduced and the limiting factor is the excess noise introduced in the local oscillator recovery. The whole analysis assumes realistic technological parameters and we consider it a useful tool to dimension a CV-QKD satellite-to-ground link.

[1] Liao et al. *Satellite-to-ground quantum key distribution*, Nature **549**, pp. 43-47 (2017).

[2] Jouguet et al. *Experimental demonstration of long-distance continuous-variable quantum key distribution*, Nature Photonics **7**, pp. 378-381 (2013).

[3] Yi-Chen Zhang et al. *Continuous-variable QKD over 50km commercial fiber*, (2017) [https://arxiv.org/abs/1709.04618].