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Author: Mr. Mohammad Iranmanesh
RAL Space, United Kingdom, mohammad.iranmanesh@stfc.ac.uk

Dr. Mamatha Maheshwarappa
RAL Space, United Kingdom, mamatha.maheshwarappa@stfc.ac.uk
Dr. David Pearson
RAL Space, United Kingdom, david.pearson@stfc.ac.uk
Dr. Nikolitsa Papachristou
RAL Space, United Kingdom, nikolitsa.papachristou@stfc.ac.uk

SYSTEM DESIGN TRADE OFF FOR A QUANTUM CHANNEL BETWEEN A LEO CUBESAT AND OPTICAL GROUND STATION

Abstract

Satellite-based Quantum Key Distribution (QKD) is a fundamental enabler of next generation communications networks. By ensuring the secure distribution of cryptographic keys over globe-spanning distances, this technology enables a step increase in the capability to secure communications. Despite rapid progress in quantum key distribution research, the range of QKD methods are limited because of quantum states' sensitivity to system noise and transmission loss. As such, free space methods of transmission are preferred. Combined with the requirement to share keys across the globe for commercial applications, space-based links are therefore very attractive to extend the range of QKD.

In-Orbit demonstration missions have proven the feasibility, at great expense, of creating a quantum channel between a payload in space and a ground station. However, a QKD solution can only be commercially viable if the space segment can be realised by affordable CubeSats as the transmitter node. This would require both the Low Earth Orbit (LEO) CubeSat and the ground station to meet challenging orientation and stability maintenance requirements in order to ensure the necessary end-to-end photon transmission performance. While many off-the-shelf solutions exist for CubeSat Ground stations in VHF, UHF and S-Bands, there are no turnkey optical ground station solutions that meet the challenging requirements for quantum channels with satellites in (LEO).

A demonstration programme with a single CubeSat and one ground station is in progress between STFC RAL Space and University of Singapore. This paper reports the trade-off study between the pointing specifications of the ground station and the CubeSat platform. From a design point of view, the challenge is to optimise the system so that the requirements are balanced between the Space and Ground segments and that the overall combined cost is minimised, whilst respecting the power and mass budgets of the space segment.

A concurrent design study (using STFC RAL Space's CDF facility) was undertaken for this assessment. AGI STK was additionally used for orbital analysis and assessment of the required pointing stability and rotation rates. A solution using a combination of coarse and fine pointing systems is proposed for the space segment, whilst keeping costs down for the ground segment, which allows for multiple ground segments to maximize availability for a demonstration mission. The paper also sets requirements for accurate pointing and reliable optical communications.