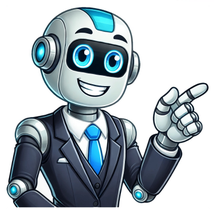
I'm not a robot



The signals transmitted from SOTA suffer from big losses and most of the transmitted photons are lost before reaching the receiver because of the divergence of the laser beam and the limited aperture of the telescope to gather the photons. Additionally, many photons are scattered and absorbed in the atmosphere. As a result, the signal arriving at the OGS is extremely weak, carrying an average of less than 0.1 photons per pulse. Since such weak signals cannot be detected by using conventional photodetectors, the quantum receiver used extremely-sensitive detectors, known as photon counters since they can detect single photons. This enables a much-higher efficient communication than conventional satellite optical communication. Also, by using signals with less than one photon per pulse, quantum cryptography allows to detect the presence of an eavesdropper, which makes it possible to deliver secret keys in a confidential way. In order to realize quantum communication and quantum cryptography with such a weak signal, a key step is to accurately time-stamp the signals, so that they are clearly recognized in the quantum receiver. Therefore, it is necessary to accurately synchronize the signals between SOCRATES and the OGS to detect the transmitted bits without errors. It is also necessary to carry out a polarization-axis matching, because the reference frames change, due to the relative motion between the satellite and the ground station. Only Japan and China have been able to demonstrate these technologies in space, but China did it by using a 600-kg-class satellite, while Japan did it by using a 50-kg-class satellite. Since the satellite moves at a fast speed relative to the OGS (about 7 km/s), the wavelength of the laser signal shifts due to the Doppler effect to a shorter wavelength when approaching the OGS, and to a longer wavelength when moving away from the OGS. Because of this Doppler effect, it is necessary to carry out an accurate time synchronization to be able to correctly detect the long sequences of bits without errors. In the China quantum-communication experiment, this synchronization was realized by using a dedicated laser transmitting a synchronization signal. By contrast, NICT was able to carry out this synchronization by using the quantum signal itself. A special synchronization sequence of about 32,000-bits was used in the quantum-communication signal for this purpose, and the quantum receiver was able to perform not only the quantum communication, but also the synchronization and the polarization-axis matching directly, by using only the weak quantum signal. In this experiment, NICT succeeded in demonstrating for the first time that quantum-communication technology can be implemented in small satellites. Fig. 4 shows the SOCRATES orbit, as well as the Doppler-shift calculation and measurement of the experiment conducted on August 5, 2016. As shown in Fig. 4a, SOCRATES flew over the Pacific Ocean from the south to the north and reached the closest distance of 744 km to the NICT optical ground station at 22:59:41 Japan time. A communication link was established for 2 minutes and 15 seconds around that time. Fig. 4b shows the theoretical value of the Doppler shift predicted from the SOCRATES orbit information, and Fig. 4c shows the experimental value. The observed value of the Doppler shift showed a good agreement with the theory, and the change of frequency due to the Doppler shift could be accurately corrected. Based on this frequency correction, the time synchronization between the satellite and the ground station was established while accurately correcting the change of the time interval of photons coming from SOCRATES every second. NICT: : QIQB: QunaSysQunaSysCEO: NICT NICT NICT2020NICT 1 NICT NICTNICTQKD1 QKDNICTQKDQKD 2 QKD NICT NICT: : QIQB: QunaSys: SIP: QST

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