# Demonstration of satellite-to-ground optical communication links using SOTA

Space Communications Laboratory, Wireless Networks Research Center
National Institute of Information and Communications Technology

Hideki Takenaka

## Overview

At the National Institute of Information and Communications Technology (NICT), we are promoting research for the realization of optical communications in space. We were aiming to demonstrate results of basic research and of device technology in communications technology and to realize communications with 1.5 micron band between low earth orbit satellites and the ground for the first time in the world. We had developed an ultra-small optical communication transponder (Small Optical TrAnsponder: SOTA) having a small size and low power consumption (mass of SOTA and control unit: 5.9 kg, power consumption: 15 W), as shown in Fig. 1. This device was launched in May 2014 mounted on a 50 kg class of ultra-small satellite. Experiments performed after the launch showed that we succeeded in a transmission experiment using self-implemented error correction functions.

Figure 1: Small optical transponder (SOTA)

## Background and Objectives

In recent years, with increased capacity of transmitted information and improved performance of observation satellites, there is a growing need for increased satellite communications capacity. Many have focused on space wave communication technology, which will not be restricted by the shortage of frequency resources in the future.

We began developing a SOTA to be mounted on a 50 kg class ultra-small satellite around 2009, and in May 2014, it was launched as a piggyback to satellite ALOS2. We have continuously been conducting a variety of experiments since its launch.

Passing through the atmosphere during satellite to ground optical communications, atmospheric fluctuations have led to data transmission errors. Therefore, the main mission in our SOTA experiments is to gather and analyze basic data on how errors are caused by air fluctuations while using 1.5 μm band lasers. This work forms the foundation towards future optical communications in space at several gigabit per second.

Previous space optical communication missions utilized lasers with wavelengths in the 0.8 μm and 1 μm bands. If we could apply laser communication technology in the 1.5 μm band, which is already being used in communications with the ground optical fiber network and apply this technology to practical use in space optical communication, we expect that ultra-high-speed and large capacity space communications may be possible to realize at a low cost.

## Satellite - Ground Optical Communication Experiments

Low-orbit satellites move very fast at a speed of 7 km/s when viewed from the ground, unlike geostationary satellites. Therefore, high accuracy in mutual acquisition and tracking is required. In addition, for communication with the ground, it is necessary to overcome the effects of atmospheric turbulence that cannot be predicted. For these reasons, optical communication between low-orbit satellites and the ground has many high degree advanced technical problems when compared to communication between geosynchronous orbit satellites and ground. To perform satellite–ground optical communications, first we need to tell the location of the ground station to the satellite. Both the ground station and the satellite use orbit and GPS information to predict the position of the other party. Even with our advanced technology, errors will occur. Because of these errors, when conducting laser communications with a small spread angle, one is not able to communicate with the other party immediately. Therefore, satellite to ground optical communication using SOTA uses a satellite acquisition method using a beacon light. Fig. 2 shows how the ground station captures the position of the satellite. First a laser light with wide spread angle is irradiated from the ground station towards the satellite. Once the satellite detects this beacon light, irradiation is initialized back towards the ground station starting the optical communication. Fig. 3 shows the actual SOTA experiment carried out where you can see the beacon light from the ground station coming back from the SOTA in response to the beacon light from the ground station.

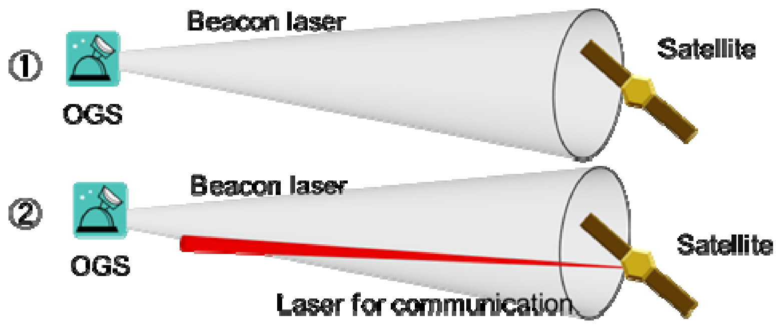

Figure 2: Positioning system using beacon light

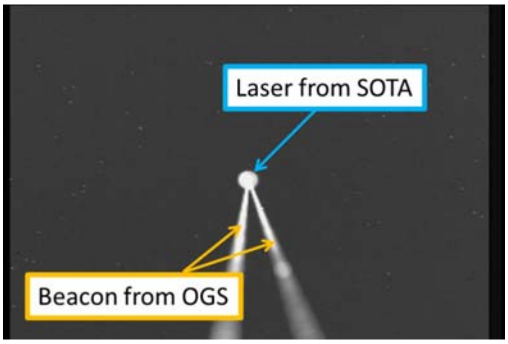

Figure 3: The actual SOTA experiment

At NICT during tests, we implemented error correction code on the satellite side with a low calculation load suitable for a small satellite (LDGM: low-density generator matrix) on SOTA in order to resolve the problem of data errors due to atmospheric fluctuations. During the experiments in orbit, we used a mounted camera on the satellite to take the Earth image shown in Fig. 4 and used


Figure 4: Transmitted image
(Australian continent northeast)

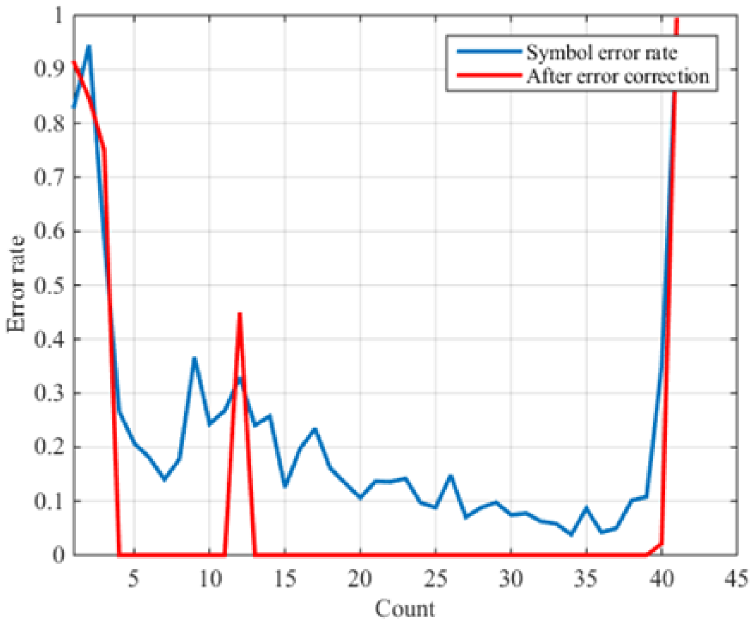


Figure 5: Comparison of the received image data before and after correction (Blue: before correction, Red: after correction)

this as the data for error correction code experiments. Using a LDGM sign-based algorithm for satellite to ground optical communication experiments allowed us to confirm the errors that occurred in the transmission path and ensure the correct receipt and decoding of image data. As you can see in the graph comparing the received image data before and after correction in Fig. 5, we confirmed that we were able to correct all errors in the received images by using our error correction code.

## Outlook for the Future

In the future, we will work on a variety of application experiments and on the development of practical use systems as well as verify that they work in orbit for long periods of time. In addition, SOTA has received great interest and requests for participation in experiments from related research institutions overseas. By gradually providing opportunities for experimental participation, we will expand our achievements as well as lead research and development around the world. These will be compiled as research results in collaboration with institutions around the world and are expected to be reflected in the recommendation documents and technical standards of the Consultative Committee for Space Data Systems, a standards organization on the data communication systems between the space agencies.