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Development of "HICALI"
- High Speed Optical Feeder Link System between GEO and Ground -

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ABSTRACT

In National Institute of Information and Communications Technology (NICT) of JAPAN, an ultra high speed optical satellite communication equipment onboard the engineering test satellite IX has been developing. The satellite is planned to be launched to geosynchronous orbit in 2021. In this project, we are aiming for ultra high-speed data transmission at the world's highest level of 10 [Gbps] for both uplink and downlink between optical ground stations and geosynchronous satellite. This paper outlines the optical communication mission, the scheduled optical communication experiment, the examination of HICALI and the ground based system at the present time - the outline of the development situation is also explained.

Keywords: Optical Satellite Communications, Geosynchronous Satellite, Laser, Adaptive Optics

1. INTRODUCTION

Since the 1980s, the National Institute of Information and Communications Technology (NICT) of Japan has been conducting research and development on optical satellite communication between artificial satellites and the optical ground stations. First, using Engineering Test Satellite VI "KIKU-VI" launched in 1994, 1 [Mbps] optical communication link between high altitude satellite and ground station was succeeded. Next, using "Kirari" (OICETS) launched in 2005, a laser communication experiment (transmission speed 10 [Mbps]) between a low earth orbit satellite and a optical ground station was conducted. Then, a small optical satellite communication terminal of total weight of about 6 [kg] called SOTA (Small Optical TrAnsponder) was installed on a small satellite of 50 [kg] class, Space Optical Communications Research Advanced Technology Satellite (SOCRATES) launched in 2014. Optical communication experiment using SOTA was carried out mainly at the earth station of Koganei, Tokyo and some experiments are also carried out at the earth station in Onna village, Okinawa Prefecture and Kashima city, Ibaraki prefecture. Communication experiments such as image transmission and verification test of LDGM code were carried out. Furthermore, we succeeded in demonstration experiment of quantum satellite communication which exchange information at photon level between SOCRATES and the ground station of Koganei.

Based on these experiences in NICT, we has been developing an ultra high-speed optical communication equipment to be installed in the next Engineering Test Satellite IX (ETS-IX) which is planned to be launched into the geosynchronous orbit of 36000 [km] above the equator in FY2021. In this satellite optical communication mission, we are aiming to establish an optical communication systems that enable the world's highest level of ultra high-speed data transmission of 10 [Gbps] for both uplink and downlink between a geostationary satellite and ground stations (Fig. 1). The optical communication equipment onboard ETS-IX is called HICALI (High Speed Communication with Advanced Laser Instrument). HICALI stands for "light" in Japanese. In this paper, the outline of the optical communication mission of ETS-IX project, the optical communications experiments, the outline of the development status of HICALI will be described.

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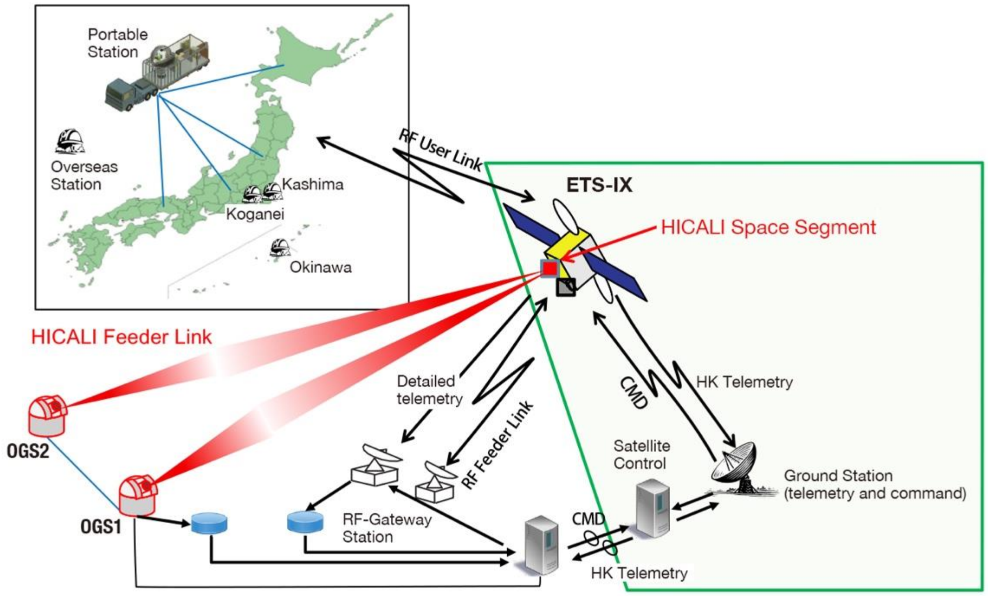
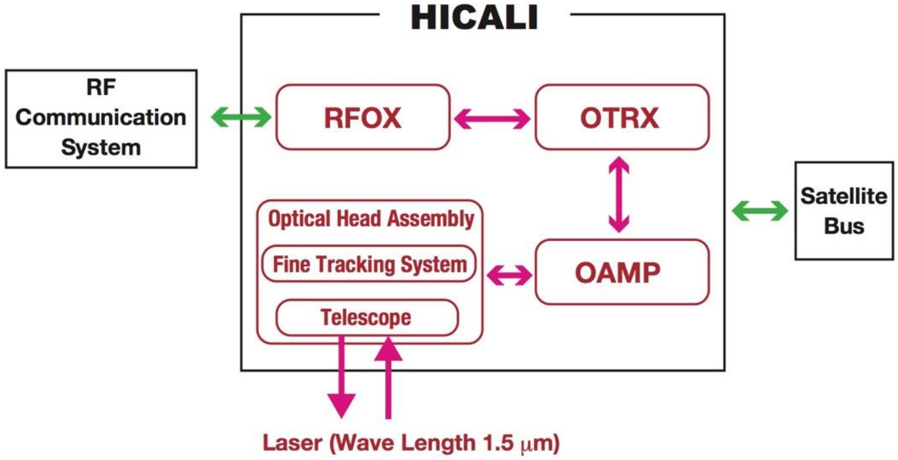


Figure 1. Figure captions are indented 5 spaces and justified. If you are familiar with Word styles, you can insert a field code called Seq figure which automatically numbers your figures.

2. OVERVIEW OF “HICALI” AND CURRENT STATUS OF DEVELOPMENT

The optical communication equipment HICALI onboard ETS-IX consists of an optical component (optical transmitter/receiver, optical amplifier) that processes signals, a part that converts data for connection with communication equipment using radio waves, A telescope section for transmission and reception, and a coarse acquisition and fine tracking mechanism for directing precisely to the ground target. Figure 2 shows the configuration of HICALI. In HICALI, laser light in the near infrared region with a wavelength of 1.5 [μm] is to be used. Since it is an eye-safe laser, safety to the human body can also be enhanced. In addition, since this wavelength is widely used in communications using optical fibers on the ground, it becomes possible to apply devices, devices, systems, etc. used in terrestrial optical communication networks to space optical communication. However, in order to use the device developed for ground use in outer space, it is necessary to prevent it from being broken for a long period under severe conditions such as cosmic radiation. Currently, for major optical communication devices, we aim to establish a screening process to ensure environmental tolerance and reliability in space.



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3. OPTICAL COMMUNICATION EXPERIMENT

Fig. 3 shows a conceptual diagram of the optical communication experiment between the next technical test satellite using HICALI and the ground. To realize the world's highest optical communication speed of up to 10 [Gbps], and to ensure the band resource of the radio wave which is becoming tight at the maximum, HICALI stationary orbit to the ground optical communication experiment The following items are scheduled. (1) Confirm basic function operation of large capacity optical communication device on orbit, (2) Confirm ultra high speed optical communication function (10 [Gbps]), (3) Propagation data of laser light), Check the line quality, coding / interleaver function/performance so that various kinds of communication methods for reducing degradation of communication quality due to atmospheric fluctuation can be demonstrated, (4) Confirm the communication function of conversion of light wave to radio waves, radio wave - light wave, (5) Perform the optical communication experiment at night (experiment in daytime as extra target), (6) Site diversity experiment according to weather conditions (7) Test a new technology on optical ground station (OGS), such as adaptive optics (AO) system, multi-aperture transmission/reception, and (8) Conduct directional/tracking test using small portable optical station. Currently, development of HICALI is at the final stage of detailed design for optical components and optics.

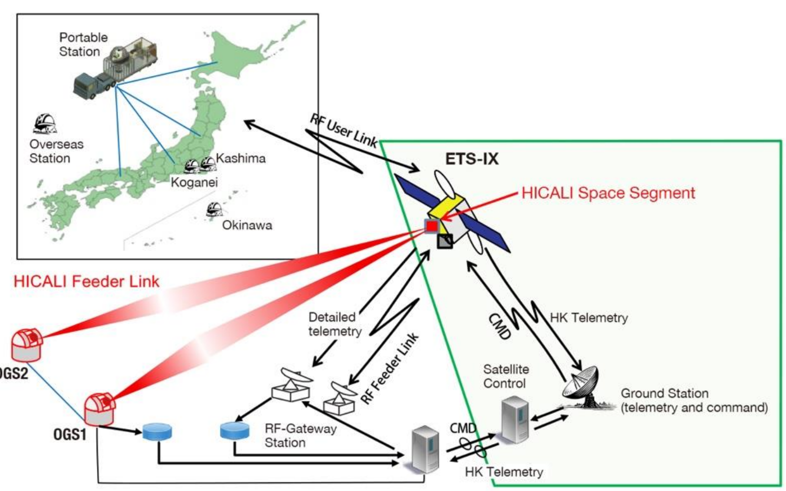

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Figure 4. Figure captions are indented 5 spaces and justified. If you are familiar with Word styles, you can insert a field code called Seq figure which automatically numbers your figures.

Table 1. Specifications of three 1 [m] telescopes.

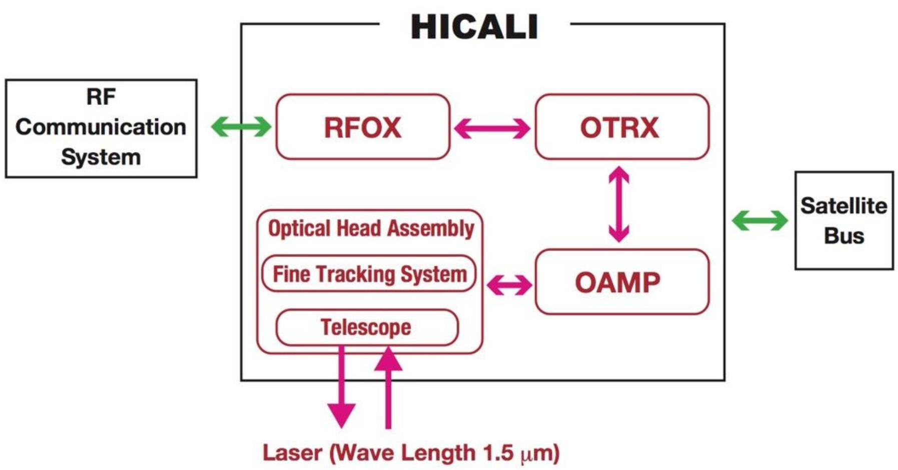
Mount	Alt - Azimuth
Focus	Classical Cassegrain
Diameter of Main Mirror	1000 [mm]
Composite Focal Length	12 [m]
Tracking accuracy LEOs Stars Stars	 < 10 [arcsec] < 0.4 [arcsec] (EL > 30 [deg]) < 1 [arcsec] (EL=15~30 [deg])
Angle coverage	Azimuth ±270 [deg] Elevation 15~88 [deg]
Total mass Tube mass	7.5 [t] 1.3 [t]
Nasmyth payload mass	1 [t] (max)

4. GROUND SYSTEM

The ground station system for realizing super high speed optical satellite communication using HICALI is located in existing 1 [m] telescopes at NICT Koganei headquarters, Kashima Space Technology Center (Kashima city, Ibaraki prefecture), Okinawa Electromagnetic Technology Center (Onna village, Okinawa prefecture, Fig. 4). The specifications of three 1 [m] telescopes are summarized in Table 1. While the 1 [m] telescope at Koganei is stored in the dome, the telescopes at Kashima and Okinawa are placed in openable sliding roof. In addition to the 1 [m] telescopes, we are planning to utilize a 1.5 [m] telescope at Koganei headquarters. We are also considering a multi aperture system that bundles small telescopes and also studying portable ground stations that can move to sunny area with communicable size and can communicate.

The optical satellite communication between the geostationary satellite and the ground station has the problem that the effect of the fluctuation of the atmosphere, the cloud in the satellite direction interrupts the communication light and can not communicate. In the field of astronomical observation, in order to alleviate the influence of atmospheric fluctuation, observe the disorder of the image of the star with a wavefront sensor such as Shack Hartmann sensor, deform the variable mirror and correct the disorder of the target celestial body The technology of compensating optics (AO) is getting common. On the other hand, in the case of optical satellite communication, the astronomical AO system can not be used as it is because it is necessary to correct the difference in light caused by the movement of the target satellite with respect to the earth station. Also, as for astronomical use, it is sufficient to compensate for the influence of fluctuation on light from space, whereas in the case of bidirectional optical satellite communication, even for uplink light irradiated from the ground toward the satellite, It is necessary to reduce the influence of fluctuation. In the sense that it receives fluctuations at the place just outside the ground station, it can be said that the uplink is rather influential. Currently, we propose a method of wavefront compensation by sensing a wave with a reception aperture wider than the transmission aperture and estimating wavefronts with different propagation paths.

On the other hand, in order to avoid the influence of the clouds, we placed 10 environmental data measuring sensors consisting of all sky cameras, cloud meter, etc. in Japan nationwide (Fig. 5). Environmental data obtained from these sensors are collected through the network and analyzed. We aim to demonstrate site diversity that predicts which area is sunny and optical communication is possible. Then we will use the ground station in this area or move a portable station to a sunny area to perform optical satellite communication (Fig. 6).



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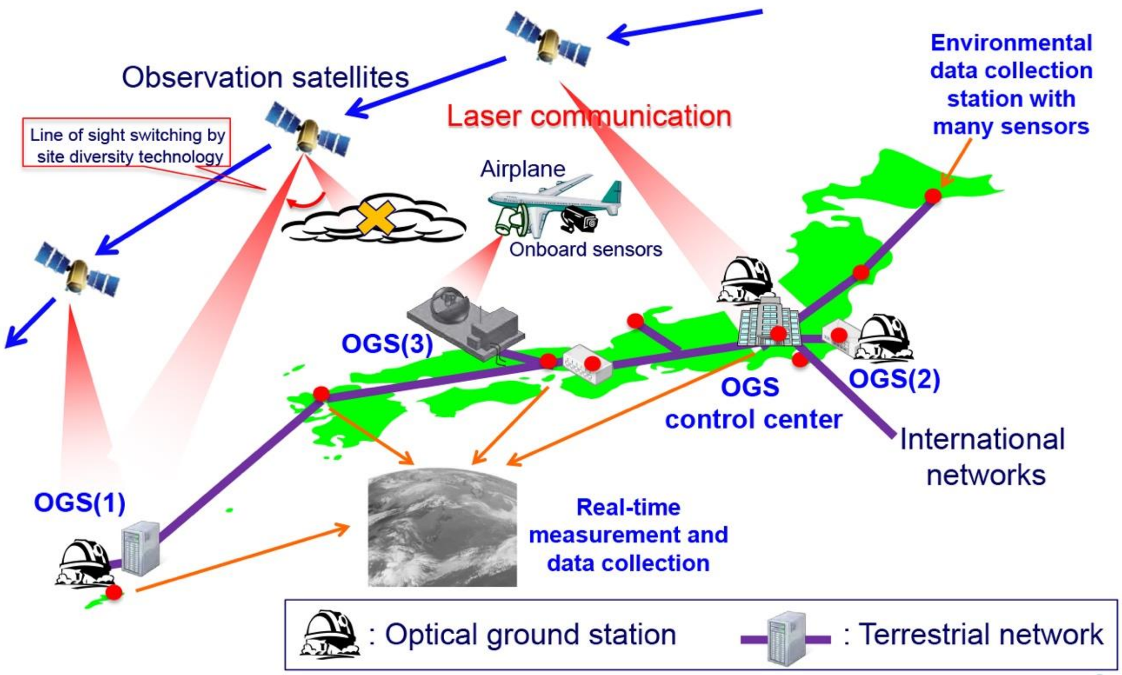

Figure 6. Figure captions are indented 5 spaces and justified. If you are familiar with Word styles, you can insert a field code called Seq figure which automatically numbers your figures.

5. SUMMARY

The optical feeder link aiming for demonstration with HICALI installed in ETS-IX will replace the radio feeder link, since tighter bandwidth as the communication capacity increases in the future. Currently, CCSDS (The Consultative Committee for Space Data Systems), which is a standardization activity in the field of space data systems, [19], standards for communication and exchange of space data in satellites, between satellites and ground stations and deep space to ground stations Discussion on the method is under way. HICALI plans to adopt standard techniques as much as possible with the aim of spreading the developed system widely.

REFERENCES

[1] Araki, K., Y. Arimoto, M. Shikatani, M. Toyoda, M. Toyoshima, T. Takahashi, T. Fukazawa, H. Okazawa and T. Aruga, "ETS-VI/LCE laser communications experiment", 20th ISTS, 96-h-11, May (1996).

[2] Toyoshima, M., T. Takahashi, K. Suzuki, S. Kimura, K. Takizawa, T. Kuri, W. Klaus, M. Toyoda, H. Kunimori, T. Jono, Y. Takayama, and K. Arai, "Results from Phase-1, Phase-2 and Phase-3 Kirari Optical Communication Demonstration Experiments with the NICT optical ground station (KODEN)", 24th International Communications Satellite Systems Conference of AIAA, AIAA-2007-3228, Korea, April 13 (2007).

[3] Takenaka, H., Alberto Carrasco-Casado, M. Fujiwara, M. Kitamura, M. Sasaki, and M. Toyoshima, "Satellite-to-ground quantum-limited communication using a 50-kg-class micro-satellite", Nature Photonics 11, 502–508, doi:10.1038/nphoton.2017.107, (2017).

[4] Kubo-oka, T., H. Kunimori, K. Suzuki, T. Fuse, Y. Koyama, Y. Munemasa, H. Takenaka, K. Dimitar, A. Carrasco-Casado, and M. Toyoshima, "Overview of Optical Satellite Communication Mission Onboard the Next-generation Engineering Test Satellite", Proceedings of the 61th Space Sciences and Technology Conference, 3D02 (2017), in Japanese.

[5] Kunimori, H., M. Toyoshima, and Y. Takayama, "4. Development of Optical Ground Station System, 4-1 Overview of Optical Ground Station with 1.5 m Diameter", Review of the National Institute of Information and Communications Technology, Vol.58, Nos.1/2, pp.35-43, (2012), in Japanese.
[6] Fuse, T., "A study on approach to atmospheric fluctuation in optical communication", Proceedings of the 61th Space Sciences and Technology Conference, 3D12 (2017), in Japanese.
[7] Maehara, M., Y. Hashimoto, T. Goda, and T. Ogawa, "Development of onboard optical communication transponder", Proceedings of the 61th Space Sciences and Technology Conference, 3D04 (2017), in Japanese.
[8] Munemasa, Y., K. Suzuki, Y. Abe, K. Okada, M. Ohkawa, A. Miura, and M. Toyoshima, "Investigation of Optical-RF system in communication mission of Engineering Test Satellite IX", Proceedings of the 61th Space Sciences and Technology Conference, 3D10 (2017), in Japanese.
[9] Suzuki, K., K. Dimitar, A. Carrasco-Casado, and M. Toyoshima, "Analysis of site diversity effect by environment data for satellite-to-ground optical communication", 3D11 (2017), in Japanese.
[10] Consultative Committee for Space Data Systems, http://public.ccsds.org/.