32nd URSI GASS, Montreal, 19-26 August 2017

Hybrid High-throughput Satellite Communications System Using Radio and Optical Frequencies

Morio Toyoshima
Space Communications Laboratory, Wireless Networks Research Institute,
National Institute of Information and Communications Technology (NICT), Koganei, Tokyo 184-8795, Japan

Abstract

Broadband communication using satellites requires use of the Ka-band. Services of this type are now emerging all over the world, some with capacities in excess of 100 Gbps. However, as the radio bandwidth resources become exhausted, high-speed optical communication is required instead. The National Institute of Information and Communications Technology (NICT) in Japan researches and develops the next generation of space communication technology. A hybrid satellite communication system using radio and optical frequencies is being studied. Here, the research and development activities of NICT are introduced, along with the concept of the hybrid high-throughput satellite communication system.

1. Introduction

Many satellite operators around the world are developing broadband satellite communication services based on the Ka-band. In December 2010, Eutelsat launched KA-SAT, which is an example of a high-throughput satellite (HTS). The KA-SAT satellite has 82 spot beams and a capacity in excess of 70 Gbps [1]. In October 2011, the ViaSat-1 known as HTS was launched; it has a capacity of 140 Gbps. Since January 2012, there has been a satellite-based broadband internet protocol (IP) service over North America. Some time after 2019, ViaSat-3 should be providing global coverage with a capacity of 1 Tbps [2]. The Inmarsat-5 satellite network is currently providing the Global Xpress service, which is a Ka-band broadband satellite communication service with 5/50 Mbps for uplink and downlink. Since August 2015, three operational Inmarsat-5 satellites have been in the geostationary Earth orbit (GEO), giving global coverage with 89 spot beams per satellite [3].

Satellite systems are now being planned to provide optical data relay for Europe, the United States, and Japan. In September 2013, the Goddard Space Flight Center of the National Aeronautics and Space Administration (NASA) conducted 622-Mbps laser communication experiments between the Lunar Atmosphere Dust Environment Explorer (LADEE) and optical ground stations as part of the Lunar Laser Communications Demonstration (LLCD) program [4]. In April 2019, NASA plans to launch the Laser Communications Relay Demonstration (LCRD) [5]. The European Space Agency (ESA) runs the Copernicus program, which is a network of Sentinel Earth-observation satellites. In November 2011, the Sentinel-1A satellite successfully transmitted observation data using the Alphasat communication satellite via a 1.8-Gbps optical link [6]. In addition, ESA runs the European Data Relay System (EDRS). This has been operational since January 2016, when the EDRS-A satellite was positioned at 9° E; in 2017, EDRS-C will be positioned at 31° E. For Japan, the Japan Aerospace Exploration Agency (JAXA) is developing the Japanese Data Relay System (JDRS) for launch in 2019 [7].

2. Space Communications Laboratory: research and development

Figure 1 shows an overview of the research and development (R&D) activities of the NICT Space Communications Laboratory. Based on HTS satellites such as Inmarsat-5, Viasat-3, and O3b, higher-capacity Ka-band communication is required for satellites. Over the next 10–20 years, the intention for space communication is to replace radio frequency (RF) systems with ones based on lasers. For this, it is necessary to have technology for site diversity to mitigate the unavailability of individual laser links due to weather conditions, which in turn requires international collaboration. Current research on RF- and laser-based satellite communication is described in the following subsections.

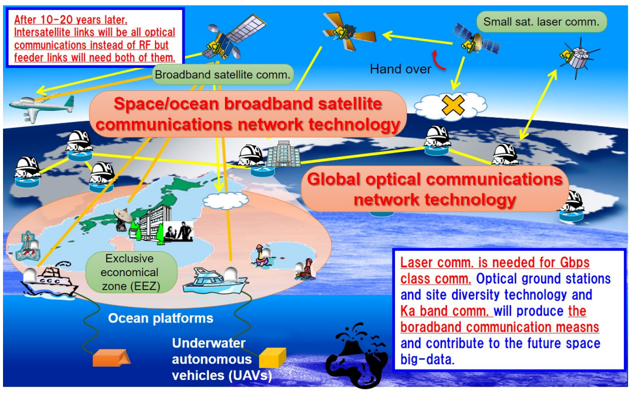

Figure 1. Overview of the R&D activities of the NICT Space Communications Laboratory.

2.1 Ocean/space broadband satellite communications network technology

Mobile satellite-based broadband communication in the Ka-band is required for ocean and aerospace coverage and for disaster situations. Including its exclusive economic zone (EEZ), Japan has the sixth largest national territory, which makes surveying its ocean resources very important. The NICT participates in such a survey project, concentrating on satellite-communication R&D for maritime use. The world's first teleoperation experiment was conducted between an autonomous underwater vehicle (AUV) and the headquarters of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) using the "KIZUNA" Wideband InterNetworking engineering test and Demonstration Satellite (WINDS), as shown in Fig. 2. The use of satellite communication can enhance the surveying of ocean resources very effectively.

Figure 2. Teleoperation experiments for surveying ocean resources using an AUV via the WINDS satellite.

Figure 3. WINDS Earth station in use when the Kumamoto earthquake was occurred in April 2016.

After the Great East Japan Earthquake in 2011, fully automatic transportable Earth stations were recognized as being among the most important resources in disaster response. The NICT began developing fully automatic Earth stations and a test facility in the Tohoku district. A satellite communication network can be deployed easily by covering the affected areas with these automatic Earth stations, and so communication links can be steadily re-established. After the April 2016 earthquake in Kumamoto, the NICT provided an internet communication link by using WINDS. Figure 3 shows a WINDS Earth station in use after the Kumamoto earthquake.

2.2 Global optical communications network technology

Come 2020, the required data rates are likely to exceed 10 Gbps. Because such rates are rather difficult to achieve using RF technology, laser communication of at least 10 Gbps will be essential. Figure 4 shows the data rates of space-qualified laser communication missions plotted by launch year. As discussed later, the NICT is working on technology for multi-gigabit optical feeder links.

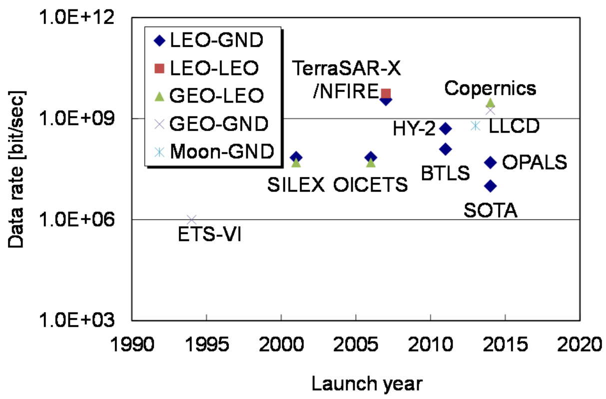

Figure 4. Data rates for space-qualified laser communication missions plotted by launch year.

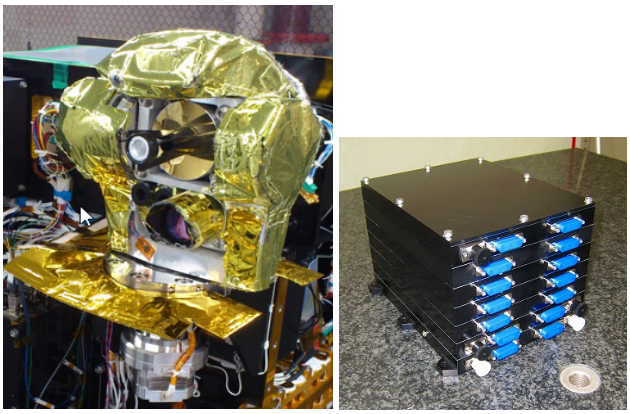

Figure 5. SOTA proto-flight model (left: optical part; right: electrical part).

With regard to the R&D of laser communication for small satellites, the NICT has developed the Small Optical TrAnsponder (SOTA) (see Fig. 5). Figure 6 shows the experimental concept of the Space Optical Communications Research Advanced Technology Satellite

(SOCRATES) project. The satellite for this project is in the 50-kg class, and carries a SOTA terminal and a small camera. Optical communication experiments were conducted at 10 Mbps from the onboard SOTA terminal to a 1-m-diameter optical ground station located at the NICT facility in Tokyo. In June 2015, an image taken by the small onboard camera was successfully downloaded via the optical link [8]. This was the first time that data had ever been transmitted successfully from a 50-kg-class micro-satellite via a laser communication link.

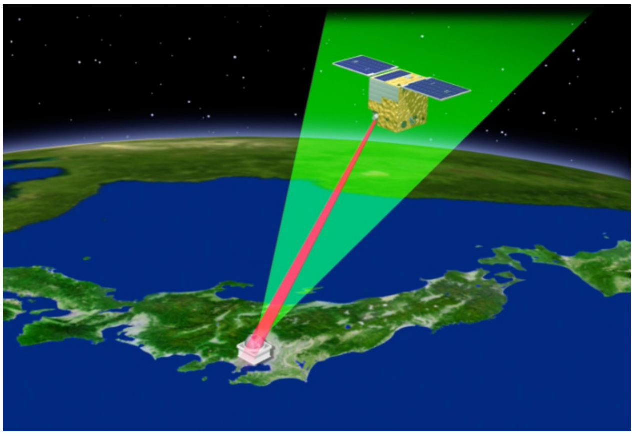

Figure 6. Laser communication experiments using SOTA mounted on a 50-kg-class small satellite.

3. Next-generation Hybrid HTS Communications System

With regard to the R&D of the next generation of communication satellites, the NICT has established a user consortium to identify the future needs of communication-satellite users, has studied satellite-communication system concepts covering those needs, and has settled on technical issues for increasing communication speeds. The NICT has also come up with a conceptual design of a next-generation large-capacity satellite communication system, as shown in Fig. 7. A feasibility study has been conducted into a prototype system, and development has begun. Our goal is to realize 100-Mbps-per-user, high-speed, large-capacity mobile communication using the Ka-band, and to implement flexible (variable-frequency bands and steerable beam) relay technology that can handle traffic fluctuations. According to projected increases in traffic and users, the feeder-link capacity in terms of frequency bands between satellites and terrestrial gateway stations will become exhausted sooner rather than later. In addition, the Radio Regulations tend to make it difficult for RF bands to be allocated. To solve these issues, the feeder links could be achieved optically instead. The NICT has initiated the HIgh-speed Communication with Advanced Laser Instrument (HICALI) project, for which NICT will develop an onboard ultra-high-speed laser communication system. The objective is to realize 10-Gbps-class optical feeder-link technology for a geostationary Earth orbit. The next step is to verify this technology on orbit, which would contribute to the next-generation hybrid (RF and optical frequencies) HTS. This will be the Engineering Test Satellite IX (ETS-IX), which is planned for launch in 2021 as described in the Basic Plan on Space Policy in Japan.

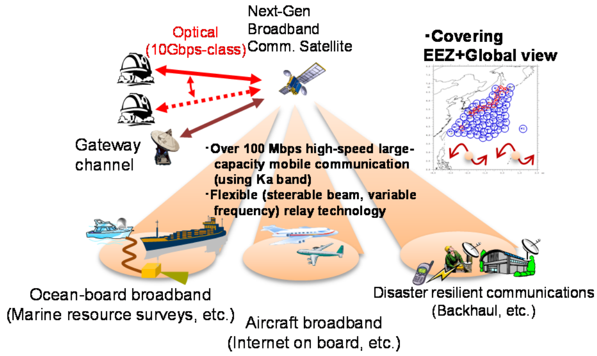

Figure 7. Overview of a next-generation hybrid HTS communication system.

4. Conclusion

The R&D being carried out by the NICT toward the next generation of space communication technology was presented. The concept of a hybrid HTS communication system based on both radio and optical frequencies was introduced. This type of satellite will create new opportunities in the next generation of the HTS field.

5. References

1. H. Fenech, E. Lance, A. Tomatis, and M. Kalama, “Next Generation High Rate Broadband Satellites,” 16th Ka-band conference, October 2010.

2. https://www.viasat.com/products/high-capacity-satellites

3. http://www.inmarsat.com/the-i-5-satellites

4. D. M. Boroson, “Overview of the Lunar Laser Communication Demonstration,” Proc. ICSOS 2014, S1-2, 2014.

5. H. Hauschildt, et. al., “European Data Relay System – Operational Service using Optical Communications Technology,” Proc. IEEE ICSOS 2015, 2015.

6. http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-1/Laser_link_offers_high-speed_delivery

7. S. Yamakawa, Y. Chishiki, Y. Sasaki, Y. Miyamoto, and H. Kohata, “JAXA's Optical Data Relay Satellite Programme,” Proc. IEEE ICSOS 2015, 2015.

8. http://www.nict.go.jp/press/2015/06/03-2.html