Communications Technologies Supporting Satellite Communications

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Abstract

NEC supplies the rocket-borne communications equipment that assists the launch of satellites to the H-IIA/B launch vehicles as part of the corporation's wide variety of technologies supporting satellite communications. NEC also developed the large deployable reflector (LDR) for the Engineering Test Satellite VIII (ETS-VIII), and this is expected to be applied to the Earth Observation Satellites and the Mobile Communications Satellites as the next-generation satellite communications technology. Other NEC developments targeting the implementation of high-capacity communications include the development and demonstration of optical communications equipment for the Optical Inter-orbit Communications Engineering Test Satellite (OICETS).

Keywords

launch vehicle, H-IIA/B, telemetry/communications system, cost reduction, observation rocket
large deployable reflector, LDR, reflector, ETS-VIII, mesh, optical communications, laser, acquisition/tracking

1. Introduction

At NEC, we not only cover every domain of satellite communications-related technologies for Earth stations, launch vehicles and satellites but also work positively with the most advanced technologies expected to become the satellite communications technologies of the future. This paper introduces the three kinds of representative products listed below.

1) Transport system communications equipment

Transport system communications equipment is mounted on a launch vehicle for use in the transmission/reception of control signals between the ground and the launch vehicle and in tracking the launch vehicle's flight path.

2) Large deployable reflectors

The large deployable reflector is a technology that miniaturizes the receiving equipment, such as mobile phones and terminals, by the reflector size enlargement enabled by folding the reflector into the rocket fairing.

3) Optical communications equipment

Ordinary satellite communications use radio waves of frequencies between 2 and 30 GHz. Optical communications equipment uses light (lasers) with higher frequencies in order to carry communications of higher capacity than can be carried by radio waves.

2. Transport System Communications Equipment

Transport system communications equipment (rocket-borne equipment) includes the telemetry/communications system avionics equipment that is also mounted in H-IIA/B launch vehicles, Japan's main commercial-use large launch vehicles.

The telemetry/communications system avionics devices we at NEC handle include data acquisition units, telemetry transmitters, tracking radar transponders and various antennas.

Data acquisition units collect data from various rocket-borne sensors, and telemetry transmitters modulate edited data and transmit it to the Earth station through the antenna. Multiple data acquisition units and telemetry transmitters are mounted in each stage of the launch vehicle because they transmit a large amount of data. Data acquisition controls are interlocked with the guidance control computer.

The tracking radar transponder is used for accurate distance measurement of rocket location using secondary pulse radar. Considering these circumstances, we do not exclusively use high-reliability components for rocket-borne equipment but also use general consumer-oriented components and perform repetitive manufacturing of three launch vehicles per year to decrease equipment costs.

Although its mission time is much shorter than that of satellite-borne equipment, rocket-borne equipment extensively employs anti-vibration measures so that it can operate normally in the vibration and impact environments of launch vehicle flight. In addition, antennas installed near the exhaust valve of the liquid propellant tank are treated with dew condensation prevention measures.

When a launch vehicle carries a satellite with an exploration mission, direct communications between the Earth station and the launch vehicle become unavailable in certain time zones. Therefore, equipment for communications through a data relay satellite can optionally also be mounted. For the Epsilon all-stage solid propellant rocket under development, we are planning to reduce cost by effectively utilizing the telemetry/communications equipment of the H-IIA/B.

Apart from commercial launch vehicles for launching satellites, there are also sounding rockets for use in research by various educational institutions. Since sounding rockets are small-sized, we are developing a system which integrates avionics equipment to save space and are allocating this saved space as space for experiments.

At present, few Japanese manufacturers other than NEC are capable of handling transport system communications equipment. We are therefore expected to play a central role in the development of future rockets.

3. Large Deployable Reflector (LDR)

A parabolic antenna, equipped on the satellite, focus weak radio waves from the ground on the power feed system by reflecting with the parabolic reflector. An LDR is a kind of parabolic antenna, which is installed into the rocket fairing in a folded configuration and deployed to be a proper reflector configuration after the satellite reaches the orbit. The LDR is required to be as light and compact as possible from the viewpoint of the payload mass and accommodation volume of the rocket.

On the other hand, an enlargement of the antenna size enables to miniaturize the receiving equipment, such as mobile phones and terminals, and therefore improves their communications environment. The LDR is a technology that makes the satellite antenna to be small when launched and be large when deployed on orbit.

As shown in **Photo 1** , which is one module of the LDR, the LDR is composed of a mirror-surface structure forming the reflector and a truss structure deploying and supporting the mirror-surface structure.The mirror-surface structure consists of a metallic mesh for reflecting radio waves and a cable network which forms the metallic mesh into a parabolic curved shape. The mirror surface is required to be high precision. For instance, in case of the S-band (2.0 to 2.5 GHz), the surface error should be no more than 3 mm RMS for the reflector larger than 10 meters. This precision should not only be achieved by manufacturing tolerance but should also consider the on-orbit deformation due to the thermal environment and the degradation.

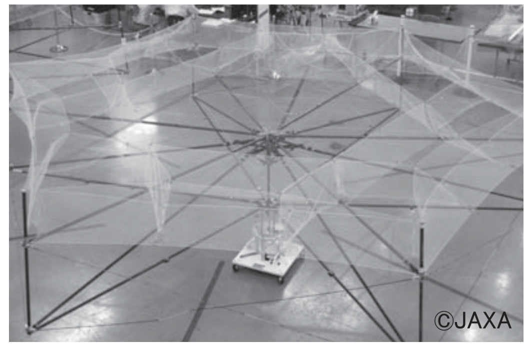

Photo 1 One module of the LDR.

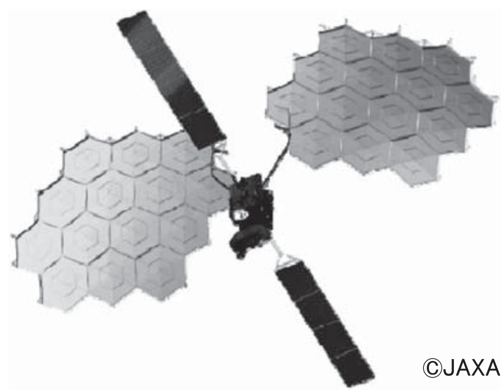

Fig. 1 Overview of the ETS-VIII.

NEC developed the LDR equipped on the ETS-VIII (KIKU-No.8) under contract with the Japan Aerospace Exploration Agency (JAXA). As shown in **Fig. 1** , which is the overview, the ETS-VIII is equipped with two LDRs (for reception and transmission) of approximately 19 m × 7 m in diameters. Each LDR is a multi-module structure composed of fourteen modules of approximately 4.8 meters in diameter. The ETS-VIII was launched in 2006. The LDRs, equipped on the ETS-VIII, were excellently successful in deployment in space and the ETS-VIII completed all of the initial planned missions (the regular operation phase). There are only a few manufacturers in the world that have been successful in the LDR deployment on-orbit, and NEC is one of them.

Based on our achievements with the ETS-VIII, we are presently developing a new VLDR (Very Large Deployable Reflector) which is light in spite of its large size. The VLDR can be deployed larger than before by an advancement of the truss structure, and is the lightest design in the world for its surface density (LDR mass/LDR area). At present we are conducting a feasibility study of this VLDR in cooperation with European manufacturers, aiming at providing to European earth observation and mobile communications satellites.

In the future, it is expected that demand for such LDRs will be increased globally, in various fields for the satellite utilization including the earth observation and the mobile communications. Although the LDRs manufactured by NEC have previously been for the Japanese projects, we are planning to compete in the global market by promoting the further development for light mass, short delivery term and low cost, taking advantage of the VLDR technology.

4. Optical Communications Equipment

1) Features of space optical communications

Increases in the resolution of Earth observation cameras have increased the amount of image data obtained by observation aircraft and spacecraft. However, with the radio wave communications, the transmission capacity (rate) is approaching the limit and making it hard to capture image data at high frequency. Optical communications equipment based on laser beams can break this limit by implementing high-capacity, high-data-rate communications with a compact, lightweight, low-power-consumption system. Optical communications have the following advantages over radio wave (millimeter wave and microwave) communications:

- High frequencies (laser beam technology uses tens of thousands of GHz while millimeter wave technology uses tens of GHz) allow data capacity to be increased.
- The ultra-sharp beam can avoid wasting transmission power without dispersion and allows equipment to be low power consumption, small aperture and small size.
- Confidentiality is high because interception is impossible unless in the proximity of the beam line. Resistance against interference avoids complex international coordination of frequency allocation and is advantageous for the quick development of multiple satellites.
- The key technology is the advanced technology required for the precise acquisition/tracking of ultra-sharp beams.

2) Global trends in space optical communications and efforts made by NEC

For the precise acquisition/tracking technology which is the key technology for aligning ultra-sharp beams between fast-moving objects (a low-orbit satellite, for example, travels at about 7 km/s), the basic test stage has been completed after almost all of the possible combination patterns were recently demonstrated in orbit by Japan and Europe (**Fig. 2**). Now that the feasibility of this new technology has been demonstrated, a global trend of space optical communications is expected towards increases in capacity data rate and decreases in equipment size.

NEC has been developing space optical communications equipment since the experimental LCE (Laser Communication Equipment mounted on the ETS-VI [KIKU-6], shown in Fig. 2) achieved optical communications between a high-altitude satellite and the ground for the first time in the world in 1994. We also for the first time in the world achieved bi-directional communications between a low-orbit satellite and a geostationary satellite or the ground in 2005 and 2006 using the LUCE (**Photo 2**) mounted on the OICETS (KIRARI). We are currently performing R&D on optical communications with higher capacity and higher data rate (NeFOC, described later) and ultra-small optical communications terminals (SOTA, described later).

3) High-data-rate (40 Gbps) free-space optical communications system: the NeFOC project

The NeFOC project refers to “R&D of Space Optical

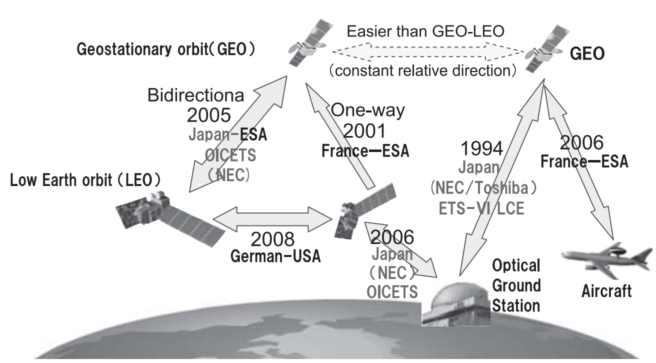

Fig. 2 World’s first success achieved in experimental optical communications in space (Published part).

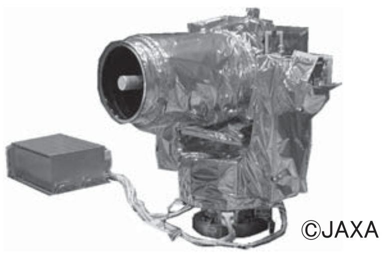

Photo 2 LUCE optical communications equipment on OICETS (KIRARI).

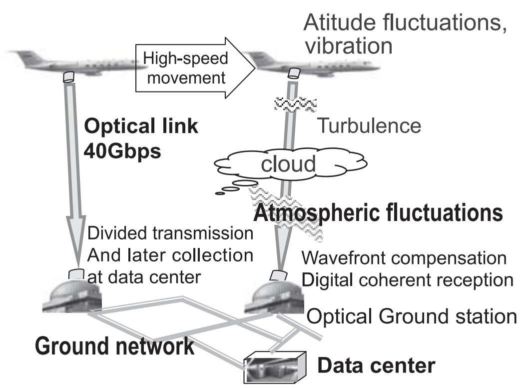

Fig. 3 Outline of NeFOC high-data-rate (40 Gbps) free-space optical communications system.

Communications Technology", which was one of the subjects of the Request for Proposals related to information communications technology started by the Japanese Ministry of Internal Affairs and Communications in FY2010. **Fig. 3** shows an outline of the system we are aiming for. Our plan is to develop a space optical communications technology that enables a data rate of over 40 Gbps from a mobile object such as an aircraft to the ground in the presence of the atmospheric fluctuations that pose problems for free-space optical communications. With this technology, even when a transmission is interrupted momentarily by an obstacle such as a cloud, the transmission is restarted without loss of time, or the data is retransmitted to another location. The divided data is collected at the ground data center through a ground optical communications network.

To deal with degradation in communications efficiency due to momentary link disruption and routing through different transmission media, we are developing a high-efficiency transmission protocol capable of linking and coordinating free-space optical communications with terrestrial networks. For variations in the optical reception level due to atmospheric fluctuations, we are developing a high-sensitivity communication method based on digital coherent technology and high-efficiency error correction. For wavefront and pointing angle variations, we are developing a stable acquisition and tracking system based on wavefront compensation and high-precision acquisition/tracking technologies. **Fig. 4** shows an outline image of the free-space optical communications terminal and a close-up picture of the fixed optics under development.

4) Ultra-small optical communications terminal: the SOTA project

The SOTA project is a project of the National Institute of Information and Communications Technology (NICT), started in FY2009, aiming at developing an ultra-small optical communications terminal weighing less than a few kilograms for mounting on a micro satellite (50-kg class). For emphasizing reductions in size and power consumption, we adopt a reduction in the data rate requirement that reduces the aperture and the overall size, and relaxation of the beam

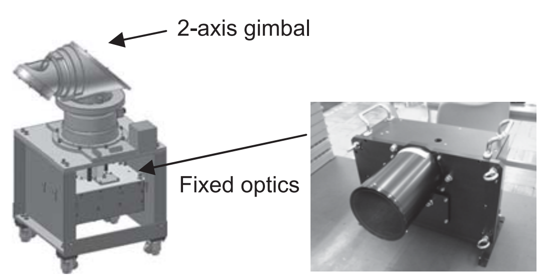

Fig. 4 Free-space optical communications terminal and its optics.

Fig. 5 Design results of SOTA's optics and acquisition/tracking mechanism.

convergence requirement (increase of the beam width). Wider beam width eases the pointing accuracy requirement that makes it possible to use a small, low-cost acquisition/tracking mechanism, because its design can be simplified and even a consumer product can be used. **Fig. 5** shows the results of designing the SOTA's optics and acquisition/tracking mechanism. This terminal carries a variety of transmission systems and a variety of wavelengths (1.55 μm, 1.06 μm, etc.) simultaneously.

5. Conclusion

In the above, we outlined NEC's technologies related to satellite communications. At NEC, we have developed a wide range of advanced products as a frontrunner in the field of satellite communications. In the future, too, we will promote technology/product development in this field to contribute to the realization of an affluent, safe and secure society.

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