Standard Components of Satellite-borne Equipment

YONEDA Masayoshi, KURII Toshihiro, KAKINUMA Masahiro, MAEKAWA Katsunori, HIGASHINO Isamu

Abstract

Satellite-borne equipment includes components that are commonly used by any satellite. These components include earth sensors, transponders, GPS receivers and star trackers. NEC supplies these components to almost all Japanese satellites, and some of them, such as the earth sensor, have a big share of overseas markets as well. This paper introduces the development of compact, high-performance standard components by NEC aiming at increasing shares further in overseas markets.

Keywords

standard components, earth sensor, transponder, GPS receiver, star tracker

1. Introduction

At NEC, we are developing equipment that can be used as standard components by Japanese and non-Japanese satellites.

We started sale of the ESA (Earth Sensor Assembly, **Photo 1**) in the worldwide satellite market in 1992. Since then we have shipped a total of about 350 units and have acquired a 50% share among main sensors for use in the attitude control of communications/broadcasting satellites around the world. By setting this achievement as the target, we are presently developing the following kinds of equipment under the guidance of the Japan Aerospace Exploration Agency (JAXA) so that they can be standard components that meet the requirements of satellites in the future:

- MTP (Multi-mode Integrated Transponder)
- Satellite-borne GPSR (Global Positioning System Receiver)
- STT (Star Tracker)

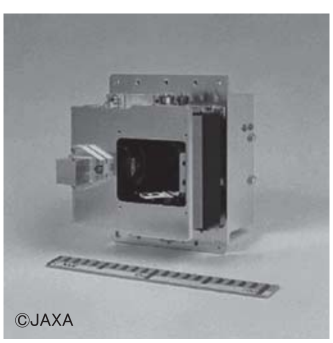


Photo 1 ESA (Earth Sensor Assembly).

For the MTP, we have already completed the development phase after passing in-orbit experimental proofing and certification assessment using a demonstration satellite. It is presently in the production and supply stage of the flight model.

Our previously developed transponder products have already achieved great results in overseas markets. However, the product developed as a standard component on this occasion has a smaller size and higher performance than before and is more competitive in terms of both cost and delivery. We are planning to use this new standard component to acquire and expand our share in overseas commercial markets to match that of the ESA. This paper introduces the standard components for the MTP, GPSR and STT.

2. MTP (Multi-mode Integrated Transponder)

(1) Outline

Regardless of its mission, every satellite bears a piece of communications equipment (transmitter/receiver or transceiver) called a transponder, which allows the ground station to perform TTC (Tracking, Telemetry and Command) of the satellite.

Most previous Japanese spacecraft, including earth observation satellites such as the ALOS (DAICHI) and GOSAT (IBUKI), lunar spacecraft such as the SELENE (KAGUYA) and explorer spacecraft such as the MUSES-C (HAYABUSA) and PLANET-C (AKATSUKI) carry transponders manufactured by NEC. With these multiple achievements, high reliability and high performance, we are now supplying a large quantity of similar equipment to overseas

Standard Components of Satellite-borne Equipment

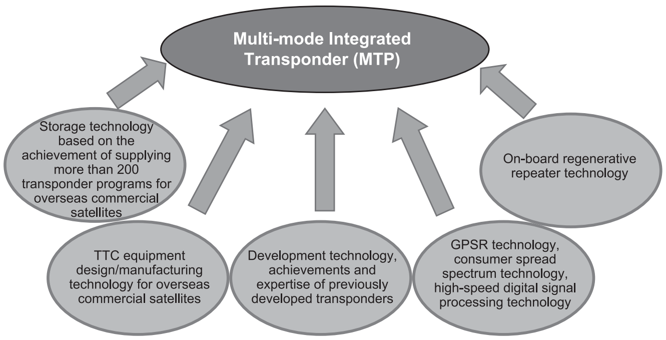
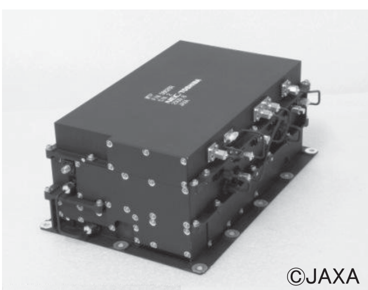


Fig. 1 Concept of the MTP (Multi-mode Integrated Transponder).



Dimensions:
287 mm × 195 mm × 110 mm
Weight:
3.4 kg
Power consumption:
37 W (during 5 W transmission)

Fig. 2 External view of the MTP.

commercial satellites.

In the past, a transponder was developed and supplied for each satellite. In order to standardize transponders for future satellites, we have developed an S-band (2 GHz band) MTP as “the standard transponder to be carried on JAXA satellites” (**Fig. 1** and **Fig. 2**).

(2) S-band standard transponder requirements and measures taken

To enable its use as a standard transponder, we developed the MTP to meet the following requirements, in addition to the traditional requirements for a transponder:

1) As a key satellite-borne device, a transponder should achieve smaller size, lighter weight, lower power consumption and lower cost and should be competitive internationally.

2) A transponder should be capable of faster data transmission than before.

3) Considering the tightening of the S-band frequency due to the increase in satellites, a transponder should make satellite operation possible even when several satellites use the same frequency.

To meet requirement (1), we decided to completely digitalize modulation/demodulation processing. We developed a dedicated ASIC and succeeded in size reduction, weight reduction, performance improvement and adjustment-free circuitry implementation.

To meet requirements (2) and (3), we added new processing modes to the traditional transponder modes so that each mode can be selected freely for use.

(3) S-band standard transponder specifications

Traditional transponders generally used the USB (Unified S-band) mode, which is the most proven mode. In case inter-satellite communication with a data relay satellite at an orbit altitude of 36,000 km was necessary, a transponder equipped with an SSA (S-band Single Access) function was used.As an S-band standard transponder, the MTP packages, in addition to the above modes, a QPSK mode for high-speed transmission and a CDMA mode for avoiding interference. While these modes are switchable with commands from the ground, it is also possible to perform modulation/demodulation in the optimal mode by identifying the received signal automatically, for improved convenience of the user. Just like traditional transponders, in addition to its communication functions, the MTP also has a distance measurement function that measures the distance to the satellite.

Table shows the main performance specifications in each mode.

(4) Future plan

The MTP has finished its certification test as an S-band standard transponder using the certification model and an in-orbit demonstration on the SDS-1 (Small Demonstration Satellite-1) using a satellite-borne demonstration model, and has been confirmed to be free of problems in all aspects, including functions and performance. In the future, production will enter the repetitive manufacturing phase so that MTPs will be installed as the standard transponders of many satellites.

3. GPSR (Satellite–borne GPS Receiver)

(1) Outline

Recent earth observation satellites carry a GPSR to identify the location and time of observation data with high precision. Since the start of practical operation of GPS satellites, most recent earth observation satellites, including the ALOS and the GOSAT, carry NEC-made GPSRs.

Unlike ground-use GPSRs, satellite-borne GPSRs require frequent processing for satellite switching, etc. because the satellite is moving at an altitude of several hundreds of kilometers with a velocity of 7 km/sec.

As shown in the development flow in **Fig. 3** , satellite-borne GPSRs have undergone size reduction, functional improvement and performance improvement in every generation. The current GPSR is the fourth-generation model carried on the GOSAT and has an external appearance and specifications as shown in **Fig. 4** .

(2) Development of a next-generation GPSR

With the goal of implementing a next-generation GPSR as a standard component, we are developing it to meet the following requirements, in addition to the traditional requirements for a GPSR:

1) As a piece of key satellite-borne equipment, a GPSR should achieve smaller size, lighter weight, lower power consumption and lower cost and should be competitive internationally.

2) A GPSR should be able to offer location and time data with higher precision than before.

3) A GPSR should increase its number of receiving channels as well as the number of GPS satellites it can receive from.

For RF circuitry, we will develop a dedicated ASIC using a radiation-resistant CMOS SOI to achieve reductions in size, weight, power consumption and cost. Correlation processing and dedicated DSP will be implemented in multichannel operations using radiation-resistant CMOS SOI and ASIC technologies. We will also improve location precision from 100 meters to a few meters by increasing the number of receiving channels and applying ionospheric correction.

(3) Outline of NEC's next-generation GPSR

Our GPSR has a maximum of six RF input channels and reserves the visual field of the antenna in any satellite attitude. The RF circuitry adopts a simple configuration by employing the direct sampling system, which converts frequencies directly from analog to digital without down-conversion. The receiving signals consist of 3 codes in 2 frequencies, including L1 (C/A): 36CH, L2P: 16CH and L2C: 36CH.

(4) Future plans

The next-generation GPSR is scheduled to complete certification testing as a standard component in FY2011. The NEC-made GPSR will be carried in a large number of satellites in the future.

Table Main performance specifications.

Item		USB	SSA	QPSK/BPSK	CDMA
Reception	Receive frequency (MHz)	Specified in the range of 2,025 MHz -2,110 MHz (TX/RX frequency ratio: 221:240)			
	Noise figure (dB)	< 2.3			
	Modulation method	PSK/PM	UQPSK	QPSK/BPSK	UQPSK
	Transmission rate (bps)	500 bps -4 kbps Specified from (500 x 2^n)	125 bps -300 kbps 2 rates specified from (125 x 2^n)	512 kbps (QPSK), 256 kbps (BPSK)	500 bps -32 kbps 2 rates specified from (500 x 2^n)
	Receive dynamic range (dBm)	-100 dBm --40 dBm (command signal)	-134 dBm (at 125 bps; depends on transmission rate) --40 dBm	-90 dBm --40 dBm	-110 dBm --40 dBm
Transmission	Transmit frequency (MHz)	Specified in the range of 2,220 MHz -2,290 MHz			
	Modulation method	PSK/PM,PM	SQPN,SQPSK	QPSK	UQPSK
	Transmission rate (bps)	500 bps -30 kbps (PSK/PM), 8.19 kbps -65.54 kbps (PM) (with convolution)	100 bps -300 kbps	1 Mbps or 2 Mbps	1 kbps -150 kbps
	Transmit power	2 levels specified in the range of +10 dBm -+37 dBm	+37 dBm	Specified in the range of +10 dBm -+37 dBm	Specified in the range of +10 dBm -+37 dBm
Distance measurement	Distance measuring signal	Tone (4 kHz -500 kHz)	PN code	—	PN code
	Delay time (μs)	< 10	< 2	—	< 2

Standard Components of Satellite-borne Equipment

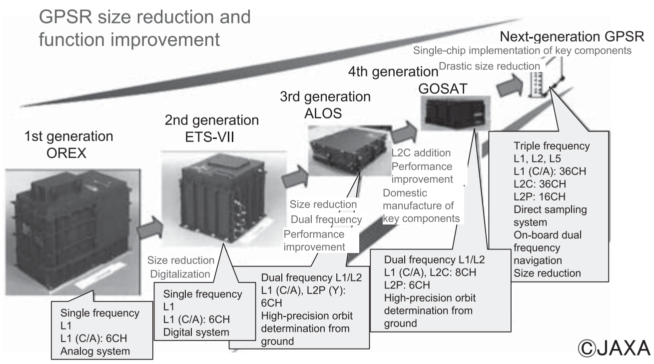


Fig. 3 Satellite-borne GPSR development flow.

Dimensions:
218 mm ×188 mm ×112 mm
Weight:
3.8 kg
Power consumption:
21.2 W

Fig. 4 External view and specifications of the current GPSR.

4. STT (Star Tracker)

(1) Outline

An satellite carries attitude sensors to determine its attitude. The STT is an attitude sensor that determines attitude with a very high precision with reference to stars.

A large number of Japanese satellites that have been launched up to the present carry NEC-made STTs. These satellites include scientific satellites such as the ASTRO-C (GINGA), SOLAR-A (YOHKOH), MUSES-B (HALCA), ASTRO-EII (SUZAKU) and ASTRO-F (AKARI) and earth observation satellites such as the ALOS (DAICHI).

Traditional STTs have been first-generation models that offer only star image capturing and star location calculation functions. However, to meet requirements for higher precision and higher agility from the viewpoint of space science and earth observation, and to improve satellite autonomy and reduce the burden of ground operations, a second-generation STT with the following features is now demanded:

1) Autonomous attitude determination.
2) High attitude determination precision.
3) Improved ease of installation and operation.

Photo 2 External view of a next-generation STT (From left to right: optical block, electrical block and buffle).

To meet these requirements, we are developing a next-generation STT that can autonomously output attitude determination results from the stellar pattern over the whole sky without using a-priori attitude information. The STT is composed of an optical block, an electrical block and a buffle, as shown in the external view in **Photo 2** .

(2) Next-generation STT requirements and measures taken

Since our next-generation STT is expected to be adopted as the standard STT of the second generation, we are developing it according to the following requirements:

1) Autonomous attitude determination

To enable autonomous attitude determination without the need for a-priori attitude information, the STT will incorporate a high-speed image processor and MPU, perform star identification based on pattern matching with the incorporated star catalogue and output attitude determination information (quarternion) based on the J2000 coordinate system.

2) High-precision attitude determination

To enable high agility by reducing random errors, the STT will employ high-sensitivity lenses and CCDs (charge-coupled devices). The optical block is equipped with a low thermal distortion structure to reduce bias errors dependent on the installation temperature environment. To reduce thermal distortion, optics (lenses and CCDs) and circuitry are thermally isolated and the optics employ a kinematic mount.

3) Improved mountability and operability

The low thermal distortion structure described above is used to comply with a wide range of temperature environments. A high optical interference rejection performance is obtained by adopting a ultra-black surface, with the world's lowest reflectance level, inside the baffle.

(3) Functions and specifications of our next-generation STT

NEC's next-generation STT is equipped with various functions and performance improvements to meet the requirements imposed on it.

(4) Future plans

The next-generation STT is presently under qualification testing using the qualification model and its development is scheduled to be completed by the beginning of FY2011. Afterward it will be subjected to an in-orbit demonstration using a satellite-borne demonstration model and then the flight model for X-ray astronomy satellite ASTRO-H will be manufactured.

5. Conclusion

This paper outlined the development situation of satellite components such as the MTP, GPSR and STT. In the future, the developed products will be carried on many satellites as standard components contributing to their missions.

In closing this paper, we would like to express our gratitude toward JAXA for their guidance in our development of standard components.

Authors' Profiles

YONEDA Masayoshi
Manager
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

KURII Toshihiro
Manager
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

KAKINUMA Masahiro
Manager
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

MAEKAWA Katsunori
Engineering Expert
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

HIGASHINO Isamu
Engineering Expert
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

Information about the NEC Technical Journal

Thank you for reading the paper.
If you are interested in the NEC Technical Journal, you can also read other papers on our website.

Link to NEC Technical Journal website

Japanese

English

Vol.6 No.1 Space Systems

Vol.6 No.1
April, 2011

Special Issue TOP