Small SAR Satellite Technology Promotes Dissemination of a Comprehensive Space Utilization System

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Abstract

The needs of synthetic aperture radar (SAR) has recently been increasing. This is because it is an image sensor capable of observing the Earth's surface regardless of weather or time of the day. Aiming at providing high performance Earth observation services, with the low price and the short delivery term, NEC is developing a small SAR satellite of the 500-kg class by utilizing the SAR system technology, spacecraft design technology and small-sized satellite standardization technology that have been accumulated up to the present. This paper introduces an outline of the small SAR satellite system, the techniques used in its development and the projected global deployment of an Earth observation data service.

Keywords

radar, SAR, synthetic aperture radar, small satellite, earth observation
remote sensing, ASNARO, NEXTAR, antenna

1. Introduction

SAR (Synthetic Aperture Radar) is a radar system for imaging the Earth's surface using radio waves. To obtain a resolution equivalent to optical sensor images, the SAR features an antenna installed on an aircraft or spacecraft and repeats electromagnetic wave transmission and reception following the movements of the platform. A virtual antenna with a large aperture is thereby synthesized in the space. For this reason it is called "synthetic aperture" radar.

Since SAR is an active sensor that transmits microwaves from an antenna and observes the reflected waves from the earth's surface, the microwaves can be transmitted through clouds and smoke etc. and it is capable of making observations at any time of day and night. These features have led to a recent increase in the necessity of SAR for earth observation and monitoring purposes, and some overseas satellites have begun to be deployed for their commercial observation services.

This paper reports on a 500 kg class small SAR satellite that is currently being developed with the aim of providing SAR-based earth observation services that feature high performance, low price and a short delivery term.

2. Development Background

2.1 History of SAR Development at NEC

NEC started independent research for the development of SAR image processing software in 1970's and succeeded in developing NEC-SAR [1], Japanese first airborne SAR, for use in our in-house R&D in 1992. This achievement led subsequently to the design and manufacture of the Pi-SAR, an airborne SAR for National Institute of Information and Communications Technology (NICT) and Japan Aerospace Exploration Agency (JAXA), in 1996 and of the Pi-SAR2 [2], a high-resolution airborne SAR that succeeded Pi-SAR, for NICT in 2008.

For the spaceborne SAR, we developed the PALSAR mounted on ALOS (DAICHI) satellite for JAXA and Japan Resources Observation System and Space Utilization Organization (JAROS). Since its launch in 2006, PALSAR has been offering high-quality SAR images up until the present time (**Fig. 1**).

In addition, we have also developed and delivered a large number of SAR sensors and image processing systems.

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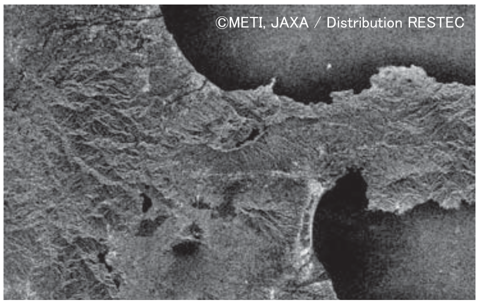

Fig. 1 PALSAR observation image (Izu Peninsula and Mount Fuji).

2.2 Motivation for the Development

The observation capability regardless of weather and time of the day of the SAR has led to a recent increase in the need for SAR observation and monitoring functions. Some overseas commercial satellites such as Canadian RADARSAT, German TerraSAR-X and Italian COSMO-SkyMed have begun to deploy their observation services.

To meet these needs, we are developing a high-resolution SAR satellite of low price and small size to follow the development of the small optical sensor observation satellite ASNARO.

3. Small SAR Satellite System

3.1 Satellite Configuration

Fig. 2 shows an image of the small SAR satellite and **Fig. 3** shows its functional block diagram. The small SAR satellite can be divided roughly into the satellite bus and the mission module. The satellite bus employs the small standard satellite bus NEXTAR (NEC Next Generation Star) described in section 4, while the mission module is composed of the SAR observation sensor subsystem including the SAR antenna and SAR electrical unit, the mission control subsystem and the data transmission subsystem.

Of the SAR components: the SAR electrical unit generates the transmitted RF signals, the SAR antenna transmits it as X-band (9 GHz band) microwaves, the same SAR antenna receives the radio waves reflected from the earth's surface, the SAR electrical unit amplifies, frequency-converts, demodulates and samples the received RF signals, and the data recorder in the mission control subsystem records the sampled observation data. When the satellite transmits the

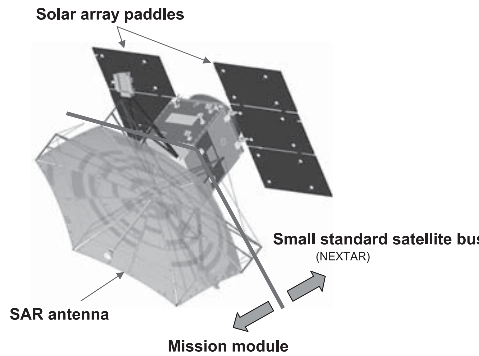

Fig. 2 Image of small SAR satellite.

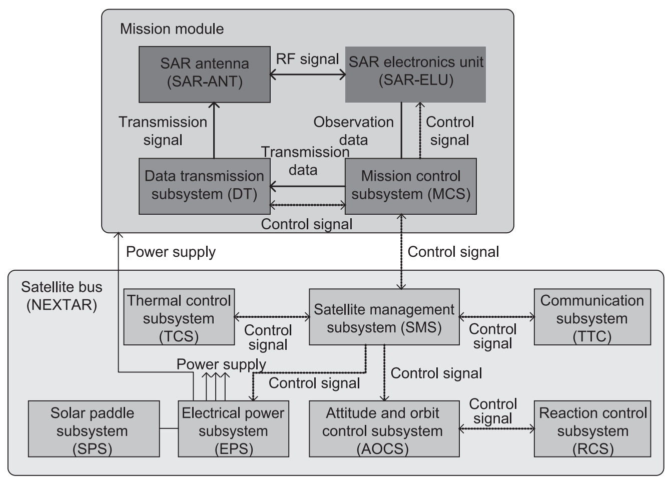

Fig. 3 Functional block diagram of small SAR satellite.

observation data to the ground, the data recorder outputs the recorded observation data, the data transmission subsystem modulates and amplifies the data and the SAR antenna transmits it to the ground station. The shared use of a single antenna for SAR observation and data transmission to the ground contributes to reduce the satellite size.

3.2 Main Features

Table shows the main features of the small SAR satellite.

The small SAR satellite achieves the high resolution of below 1 meter by utilizing the X-band radio waves of the 9 GHz band. We selected the X-band frequencies because of their three advantages, which are; the possibility of achieving a high resolution, that of reducing the antenna size relatively easily

Table Main system features of the small SAR satellite.

Item	Value
Installed sensor	SAR
Sensor frequency band	X-band (9 GHz band)
Observation modes	Spotlight, Stripmap
Highest resolution	Below 1 meter
Pointing function	Both side looking available
Data transfer rate	≥800 Mbps
Data transmission frequency band	X-band (8 GHz band)
Altitude	Approx. 500 km
Satellite weight	500 kg class

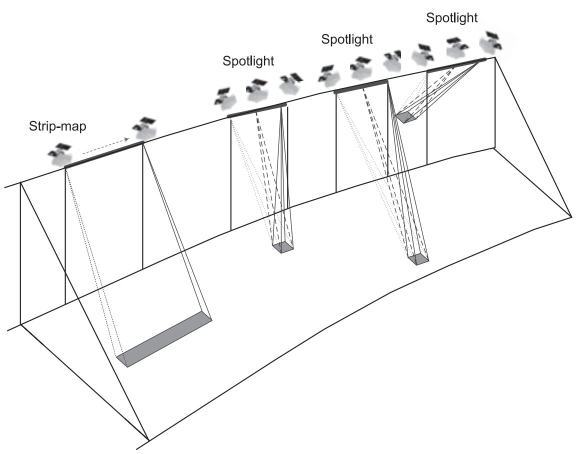

Fig. 4 Observation operations of small SAR satellite.

and that of observation regardless of weather.

While it is required to use a broad frequency band to improve the resolution of SAR, consideration of the radio wave usage restriction and fractional bandwidth led us to the conclusion that a high frequency band like the X-band should be selected in order to achieve a resolution of below 1 meter. When high frequencies are used, it is also possible to reduce the antenna size because a high antenna gain can be implemented by narrowing the antenna beam. However, bands of a higher frequency than the X-band such as the Ku band (13 GHz band) and Ka band (35 GHz band) are sensitive to the effects of rain and cloud so that the all-weather advantage of the SAR compared to the optical sensors would be lost if these bands were used. These are the reasons why the X-band was selected.

The observation modes include the spotlight mode for observations at the highest resolution of below 1 meter covering narrow spot area and the strip-map mode for observation of an area composed of strips (**Fig. 4**). The SAR is additionally equipped with a function for switching the observation direction to the left or right according to the satellite flight direction.

The observation data is transmitted to the ground at the high speed of more than 800 Mbps using the X-band. The standard satellite altitude is set at about 500 km. For the satellite weight, the development target is set to the 500 kg class, which consists of the small satellite bus NEXTAR with a 300 kg class weight and the 200 kg class mission module developed by the size reduction technology described in section 4.

4. Development Techniques

This section describes the development techniques that are adopted in order to reduce the size, reduce the weight and improve the performance of the small SAR satellite. The small SAR satellite is developed using the techniques shown in **Fig. 5** .

4.1 Development of Parts Other than the SAR Antenna and SAR Electrical Unit

The SAR satellite consists of the mission module that performs the SAR observation and data transmission to the ground and the satellite bus that manages the entire satellite.

NEC started the development of NEXTAR, which is a standard satellite bus with a 300 kg class weight for use on 500 kg class small satellites, in FY2007. NEXTAR has

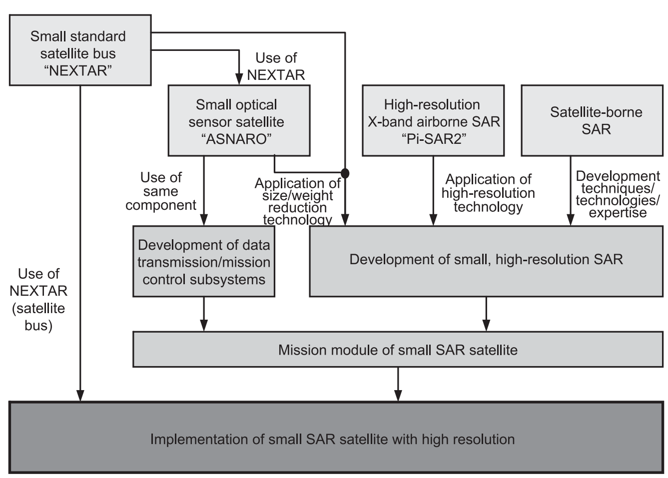

Fig. 5 Development flow of small SAR satellite.

already been adopted for the small optical sensor satellite ASNARO. It will also be adopted in the small SAR satellite in order to achieve a short term development of its satellite bus at a low price and to implement a 500 kg class satellite by combining the 200 kg class mission module.

The mission module of ASNARO is composed of the optical sensor, data transmission and mission control subsystems. On the other hand, the mission module of the small SAR satellite is composed similarly to include SAR, data transmission and mission control subsystems. Furthermore, the data transmission and mission control subsystems adopt the same components as ASNARO in order to minimize the number of newly developed elements and to enable development over a short period, at a low price and with a small size.

4.2 Development of the Small Spaceborne SAR

The expertise and technical achievements as described below will be applied to the SAR currently under development. These achievements refer to the comprehensive system technologies including those of various satellites and SARs as well as the image processing components that were deployed with the SARs for the large satellite (PALSAR, etc.) and the high-resolution airborne SAR (Pi-SAR2).

We will enable high resolution and a short development term for SAR of small satellites by utilizing the technologies of PALSAR and Pi-SAR2. PALSAR was developed by utilizing the technologies previously applied for the airborne SAR Pi-SAR-L (the L-band (1.3 GHz band) section of the Pi-SAR) and by providing them with a satellite- mounting capability. With the SAR currently under development we will also enable high resolution and a short development term by effectively utilizing the technologies developed for Pi-SAR2 and by providing them with a satellite-mounting capability. The key technologies applied in the development include the technologies required for the high resolution of below 1 meter, such as the high-frequency technology for the X-band (9 GHz band) broadband circuit design technology and the spotlight SAR observation technology.

To reduce the size and weight of the small spaceborne SAR, we utilize the technologies of NEXTAR, ASNARO and the large deployable reflector (LDR) antenna. The technologies adopted with NEXTAR and ASNARO for the size/weight reductions refer to the high-density packaging and high-speed signal interfacing technologies.

The antenna size/weight reduction is particularly important for the implementation of the small SAR satellite. With the newly developed small SAR satellite, we adopt a parabolic antenna featuring a simple design, light weight and low price in place of the phased-array antenna that is complicated, heavy and expensive, in spite of its high functionality, in order to meet the needs for frequent high-resolution observation with a low price and short delivery term rather than pursuing high functionality in observation. The development of the parabolic antenna will be ensured by utilizing the technologies of the large deployable reflector (LDR).

To evaluate and confirm the above-described key technologies for resolution improvement and size/weight reduction, we had developed partial bread board models of the signal generator/processor that requires broadband and small size and the high-power amplifier block that is necessary for using the parabolic antenna. The technologies applied in the development of the signal generator/processor include the broadband circuit design technology for the airborne SAR described above and the high-density packaging technology for the small satellite.

5. Conclusion

NEC are developing a small SAR satellite featuring high performance, low price and a short delivery term by utilizing the SAR technology, spacecraft design technology and size reduction technology that have been accumulated up to the present. The small SAR satellite uses the same small standard satellite bus NEXTAR as the other small optical sensor satellite. It belongs to the series of small earth observation satellites that are based on a common platform that can handle tasks from the operation of satellites to the use of observation images on the ground.

The lineup of the small earth observation satellite series will allow us to commercialize the earth observation data services (sale, use and application of data) combining SAR images, optical sensor images and other sensor images. At the same time, we will also deploy an integrated space utilization system based on small earth observation satellites in overseas markets by representing it as a social infrastructure system for the emerging countries.

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