

OPTICAL AND MICROWAVE SENSORS ON JAPANESE MAPPING SATELLITE – ALOS

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ABSTRACT:

The Advanced Land Observing Satellite (ALOS), which is planned for launch in 2004 by Japanese H-IIA vehicle, has five objectives: to advance land-observing technology, to contribute to cartography, regional observation, disaster monitoring, and the Earth resources surveying. Its major sensors are Panchromatic Remote-sensing Instruments for Stereo Mapping (PRISM), Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), and Phased Array type L-band Synthetic Aperture Radar (PALSAR).

The PRISM is the sensor mainly for mapping. It consists of three independent telescopes for forward, nadir and backward view and each telescope provides 2.5m spatial resolution. These specifications are given to generate precise Digital Elevation Model (DEM), and to achieve the accuracy for 1/25,000 scale maps. The PRISM will provide not only high resolution, but also wide swath image up to 70km. The PRISM's optics, which is three-mirror type, has no chromatic aberration over wide field of view, gives us clear and sharp images.

The AVNIR-2 is a successor to ADEOS/AVNIR, which was a four-band optical sensor launched in 1996. The AVNIR-2 has almost same optics and configuration as the AVNIR. The main modification is detectors and following electronics.

The PALSAR, which is developed in cooperation with JAXA and METI/JAROS, has a variable off-nadir capability between 10 to 51 degrees using active phased array technique with 80 transmitting/receiving modules. Operation modes of PALSAR are "fine mode" which is 10m spatial resolution and 70km swath width in HH or VV single polarization, "ScanSAR mode" which is 100m resolution and up to 350km swath with HH or VV, and "Polarimetric mode" which will be operated in an experimental basis. Polarization is changed in every pulse of transmission signal, and dual polarization signals are simultaneously received.

This paper describes the detail of these three sensors and supporting subsystems.

1. INTRODUCTION

Japanese Earth Observation Satellites are divided into two categories: land observation satellite series and atmospheric and oceanic observation ones. Land observation satellite series, such as the ALOS, is mainly for practical use and high-resolution is one of the most important characteristics of them. On the other hand, atmospheric and marine observation satellite series, such as the ADEOS-II, is mainly for scientific use and characterized

by multi-channel observation.

The ALOS is the largest satellites ever built in Japan. The size of the ALOS is roughly 9m in length and 28m in width and its mass is 4,000kg. In-orbit configuration of the ALOS is shown in Fig.1 and Table 1 shows ALOS's typical characteristics.

Detail of ALOS mission objectives can be found in published papers (Hamazaki, 1999; Tomii, 2002).

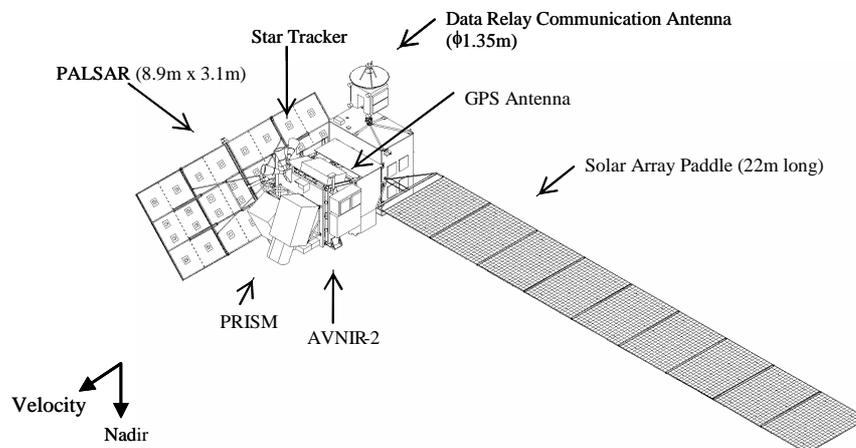


Figure 1. ALOS orbit configuration

Table 1. ALOS characteristics.

Item	Characteristics
Orbit	Sun synchronous, Sub recurrent
Altitude	691.65 km
Recurrent period	46 days, sub-cycle: 2 days
Inclination	98.16 degree
Generated power	More than 7 kW (end of life)
Weight	Approx. 4,000 kg
Data recorder	96 G bytes, solid-state
Data link	240 Mbps (via DRTS) 120 Mbps (direct down link)

2. MISSION INSTRUMENTS

2.1 PRISM

The PRISM (Osawa, 1998) is the sensor mainly for mapping. It consists of three sets of telescopes for forward, nadir and backward view and each telescope provides 2.5m spatial resolution. These specifications are given to generate precise Digital Elevation Model (DEM), and to achieve the accuracy for 1/25,000 scale maps. The PRISM will provide not only high resolution, but also wide swath image up to 70km. The PRISM's optics, which is three-mirror type, has no chromatic aberration over wide field of view, gives us clear and sharp images.

Table 2. PRISM characteristics (nominal).

Item	Performance
Scanning Method	Push broom with 8 CCDs for each telescope.
Wavelength	0.52 ~ 0.77 μm
FOV	≥ 7.6 deg
IFOV	3.61 μrad
Swath Width	70 km (nadir)
Spatial Resolution	2.5 m (nadir)
MTF @ Nyquist freq.	0.27 for cross-track 0.21 for along-track
Stereo Imaging	B/H = 1.0
Pointing Angle	± 1.5 deg
Quantization	8 bits

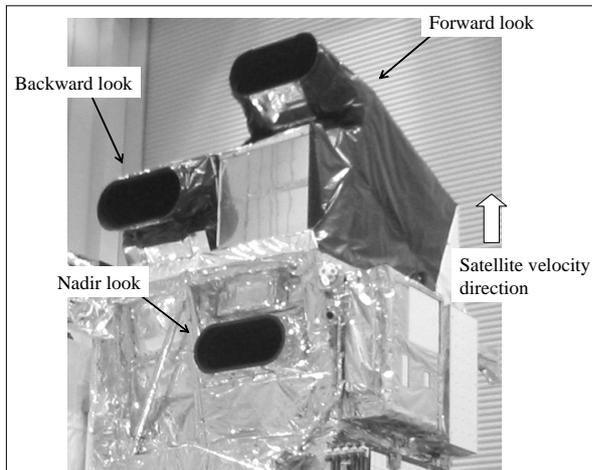


Figure 2. PRISM PFM on the ALOS at JAXA.

2.2 AVNIR-2

The AVNIR-2 is a successor to ADEOS/AVNIR (JAXA, 2004), which was launched on 17 August 1996 by Japanese H-II rocket. The AVNIR-2 has almost same optics and configuration as the AVNIR. The main modification parts are detectors and following electronics. These changes are given to achieve 10m spatial resolution compared to 16m of the AVNIR. Another modification from the AVNIR is pointing capability, which is ± 44 degree from nadir in cross-track direction. Its flexible pointing ability realizes frequent observation, e.g. every 48 hours in higher latitude area. Figure 3 and Table 3 show AVNIR-2 overview and characteristics, respectively.

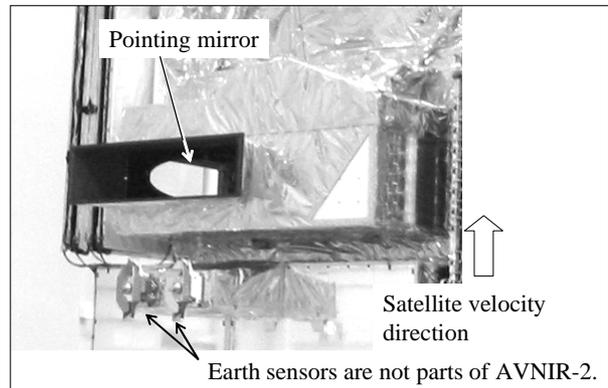


Figure 3. AVNIR-2 PFM on the ALOS at JAXA.

Table 3. AVNIR-2 characteristics (nominal).

Item	Performance
Scanning Method	Push broom with 1 CCD for each band.
Wavelength	band 1: 0.42 - 0.50 μm band 2: 0.52 - 0.60 μm band 3: 0.61 - 0.69 μm band 4: 0.76 - 0.89 μm
FOV	5.8 degree
IFOV	14.28 μrad
Swath Width	70 km (nadir)
Spatial Resolution	10 m (nadir)
MTF @ Nyquist freq.	> 0.25
Pointing Angle	± 44 degree from nadir
Quantization	8 bits

2.3 PALSAR

The PALSAR (Wakabayashi, 1998), which is developed in cooperation with JAXA and METI/JAROS, has a variable off-nadir capability between 10 to 51 degrees using active phased array technique with 80 transmitting/receiving modules. One of the major observation modes is "fine" mode. It is a high-resolution mode and the common operating mode for interferometric observation. ScanSAR mode enables us to obtain up to 350km swath data with HH or VV single polarization. Spatial resolution is about 100m in both azimuth and range directions. Polarimetric mode will be operated in an experimental basis. Polarization is changed in every pulse of transmission signal, and dual polarization signals are

simultaneously received. The operation is limited in lower incident angle in order to achieve better performance. The swath width is 30km with 30m spatial resolution under the maximum data rate condition (240M bps). Figure 4 and Table 4 show PALSAR antenna PFM and PALSAR characteristics, respectively.

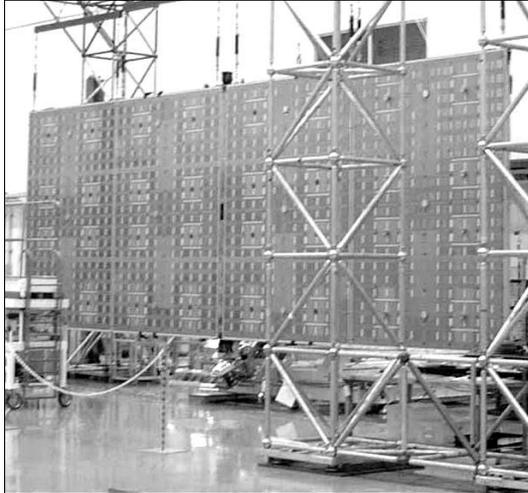


Figure 4. PALSAR antenna PFM under integration.

3. MISSION SUPPORTING SUBSYSTEMS

For supporting these observation sensors and achieving mission objectives, the ALOS bus subsystems have some unique characteristics. First one is highly stable attitude control system. In order to minimize geometric distortion of the image, satellite attitude (angular velocity) is stabilized within 2×10^{-4} degree per 5sec (equivalent to 2.5m distortion within 35km² scene). Disturbances from major vibration source, such as, data relay communication antenna pointing mechanics, AVNIR-2 pointing mirror drive mechanics, and solar array drive mechanics are carefully controlled using feed forward technique and onboard parameter tuning. Second is autonomous position and attitude determination system. High precision satellite position and attitude determination system enables users to locate exact position of each image pixel without any ground reference points. This capability is crucially important for cartography for

unmapped area. This is achieved with accurate star trackers, dual-frequency carrier phase tracking GPS receivers, and jitter sensors on board. Combining the data from dual-frequency carrier phase tracking GPS receiver onboard ALOS and that of ground GPS reference stations, ALOS position is determined within 0.2m accuracy.

Third is mission data handling system. Optical sensors' data are compressed real-time up to 1/9 using Discrete Cosine Transform for lossy compression and Differential Pulse Code Modulation for lossless compression in order to fit its communication link bandwidth. Inter-satellite communication capability allows real-time data acquisition via Japanese data relay satellite (DRTS) in 240 Mbps (Hihara, 2002). This capability is of great importance for disaster monitoring mission. The ALOS has a conventional 120 Mbps X-band direct down link for back up and for additional services to foreign receiving stations. Bit error rate is drastically reduced to the order of 10^{-16} with Reed-Solomon error correction code. The ALOS's solid-state data storage has 768Gbits memory and allows 50 minutes recording at 240M bps.

4. ALOS DATA DISTRIBUTION

The observation data produced by the ALOS on a daily basis will be about one tera byte (one trillion bytes per day) which is beyond the capabilities of any single agency to manage, however there is worldwide interest in the use of the ALOS data, JAXA proposed the concept of the "ALOS Data Nodes (ADN)". The benefits of the ADN concept are:

- to increase capacity for ALOS data processing and archiving;
- to accelerate practical and scientific use of ALOS data;
- to increase international cooperation including joint validation and joint science study activities;
- to enhance service for potential users.

The current concept envisages four nodes worldwide, shown in Table 5, in order to achieve the necessary global coverage. Each Node, associated with a geographical zone shown in Figure 5, has responsibility for the physical residents therein as potential ALOS users. The Antarctica is a common region to all nodes' agencies.

Table 4. PALSAR characteristics.

Operation mode	FBS	FBD	Direct downlink	ScanSAR	Polarimetric
Chirp bandwidth	28MHz	14MHz	14MHz	14MHz, 28MHz	14MHz
Polarization	HH, VV	HH+HV, VV+VH	HH, VV	HH, VV	HH+VV+HV+VH
Incidence angle	8 - 60 deg.	8 - 60 deg.	8 - 60 deg.	18 - 43 deg.	8 - 30 deg.
Range resolution	7 - 44 m	14 - 88 m	14 - 88 m	100 m (multi Look)	24 - 89 m
Observation swath	40 - 70 km	40 - 70 km	40 - 70 km	250 - 350 km	20 - 65 km
Bit length	5 bits	5 bits	3 / 5 bits	5 bits	3 / 5 bits
Data rate	240 Mbps	240 Mbps	120 Mbps	120Mbps, 240 Mbps	240 Mbps
Radiometric accuracy		scene : 1 dB / orbit : 1.5 dB			
Center frequency		L band (1270MHz)			

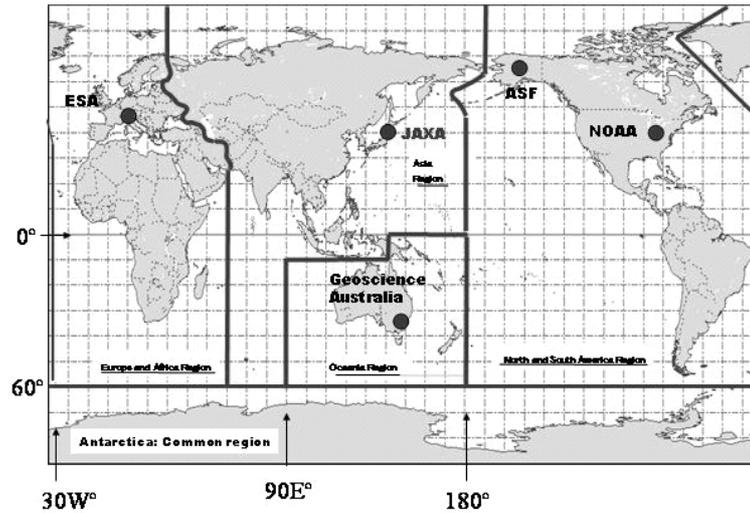


Figure 5. ALOS data nodes' zones defined geographically.

Table 5. ALOS data node partners.

Agency	General zone of responsibility
ESA	Europe and Africa
NOAA/ASF	North and South America
Geoscience Australia	Oceania
JAXA	Asia

5. MAPPING CAPABILITY

As stated above sections, the ALOS system design is optimized for satellite mapping. Unlike current high-resolution commercial satellites, the ALOS realizes:

- **global coverage** by wide swath (up to 70km) and high resolution (2.5m) optical sensors, a massive data storage (96G bytes) on-board and longer visibility from a ground receiving station using a Japanese data relay satellite in geostationary orbit,
- **better quality and frequent stereo/triplet images**, with the height accuracy of 5m, even in cloud-capped area by in-track optical sensors and/or SAR in conjunction with a highly stable attitude control system,
- **GCP-free pixel position determination** by highly accurate position and attitude determination with very low thermal distortion structure.

The ALOS will provide "homogenous quality data for 1/25,000 scale global maps" including elevation, vegetation, land use and land cover data.

6. CONCLUSION

We are convinced the specification and performance of PRISM, AVNIR-2, PALSAR and other subsystems are fully met mission requirements, e.g. mapping. The ALOS data will be utilized mainly by Japanese governmental ministries, agencies and institutes, e.g. Ministry of Land, Infrastructure and Transport, Ministry of Agriculture, Forestry and Fisheries, Ministry of the Environment, Geographical Survey Institute, Japan Coast Guard, and so forth. In addition, we hope many

foreign countries try to use ALOS data as the source for their public purpose.

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