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FEASIBILITY STUDY OF SYNTHETIC APERTURE RADAR - ADAPTABILITY OF THE PAYLOAD TO KOMPSAT PLATFORM

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ABSTRACT

Synthetic Aperture Radar (SAR) has been used for mapping the surface geomorphology of cloudy planets like Venus as well as the Earth. The cloud-free Mars is also going to be scanned by SAR in order to detect buried water channels and other features under the very shallow subsurface of the ground. According to the 'Mid and Long-term National Space Development Plan' of Korea, SAR satellites, in addition to the EO (Electro-Optical) satellites, are supposed to be developed in the frame of the KOMPSAT (Korean Multi-Purpose Satellite) program. Feasibility of utilizing a SAR payload on KOMPSAT platform has been studied by KARI in collaboration with Astrium U.K. The purpose of the SAR program is Scientific and Civil applications on the Earth. The study showed that KOMPSAT-2 platform can accommodate a small SAR like Astrium's MicroSAR. In this paper, system aspects of the satellite design are presented, such as mission scenario, operation concept, and capabilities. The spacecraft design is also discussed and conclusion is followed.

Keywords: SAR, KOMPSAT, radar

1. INTRODUCTION

Synthetic Aperture Radar (SAR) is an active sensor using microwaves, so that observations can be made without disturbance of atmosphere and regardless of light (i.e. day and night). Therefore, SAR is an effective and efficient means, as it acquires same objects frequently without interruption by atmospheres. It can also be useful in emergency state by the same reason.

The surface of Venus cannot be seen in optical region from outside because of the dense and opaque atmosphere of Venus. Therefore, Magellan equipped a SAR and the surfac was scanned through the thick cloud. Geomorphology maps were achieved three times during 1990 and 1992, with a vertical resolution of approximately 100m (see http://www.jpl.nasa.gov/magellan/)(Figure 1 and 2).

Other aspect of SAR may be used on Mars. A SAR would be used for detecting buried water under the very shallow surface ($3 \sim 5$ meters deep) as well as mapping the surface geomorphology. The proposal of 'Mars Scout Radar' by Institution's National Air and Space Museum was selected as one of ten concepts under NASA's Mars Scout program (Savage 2001). It is in the stage of further study for detailed concept design.

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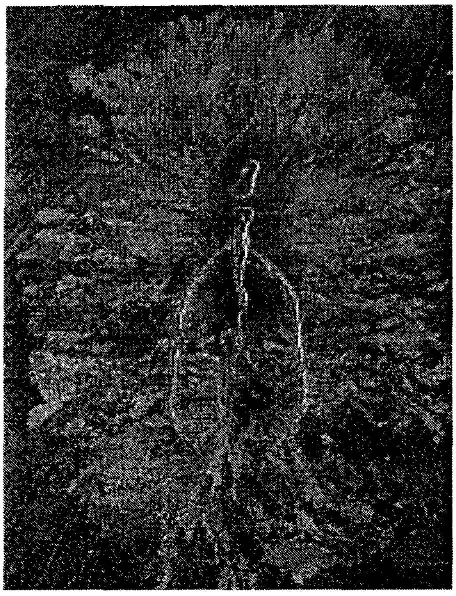

Figure 1. A section of a Magellan radar image of a 40 x 60 km "petal" type volcano in eastern Aphrodite Terra.

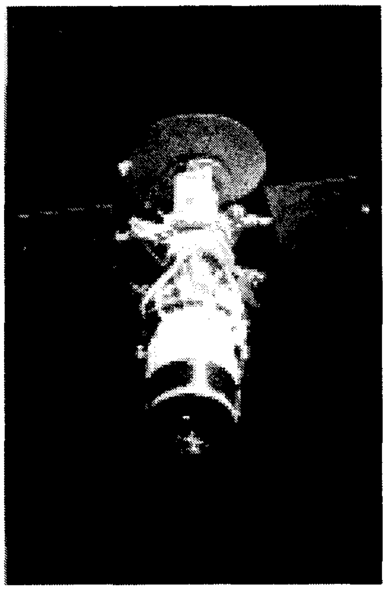

Figure 2. Magellan spacecraft.

Table 1. Characteristics of SAR satellites for remote sensing.

Satellite	Mission Dates	Band	Polarization	Incidence angle	Swath width [km]	Resolution [m]
Seasat	1978	L	HH	23	100	25
SIR-A	1981	L	HH	50	50	40
SIR-B	1984	L	HH	15 ∼ 55	20 ∼ 50	17 ∼ 58
SIR-C	1990	L,C,X	all	15 ∼ 55	15 ∼ 90	10 ∼ 60
ERS-1/2	1991, 1995	C	VV	23	100	30
JERS-1	1992	L	HH	35	75	18
RADARSAT	1995	C	HH	20 ∼ 59	50 ∼ 500	10 ∼ 100

On the other hand, SAR has long been used for Remote Sensing. Since the development and launch of Seasat in 1978, a dozen of SAR satellites has been launched. Table 1 shows the characteristics of major SAR satellites (Youn et al. 2001).

Korea is also going to develop SAR satellites. According to the 'Mid and Long-term National Space Development Plan' (MOST 2000) of Korea, as represented in Table 2, Two SAR satellites are supposed to be developed among the eight KOMPSAT (Korean Multi-Purpose Satellite) satellites. They are KOMPSAT-5 in 2010 of launching year and KOMPSAT-7 in 2014.

In order to launch the KOMPSAT-5 in 2010, design and development of the satellite would start from 2005, and feasibility study should be finished prior to that. In this timeline, KARI (Korea Aerospace Research Institute) started a study on SAR program in collaboration with Astrium U.K. in 2001. The study has been performed for the feasibility of utilizing a SAR payload on KOMPSAT platform. In this paper, a result of the feasibility study is presented. It is about the system aspects of the satellite design are presented, such as operation concept and capabilities. The spacecraft design is also discussed and conclusion is followed.

Table 2. Mid and long-term national space development plan.

Classification		Implementation Plan																			
		1st Stage						2nd Stage					3rd Stage					4th Stage			
		96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
5 GEOSs[a]	KOREASAT				3rd						4th										5th
	CBMS[b]													1st						2nd	
8 KOMPSATs	Electro-Optical Satellite				1st					2nd				3rd				6th			
	SAR Satellite															5th				7th	
	Hyperspectral Satellite														4th						8th
7 SSs[c]	KITSAT				3rd																
	Science Satellite							1st			2nd			3rd			4th		5th		6th

[a]Geostationary Orbit Satelites; [b]Communication, Broadcasting & Metorological Satellites; [c]Science Satellites

Table 3. Characteristics and specification of KOMPSAT-2 spacecraft.

Item	Specification/Characteristics
Mission Orbit	Altitude of 685.13 km +/- 1 km
	Circular Sun-synchronous orbit
	Eccentricity of 0 to 0.001
	Inclination of 98.13° +/- 0.05°
	Mean Local Time Ascending Node 10:50 A.M
Accommodated Payload	Mass: 141 kg
(Multi-Spectral Camera)	Power (average): 120 W
Payload Mission	2-orbit consecutive operations
Operation	- 20 % duty cycle with nadir pointing
	- 10% duty cycle with 30° roll maneuver
Spacecraft Bus Mass	520 kg (Total 750 kg launch mass)
Satellite Power	955 W [EOL]
Mission Life	3 years
Reliability	0.9 at 3 years
Attitude Stabilization	3-axis Stabilization (zero momentum bias)
Off-pointing Capability	56° Roll Maneuver, 30° Pitch Maneuver
Pointing Accuracy	Roll & Pitch: 0.025 degrees; Yaw 0.08 degrees (2σ)
Link compatibility	NASA/STDN, ESA Standard
Link margin	A minimum 3 dB on the S-band link at 5-degree
	elevation angle
Data rate (S-band)	Uplink: 2 kbps
	Downlink: 2.048 kbps(real time), 1.5 Mbps(playback)
Data rate (X-band)	Downlink: 320Mbps (part of MSC)
Data format	CCSDS Compatible

2. KOMPSAT SYSTEM

The feasibility study is based on the structure of present KOMPSAT design and it finds out the possibility of loading SAR payload on the KOMPSAT bus. The basic data of KOMPSAT-2 was given as below in Table 3 and the configuration is shown in Figure 3.

Further key features of the KOMPSAT-2 spacecraft bus are summarized as follows:

- Modular design, which is a hexagonal shape, allows for simple design modification and parallel integration
- All panels, platforms with aluminum alloy facesheets bonded to a aluminum alloy honeycomb core with the exception of solar array

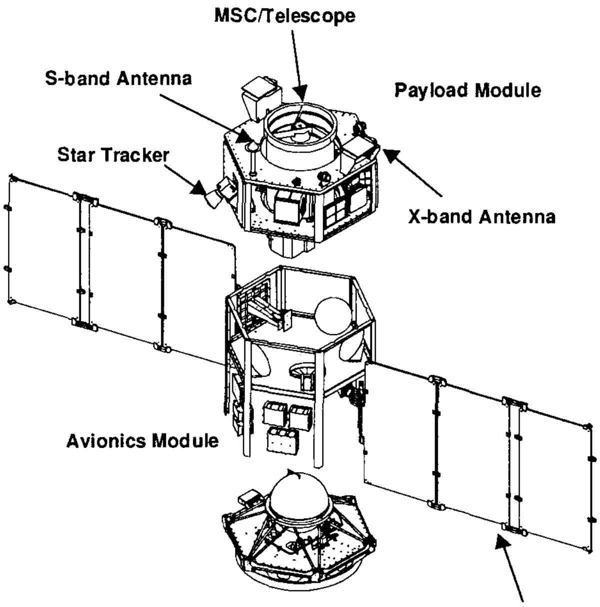

Figure 3. KOMPSAT-2 Configuration with Modular Design.

- Dedicated heat pipes and second surface mirror radiator for battery assures proper battery thermal control
- MIL-STD-1553B data bus which provides open architecture and facilitates technology insertion and growth for future missions
- Precision attitude determination using star tracker and gyro
- Zero momentum bias (ZMB) closed-loop system with four reaction wheels, providing accurate three-axis pointing capability
- C & assembly language coded flight software with 80386 processors
- GaAs cell solar array solar as prime power source
- 37 A-hr super NiCd battery
- Hydrazine monopropellant thrusters with blowdown pressure-fed system
- Diaphragm propellant tank with 73kg propellant

3. MICROSAR

MicroSAR, as the name depicts, is a group of small-size SAR satellites which has been developed by Astrium U.K. funded by BNSC (British National Space Centre). The aim of MicroSAR program is development of a range of low-cost SAR satellites. It uses much of the existing technology, therefore it is in a risk-reduced phase. There are three members in the family of MicroSAR, MicroSAR-1000, MicroSAR-2000, and MicroSAR-3000, at present.

MicroSAR-1000 is the smallest of the MicroSAR range with lowest cost. The performance is primarily defined by storage and downlink speed of the data, and the simplest technology is employed. The mass would be about 200 kg, and size is 2.6 m$\times$1.1 m. Altitude of the orbit is between 500 $\sim$ 600 km. Table 4 shows the performance of the MicroSAR 1000. MicroSAR-2000 is an

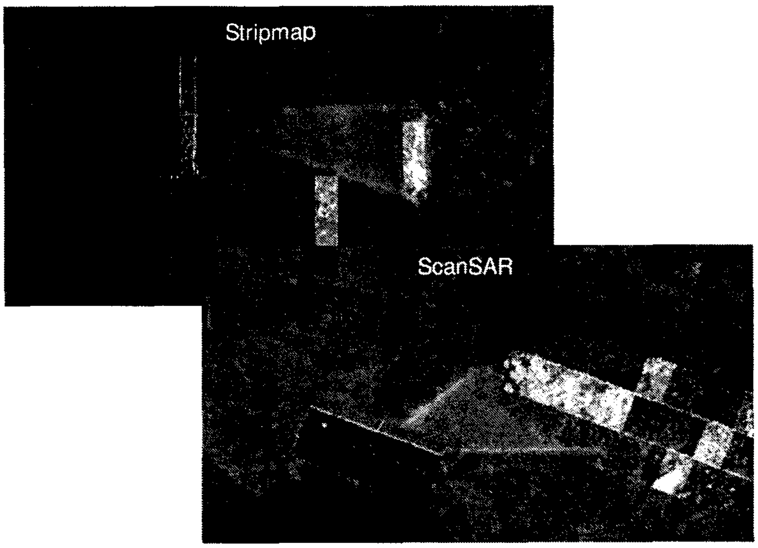

Figure 4. Stripmap and ScanSAR modes for MicroSAR.

Table 4. Performances of MicroSAR-1000.

Mode	Polarisation	Resolution	Swath Width	Swath Length	Sensitivity
Stripmap	single HH	5∼10m	15km	40 - 50km for 2Gbit store, 200 - 250km 10Gbit store	-20 dB
ScanSAR	single HH	15∼30m	40∼50km	100km for 2Gbit store, 500 - 700km 10Gbit store	-22 dB

enhanced form of MicroSAR-1000 (Figure 4).

The payload is an X-band SAR which operates in various modes providing resolution from a few meters to several tens of meters. A typical x-band SAR antenna has dimensions about 3m to 5m long and 0.5m to 1m wide. The antenna view is offset from nadir by about 30 degrees, which would be adjusted between 15 to 50° left and right-hand side of track. The adjustment can be achieved either by mounting the antenna at an angle to the spacecraft body or maneuvering the spacecraft at an angle of the orbit axis. Table 5 gives the detail of MicroSAR payloads (Astrium Ltd. 2001).

The radar equipment requires 47W during warm-up, lasting 10 minutes prior to imaging. During imaging, though the actual power requirements depend on mode, average power is 150W and the radar transmitter can take up to 1500W (radar peak power). The radar peak power will be supplied by batteries built into the radar.

In fact, there may be a drawback for the MicroSAR payload. It is based on X-band SAR, which has not been used much in space for remote sensing of the Earth. As is depicted in Table 2, most of the SAR missions have been operated in C-band and L-band.

4. FEASIBILITY STUDY

Feasibility of applying MicroSAR payload by using KOMPSAT-2 platform has been studied. Table 6 depicts summary of the system, and the other details are the same as those of KOMPSAT, as described in chapter 2 and Table 3. The MicroSAR payload has a nominal mass of 150 kg in

Table 5. Characteristics of MicroSAR payloads.

Equipment	MicroSAR-1000	MicroSAR-2000
Antenna size	2.5 m×1.1 m	2.5 m×1.1 m
Polarization	Single	Dual
Structure	MicroSAR antenna	MicroSAR antenna
Radar RF	50 MHz single channel	50 MHz dual redundant
Data Store	16 Gbit	64 Gbit
Data downlink	15 Mb/s minimum	105 Mb/s

total, which includes approximately 100 kg of the active antenna. The simplest arrangement is to mount the SAR antenna on to one of the side panels of KOMPSAT, and to mount the control electronics units in the payload module. The maximum launch mass of the system is 800 kg, which is similar to the launch mass of KOMPSAT-2, 750 kg. Therefore, the mass is within the overall mass capability of KOMPSAT as the payload mass is similar to that of KOMPSAT-2. The subsystems of the KOMPSAT-2 would be applied directly to this system. As for the power supply, it seems capable of using KOMPSAT-2 power supply subsystem because the required power of MicroSAR (150W) is similar to that of the KOMPSAT-2 payload (120W). The surplus of 30W is not a big matter considering the total power of KOMPSAT-2, 955W.

5. CONCLUSION AND DISCUSSIONS

A feasibility study has been conducted, which is employing a MicroSAR payload on the KOMP SAT-2 platform. The study showed that KOMPSAT-2 platform can accommodate the payload of MicroSAR. The dimensions of the structure allow a SAR antenna capable of resolution below 3m, while the power generation is capable for sun-synchronous orbit. The mass is also allowable to the capability of KOMPSAT-2.

Among the specifications, the data downlink system is one to be investigated further. The present KOMPSAT installation provides the capacity for high data rate downlinks of 320Mbps, which can be reduced to 105Mbps, the downlink data rate of MicroSAR. A trade-off study may be needed to avoid over-design.

One more aspect to be considered is that a X-band SAR is applied for the study, which has been less frequently used than C-band or L-band SAR. More detailed survey and further study should be made regarding SAR data applications.

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