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A Conceptual Study on RICESAT

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Abstract: The conceptual study results on a small satellite named ''Ricesat'' is performed. This satellite carries dual frequency (L band and C band) SAR dedicated for rice paddy area classification and grow monitoring. A non-sun synchronous orbit is chosen with the inclination angle of 28 degrees and altitude of 618 km so that it covers most of rice growing area and achieves high observation repeatability.

Zusammenfassung: *Eine Konzept-Studie zum Ricesat*. Die Ergebnisse der konzeptionellen Studie über den Kleinsatelliten „RICESAT“ liegen vor. Dieser Satellit trägt ein Dual-Frequenz-SAR (L-Band und C-Band), das für die Klassifizierung von Reisfeldern und Wachstumsmonitoring vorgesehen ist. Ein nicht-sonnensynchroner Orbit mit einem Inklinationswinkel von 28° und einer Höhe von 618 km wird ausgewählt, so dass der größte Teil der Reisanbauflächen überdeckt und eine hohe Wiederholbarkeitsrate der Überwachung erreicht wird.

1 Introduction

In 6th Asia Pasific Regional Space Agencies Forum held at Tsukuba Space Center of NASDA, Japan (1999), a group of experts from Asian countries created an idea to initiate a satellite system to benefit regional people in Asian countries and proposed an Earth observation satellite which carries synthetic aperture radar. Mission of the satellite is to provide means to evaluate rice harvest and grow monitoring from space, and to establish real time direct data path to local end users. This paper introduces a design of a satellite and sensors to fulfill their requirements.

2 Basic Requirements

To realize the mission of the satellite system, basic parameters were set as design goal. They are:

(1) Sensors are dual frequency and dual polarization
(2) Spatial resolution of SAR must be less than 30 m
(3) To observe all area of interest once a week,
(4) Capability of repeat path interferometry,
(5) Satellite path covers only tropical areas.

3 Total System Concept

Total system concept is drawn by reflecting slow response of data distribution. Basic concept is to deliver satellite row image data to local end users on real time basis. The computer environment is matured enough to handle row SAR data on PC as well as SAR data analysis on PC. Only the problem is data link margin for small ground antenna of end users. To solve the problem satellite data link antenna coverage is designed to illuminate the SAR antenna coverage. End users located SAR observation area can receive real time data by the concentrated data link antenna illumination. Traditional wide coverage data link also remains to accumulate regional archive of data or analysis. Total system configuration is illustrated in Fig. 1.

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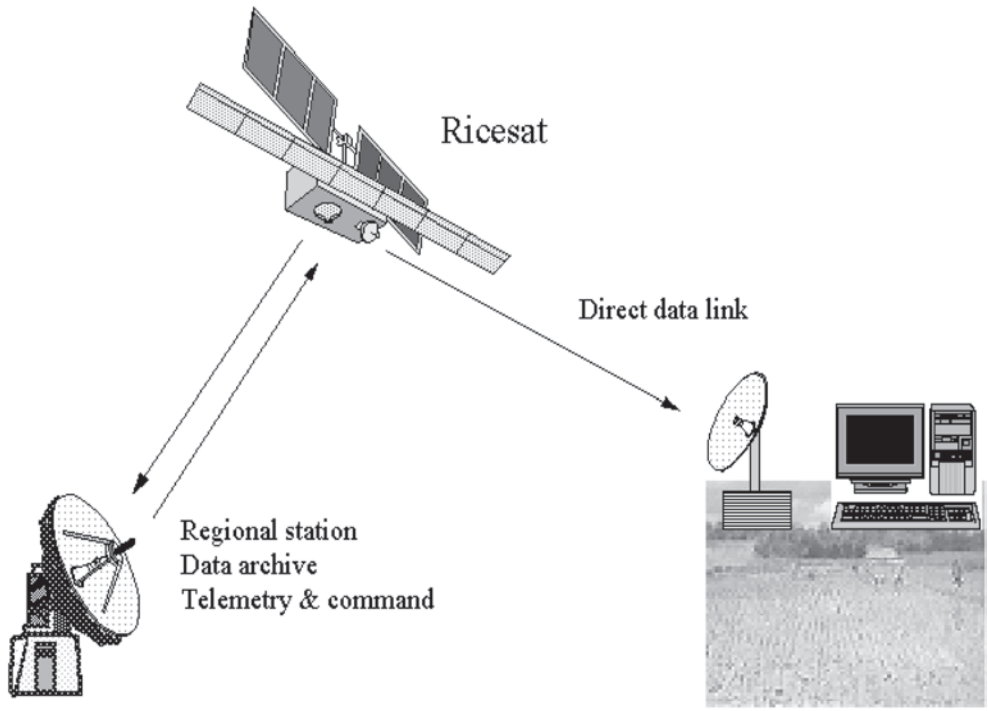

Fig. 1: System concept of "Ricesat".

4 Satellite Orbit Design

Orbit design of SAR satellite is mainly restricted by achievable swath width of SAR. To fulfill the requirement of high repeatability, swath width must be as wide as possible. As a result, along track SAR antenna size become large. Alternative for SAR design to reduce SAR antenna dimension is to use short burst scan SAR but it increases complexity of SAR antenna design and increase mass of antenna sub system. In our design, simple strip mode SAR is adopted and achieves swath width of 210 km.

In order to satisfy the request of high repeatability to all observation region and to achieve repeat path interferometry, an sun-asynchronous quasi recursive orbit is adopted. By choosing sub recursion as 7 days, any location is observed every 7 days. To fill gaps between adjacent sub tracks by the 200 km swath, orbit inclination is reduced significantly compared with polar orbited sun synchronous satellite. To satisfy the capability of repeat path interferometry, orbit of the satellite must return to the same orbit with very small displacement. In our approach a small orbit control error is allocated to achieve the small displacement. As the result of several candidates an orbit parameter is

Tab. 1: Orbit parameters.

Parameter	Value
Altitude	617.74 km
Inclination	28.075 degree
Period	97.057 minutes
Major recursion	49 days
Sub recursion	7 days
Nodal cycle	727

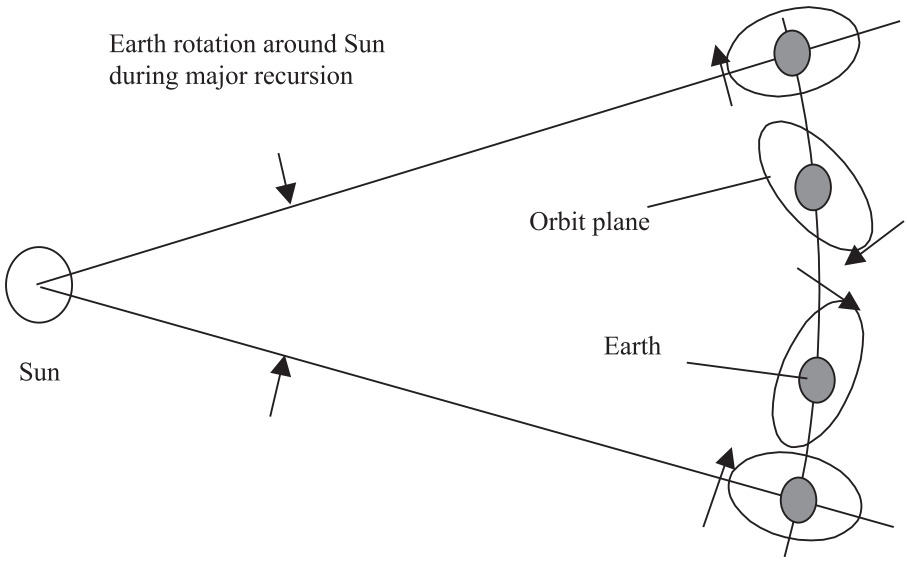

Fig. 2: Nodal point rotation of synchronous recusive orbit.

selected to satisfy most of the orbit requirements as shown in Tab. 1.

Orbit inclination is 28 degrees, by which most of rice growing area is covered by SAR observation. Sub recursion of the orbit is 7 days and major recursion is 49 days. By strip mode SAR operation, a place on the Earth is observed every 7 days with 7 different incident angles. A pair of single look complex data with 49 observation day separation make an interferometry pair. By the low inclination angle, there is no gap between adjacent 7 days sub recursion locus of sub satellite trace even with 210 km swath width SAR. Nodal point of orbit in inertial space rotate opposite direction of earth rotation, which is illustrated in Fig. 2.

5 SAR System Design

SAR system is simple strip mode operation. Designed parameter is shown in Tab. 2 (L and C band). Rice paddy area estimation is mainly performed by L band SAR and grow monitoring is performed by C band SAR. Since the target area is agriculture field, noise equivalent sigma naught is set relatively high compared with all purpose SAR system. This setting allows us to realize the system with feasible electric power range onboard satellite.

Tab. 2: SAR parameters.

Item	L band	C band
Frequency (GHz)	1.3	5.3
Incident angle (degree)	26.5	26.5
NE sigma naught (dB)	−25	−22
Resolution (meter)	25	25
PRF (pps)	1184	1184
Number of Looks	4	4
Antenna size (meter)	12.75 × 0.85	12.75 × 0.21
Signal Band width (MHz)	16.11	16.11
Bit/sample	3	3
Data rate (Mbps)	76.09	76.09
Transmission Power (Kw)	2.43	4.51
Power Consumption (Kw)	0.58	1.18

Data rate is still high for local PC data reception system. Relaxation of ground resolution or reduction of sample bit may be required in more detailed design phase.

6 Satellite Design

To realize the satellite system, satellite bus system must be carefully designed. In consideration of the request for interferometry,

Tab. 3: Mass Allocation.

Subsystem	Mass	Note
SAR Antenna	100 kg	L(HH,HV) + C(HH,HV)
SAR Electronics	60 kg	L + C
Sat. Structure	120 kg	
Thermal	25 kg	
Power	100 kg	16 sqm, Power = 2.3 Kw (EOL), battery is minimum (no operation at eclipse)
TT&C	26 kg	
ADCS	40 kg	Attitude determination and control
Propulsion	40 kg	
Total	511 kg	

satellite attitude control system is 3 axis stabilization. From existing component and our experience, rough sketch of satellite mass allocation is estimateds as shown in Tab. 3. Total mass exceeds 500 kg at this level which may a bit heavy from general small satellite concept. To reduce total mass, mission must be separated into several satellites like L band mission and C band mission, or narrow swath convoy of satellites. This mission separation will also relax data link restrictions.

7 Conclusion

In conclusion, "Ricesat" design is performed with a feasible design example. From the designed parameter, data link is a bit heavy load and mass of the satellite is exceeding small satellite concept. We may have to divide satellite into 2 or more separate missions to reduce the size of satellite in the more precise design phase. Yet, SAR satellite with sun-asynchronous orbit is a promising solution for the monitoring of Earth's surface.

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