A MICROWAVE RADIOMETER PAYLOAD DEFINITION FOR TAIWAN'S SMALL SATELLITE MISSION

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ABSTRACT: Monsoons and typhoons bring along heavy precipitation that produce great threats (i.e., mud slide, land slide, river flooding, etc.) in Taiwan which have caused tremendous disasters and the predicted future trend of them can be even more devastating. A multi-channel MicroWave Radiometer (MWR) space instrument, with its advantages of all-weather capability, repeat pass orbit selected, wide swath, can provide not only in-time coverage and daily monitoring for a disaster early warning system (i.e., beyond the ground radars ranging distances from the Taiwan island) in terms of the key precipitation and other parameters needed by the CWB (Central Weather Bureau) of Taiwan and the operations organizations/agencies for disasters mitigation in Taiwan. This paper describes a payload definition effort for an envisioned Taiwan's small satellite mission with its on-going and projected work.

1. Introduction

MWR space instruments have been developed and deployed in a few countries across Asia, including the AMSR-E of Japan upon the international EOS Aqua platform, the MWRI upon the FY-3 platforms of China, and the DREAM upon the Korea's STSAT-2 microsatellite. Normally, a MWR space instrument will be accommodated in a space platform with other remote sensing payloads. NSPO of Taiwan has developed a few optical imaging missions upon its small satellite bus. A small satellite SAR space instrument mission has also been studied as a possible future primary payload (Chen, 2010) upon a satellite to be launched by a small satellite launcher. It is envisioned that a secondary payload like the MWR space instrument would be a good candidate to be studied as well. Thus, it is logical to plan a small satellite MWR payload which can satisfy the vital interest in early precipitation estimation for the disasters mitigation in Taiwan along with a SAR payload when operated together upon a small satellite platform.

2. Mission System Architecture

The first mission orbit has been considered for the two microwave payload satellite mission is a SSO (Sun Synchronous Orbit) with the spacecraft flying in a LEO (Low Earth Orbit). The orbit was selected mainly for imaging (via side-looking of SAR and down-looking of MWR) the Taiwan island and its neighboring environments (atmosphere and sea) twice per day. The mission system architecture will be active in operations when the satellite passing above Taiwan. Since it will pass above Taiwan twice a day (with one ascending pass and the other descending pass roughly 12 hours later) which is different from other envisioned SSO space MWR instruments to be concurrently flown (GMI, other NOAA and USAF payloads, etc.). It has thus formed a MWR mission system architecture (see Table 1) allowing a loyal watchman (the satellite in mission operations) to watch for Taiwan twice daily with other infused data.

Table 1: MWR Mission System Architecture (for illustration only)

Altitude / Inclination	561 km / 97.64 deg	First orbit selection
Mean Motion	15 rev / day	
Revisit Cycle / Repeat Cycle	1 day / 1 day	Two passes (one ascending pass and one descending pass)
MWR Swath Width	more than 1,200 km	To be Verified
Daily Ground Contact Time for Elevation of 10 degrees / 20 degrees / 30 degrees	20 minutes / 5 minutes / 4 minutes	Existing NSPO ground infrastructure will be employed
Mission Operations Concept	Needs to coordinate with the SAR primary payload to maximize the satellite mission value for the operations above Taiwan	X-band data download capability (satellite) will be shared by the two payloads

3. Mission Feasibility Framework Constructed

A mission feasibility study was performed to investigate the possibility to place a MWR space instrument upon a small satellite platform based on the user requirements surveyed and studied (Liu, 2011a). The main user requirements specified in the report are the sensing frequencies of 1.4 GHz, 6.9 GHz, 10.7 GHz, 18.7 GHz, 23.8 GHz, 36.5 GHz, and 89 GHz for various targets of observation such as soil moisture, water vapor, raindrop, cloud liquid water, fog, sea surface temperature, sea surface wind speed, vegetation, etc. The 1.4-GHz frequency channels will not be considered due to the small antenna size selected for the optimal MWR payload accommodation as shown in Figure 1. Furthermore, the spatial resolution requirements and radiometer sensitivities upper bound for each frequency have been studied and recommended as shown in Table 2 (Liu, 2011b). These findings should represent a set of top-level payload system requirements for deriving and defining the payload system since these limits have been considered and constructed by comparing them with those of the similar instruments like AMSR-E, TMI, and SSM/I.

Table 2: Top-level MWR Payload Resolution Requirements and Sensitivities (to be achieved)

Frequency (GHz)	6.9	10.7	18.7	23.8	36.5	89
Resolution (Km)	64	42	23.7	18.6	12.3	5
NEDT (K)	0.4	0.6	0.7	0.7	0.5	0.9

Normally, physical constraint of payloads sizing is caused by the limited available payloads accommodation space upon the space platform. A SAR primary payload has been studied for a possible future NSPO satellite mission and a MWR secondary payload is to take advantage of the residual dimension of the satellite under the faring size of a baseline small satellite launcher (see Figure 1 for the two payloads upon the small satellite bus used for the FORMOSAT-2 mission). Figure 1 shows that there may have enough space for accommodating the two microwave payloads if the SAR payload architecture can be constructed based on a deployable lightweight reflector antenna technology (Yaung, 2011). Understanding the sizing issue, one should always know that the weight of a secondary payload will be limited in the practice of NSPO mission and payloads planning. For the time being, it is understood that the weight of the MWR payload should be no more than 100 kg for avoiding the weight to grow into a quantity similar to AMSR-E. This weight limit has established the engineering challenge upon our current payload design while trying to satisfy the top-level payload system requirements formed with the above mentioned process.

4. Payload System Definition

4.1 Preliminary MWR Payload Mission Requirements

Understanding the system design requirements and the possibility of the two payloads accommodation, MWR payload system definition study has been performed with three reports generated (Chung, 2011). An 11-channel mechanical scanner system has been defined with the six identified frequencies (i.e., 6.9 GHz, 10.7 GHz, 18.7 GHz, 23.8 GHz, 36.5 GHz, and 89 GHz) for satisfying a set of preliminary MWR payload mission requirements as follows.

- Frequencies (center): See their values in Table 2 for all frequencies
- Sensitivities: See their values in Table 2 for all frequencies
- Spatial Resolutions: See their values in Table 2 for all frequencies
- Swath: ≥ 1,200 km (TBR)

- Satellite Downlink capability: 300 Mbps
- Revisit Time above Taiwan: 2 per day
- Space platform: small satellite
- Launcher: Potential small satellite launcher
- Store-and-Dump capability should be available to reduce the downlink data rate requirement
- X-band down-link, S-band Command and Telemetry
- Mission Lifetime ≧ 5 years

4.2 Payload Architecture

After trade studies performed, a feasible payload architecture was formed to determine the key parameters for the payload system and its subsystems and interfaces. The trade studies and payload system/subsystem definition work have been performed with the surveyed data (such as the data specifications for the receivers key parts/components).

The trade study results are summarized as follows:

1) Based on the stowed satellite configuration, the antenna size of an off-center reflector was designed to be equal to or less than 1.2 meter for deriving the key payload system parameters for each frequency with the selected conical scanning mechanism. Two-point hot/cold source calibration techniques will be applied along with the antenna design. The key system parameters to be examined first for the trade study include antenna size, footprints, integration time, reflector revolution rate and sensitivity (Skou, 2006).

2) Dicke-type radiometer has been favorably selected as the baseline technology among the other two kinds of radiometer (i.e., total power radiometer and NIR-type radiometer). Noise figures of possible receivers for each frequency have also been estimated based on the collected specification sheet data for the receiver front-end device, such as LNA.

4.3 Payload Parameters Determination

Table 3 shows some preliminary result of this payload system parameters derived with a goal of satisfying the top-level system requirements for the 561-km SSO case. Note that MWR soil moisture mapping using the 6.9 GHz channels with its intended resolution may be still of some interest to the users with the needs of generating large scale maps. For finer investigation of the local disaster areas such as those in Taiwan, it will be better taken care by the SAR soil moisture imaging capability since it can provide mapping of finer resolution with the SAR in its baseline Stripmap mode.

5. Description of Further Important Work

Further design into the level of payload subsystems has been performed for better defining a payload specification for future hardware procurement and/or development in Taiwan. Current investigation result has shown that it is possible and feasible to place a MWR payload system upon the small satellite as a secondary payload with a 6-frequency system under 100 kg. The system performances need to be optimized between the antenna size and the top-level system requirements.

The mission objective of enhancing the disasters mitigation capability in Taiwan via the complementary operations of the MWR payload defined with the SAR primary payload will definitely cause social impacts once the system in operations with the other concurrent space systems for sharing the data.

The mission operations scenarios study for the MWR MDD to be performed will be important. Other possible MWR payload applications studied (Liu, 2011c) including areas for the scientific contributions and international cooperation can also be further investigated for their mission operations feasibilities.

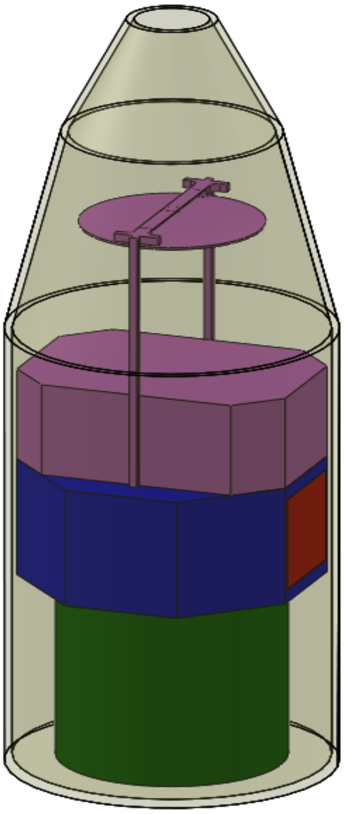

Figure 1: Stowed Satellite Configuration for Illustration of the two Microwave Payloads to be Accommodated

(Note 1: 1.2-m reflector MWR allocation (colored in purple) at the top, SAR allocation (colored in blue) in the middle, and FORMOSAT-2 satellite bus (colored in green) at the bottom within the fairing of a Taurus Launcher)

Table 3: Preliminary Result of Payload System Parameters Derived (561-km SSO Case)

Parameter	**Characteristic**					
Frequency (GHz)	6.9 (1.2)	10.7 (1.0)	18.7 (1.0)	23.8 (0.8)	36.5 (0.8)	89(0.6)
Beam efficiency	Higher than 92%					
Beamwidth (°)	2.9	2.25	1.28	1.26	0.82	0.45
Diameter of reflector (m)	1.2					
Swath (km)	1205 (β=70°)					
Incidence Angle (degrees)	53 (Conically Scanned)					
Foot print (km)	44.3* 73.6	34.2* 56.9	19.6* 32.6	19.3* 32.0	12.5* 20.9	6.9* 11.4
Integration time (ms)	57.0	34.1	11.2	10.8	4.6	1.4
Revolution speed (rpm)	27.2					
Noise Figure (dB)	2.9	3.2	3.2	3.4	3.4	5.3
Bandwidth (MHz)	350	100	500	400	1500	3000
ΔT (K)	0.22	0.59	0.46	0.55	0.44	0.91

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