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Development of Synthetic Aperture Radar onboard Aircraft and Microsatellite for Global Land Deformation Observation

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Abstract

Synthetic Aperture Radar (SAR) is well-known as a multi-purpose sensor that can be operated in all-weather and day-night time. As our laboratory roadmap for microsatellite, aircraft, and unmanned aerial vehicle development, our laboratory develops synthetic aperture radar (SAR), especially Circularly Polarized Synthetic Aperture Radar or Elliptically Polarized Synthetic Aperture Radar (CP-SAR or EP-SAR, Patent Pending 2014-214905) to monitor global land deformation. The sensor is designed to transmit and receive left-handed circular polarization (LHCP) and right-handed circular polarization (RHCP). For this purpose, we also develop unmanned aerial vehicle (UAV) for ground experiment of this sensor. The main mission of CP-SAR is to hold the basic research on elliptically polarized scattering and its application developments. In the basic research, we will investigate the elliptical (including circular and linear polarizations) scattering wave from the land surface, generation of axial ratio image (ARI), ellipticity and tilted angle images etc. We will hold the analysis and experiment of circularly polarized wave scattering on vegetation, snow, ice, soil, rock, sand, grass etc to investigate the elliptical scattering wave. These images will be extracted by using the received RHCP and LHCP wave. CP-SAR sensor transmits only one polarization, RHCP or LCHP, then this sensor will receive RHCP and LHCP scattering waves simultaneously. The image is employed to investigate the relationship between the physical characteristics of vegetation, soils, snow etc. The image of tilted angle as the response of land surface also will be extracted to mapping the physical information of the surface, i.e. geological matters etc. In application development, CP-SAR sensor will be implemented for land cover mapping, disaster monitoring, Cryosphere monitoring, oceanographic monitoring etc. Especially, land cover mapping will classify the forest and non-forest area, estimation of tree trunk height, mangrove area monitoring, Arctic and Antarctic environment monitoring etc. In disaster monitoring, CP-SAR sensor will be employed for monitoring of earthquake area, volcano activity, landslide etc. This paper introduces progress on development of our SAR onboard Boeing 737-200 aircraft and microsatellite.

Keywords
Microsatellite, synthetic aperture radar, CP-SAR, UAV, Aircraft

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1. Introduction

Synthetic Aperture Radar (SAR) is well-known as a multi-purpose sensor that can be operated in all-weather and day-night time. As our laboratory roadmap for microsatellite, aircraft, and unmanned aerial vehicle development (refer Fig. 1), our laboratory develops SAR, especially Circularly Polarized Synthetic Aperture Radar or Elliptically Polarized Synthetic Aperture Radar (CP-SAR or EP-SAR, Patent Pending 2014-214905) to monitor global land deformation. The sensor is designed to transmit and receive left-handed circular polarization (LHCP) and right-handed circular polarization (RHCP), see Fig.2. For this purpose, we also develop unmanned aerial vehicle (UAV) for ground experiment of this sensor (Sri Sumantyo 2011 & 2012), see Fig.3 and Fig.4.

The main mission of CP-SAR is to hold the basic research on elliptically polarized scattering and its application developments. In the basic research, we will investigate the elliptical (including circular and linear polarizations) scattering wave from the land surface, generation of axial ratio image (ARI), ellipticity and tilted angle images etc. We will hold the analysis and experiment of circularly polarized wave scattering on vegetation, snow, ice, soil, rock, sand, grass etc to investigate the elliptical scattering wave. These images will be extracted by using the received RHCP and LHCP wave. CP-SAR sensor transmits only one polarization, RHCP or LCHP, then this sensor will receive RHCP and LHCP scattering waves simultaneously. The image is employed to investigate the relationship between the physical characteristics of vegetation, soils, snow etc. The image of tilted angle as the response of land surface also will be extracted to mapping the physical information of the surface, i.e. geological matters etc.

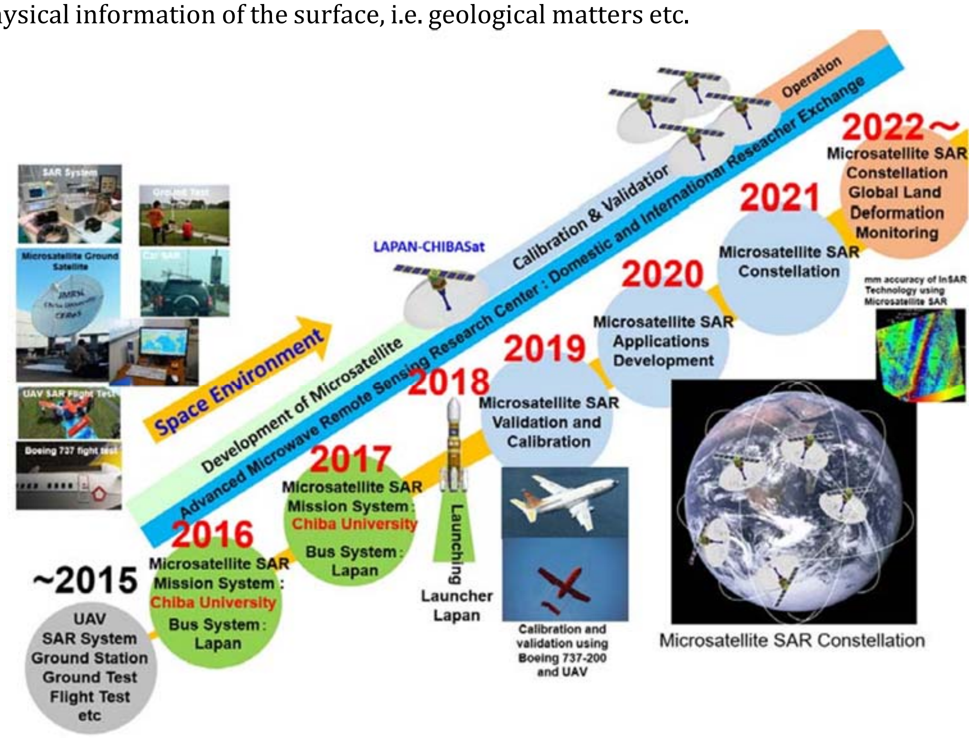

Fig.1. Roadmap of Chiba University Microsatellite

(A) L Band CP-SAR for UAV and Aircraft

(B) C & X Bands CP-SAR system for Boeing 737-200

(C) Antenna for CP-SAR onboard Boeing 737-200

Fig. 2. Circularly Polarized Synthetic Aperture Radar (CP-SAR) onboard Boeing 737-200

Fig. 3. Flight test of CP-SAR onboard UAV JX-1 at Fujikawa Airport, Japan on 29 August 2013.

Fig. 4. The 2nd Josaphat Laboratory Experimental Unmanned Aerial Vehicle (JX-2) for microwave sensor ground test

In application development, CP-SAR sensor will be implemented for land cover mapping, disaster monitoring, Cryosphere monitoring, oceanographic monitoring etc. Especially, land cover mapping will classify the forest and non-forest area, estimation of tree trunk height, mangrove area monitoring, Arctic and Antarctic environment monitoring etc. In disaster monitoring, CP-SAR sensor will be employed for monitoring of earthquake area, volcano activity, landslide etc. This paper introduces progress on development of our SAR onboard Boeing 737-200 aircraft and microsatellite.

2. CP-SAR Onboard Aircraft

The CP-SAR onboard Aircraft (Fig. 5) is mainly composed by Flight Control System, Telemetry and Command Data Handling, Attitude Controller, and Sensors. Attitude Controller is composed by Inertial Measurement Unit (IMU) and GPS units. Sensors are composed by CP-SAR as main mission sensor, and other sensors. CP-SAR sub-system itself is composed by chirp pulse generator module, Transmitter and Receiver (Tx-Rx) module, and Image Signal Processing module. Ground control segment was used for CP-SAR sensor monitoring and image processing. The CP-SAR system is composed by transmitter and receiver sub modules. The input of transmitter is In-phase (I) and Quadrature (Q) signal of chirp pulse generated by pulse generator with baseband range is DC to 150 MHz (normally 50 MHz), 400 MHz, and 800 MHz for L, C and X band, respectively. Then chirp

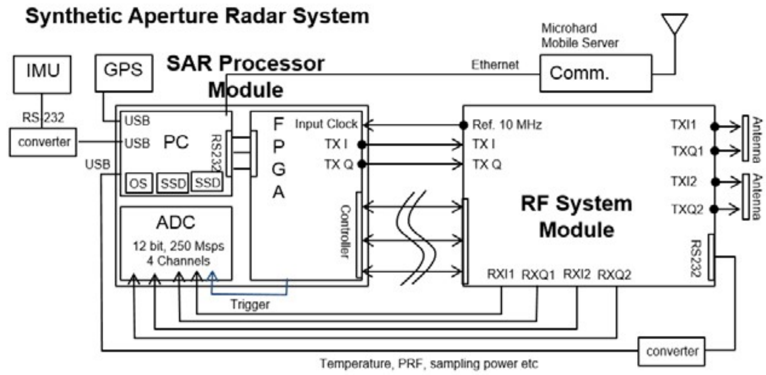

Fig. 5. Aircraft onboard CP-SAR System

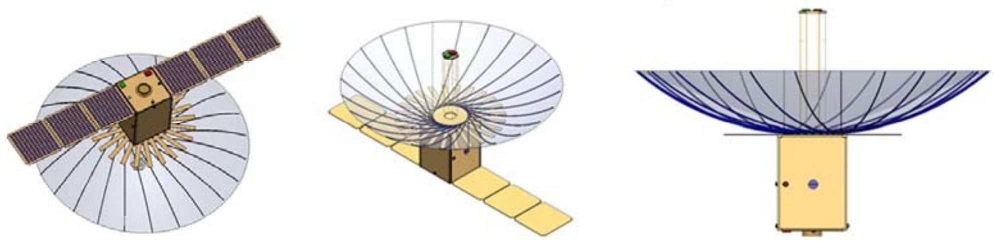
Fig. 6. Microsatellite CP-SAR


Fig. 7. Deployment experiment of meshed parabolic antenna

pulse is modulated by frequency 1,270 MHz, 5,600 MHz, and 9.400 MHz, respectively. The transmission system has gain tuning function as 1, 2, 3, 8, 16 dB or 0 to -31 dB, and receiver has gain tuning function as 1, 2, 3, 8 and 16 x 2 or 0 to -62 dB. Power amplifier (PA) is available to control pulse transmission output power 50 W, 400 W and 1000 W respectively with pulse width maximum 10 μs, and maximum duty circle is 2%. The switching speed of transmission and receiver system antennas (RHCP and LHCP) is typically 1 μs and maximum 2 μs. The antenna is composed by two sets of CP microstrip array antenna (LHCP and RHCP panels), totally 4 panels to realize full polarimetric CP-SAR sensor. We could control the pulse length and bandwidth of chirp pulse, and save data to SSD memory.

In this research, the CP-SAR onboard unmanned aerial vehicle (CP-SAR UAV, Fig. 3 and 4) is developed for ground testing of CP-SAR and other sensors. The platform called Josaphat Laboratory Experimental UAV (JX-1 and JX-2) has 25 kg of payload. The operation altitude is 1,000 m to 4,000 m. The specification of CP-SAR sensor for UAV is frequency of L, C and X bands, ground resolution up to 1 m, pulse length could be tuned from 4.5 to 48 μs, off nadir angle 30o to 60o, swath width 1 km, 4 panels of antenna, and PRF 1,000~2,500 Hz. We held ground experiment with altitude less than 2 km with pulse transmission output power 50 W for L band, 4 km with output power 400 W for C band, and 10 km with output power 1000 W for X band, respectively. The data retrieved by LHCP and RHCP antenna (Yohandri 2011) is employed to investigate the characteristics of elliptical polarization, including circular and linear polarizations. In the future, further investigation of characteristics of circular polarization will be done by using Boeing 737-200 aircraft.

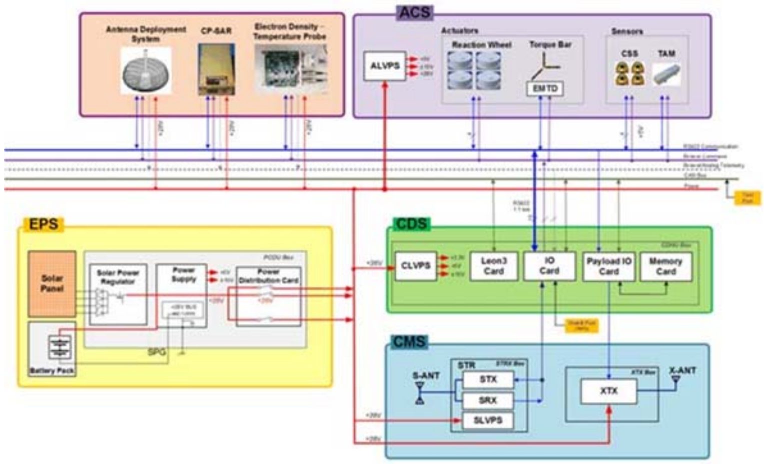

Fig. 8. Modules of Microsatellite CP-SAR

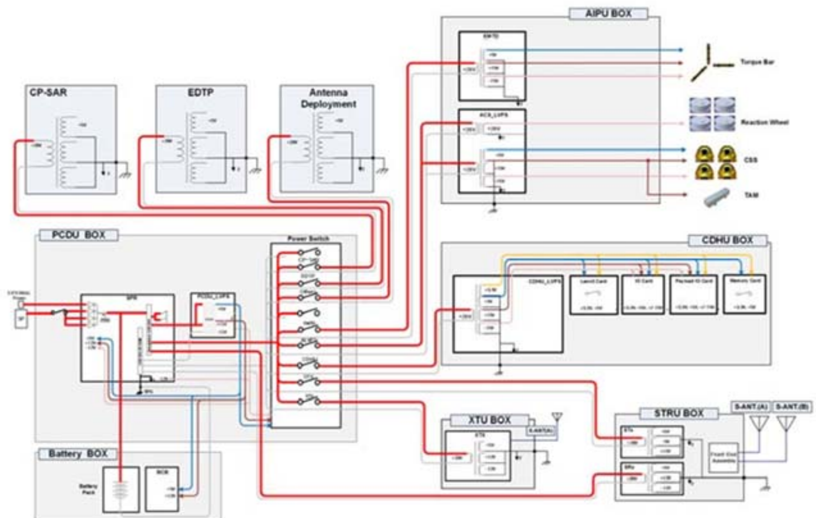

Fig. 9. Power network of CP-SAR microsatellite

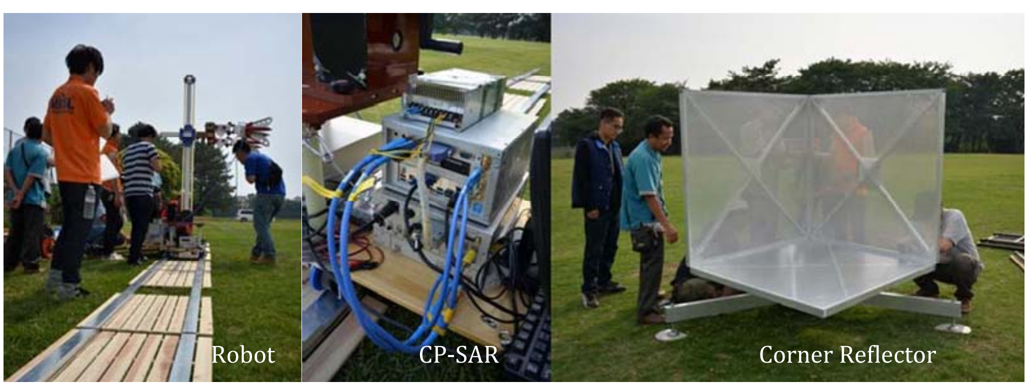

Fig. 10. Ground test of CP-SAR system for UAV

Fig. 11. Ground station for our microsatellite CP-SAR

3. Microsatellite CP-SAR

Fig. 6 shows model of CP-SAR onboard microsatellite (Microsatellite CP-SAR, 100 kg class) that developed in Josaphat Microwave Remote Sensing Laboratory (JMRSL), Center for Environmental Remote Sensing, Chiba University. We proposed meshed parabolic antenna to reduce weight of SAR system to realize 100 class SAR onboard microsatellite. Fig. 7 shows deployment experiment of meshed parabolic antenna of Microsatellite CP-SAR. Fig. 8 shows microsatellite is composed by Command and Data Handling Sub-system (CDS), Communication Subsystem (CMS), Electrical Power Subsystem (EPS), Altitude Control Subsystem (ACS) and payload. CDS uses Leon3 card, low power supply card (LVPS), IO card, payload IO card, and non-volatile memory card. CMS is composed by LVPS, low power supply card, S band transmitter & receiver (STX and SRX) and antenna for telemetry, X band transmitter and antenna for data downlink. EPS is composed solar panel, solar power regulator, power supply card, power distribution card, Li-Ion battery pack and battery control card. ACS employs LVPS, actuators (reaction wheels assembly–RWA and electromagnetic torque bar-EMTB) and sensors (coarse sun sensor-CSS and three-axis magnetometer-TAM), and GPS Receiver-GPSR. Payload is composed by main sensor CP-SAR for Earth surface monitoring and minor sensors: electron density – temperature probe (EDTP) for ionospheric monitoring. Power network of our microsatellite is shown on Fig. 9. We also develop SAR ground test measurement system as shown on Fig. 10, with moving precision of robot is 0.1 mm.

We also develop sub mission sensors, i.e. GPS-RO and electron density - temperature probe (EDTP) to monitor ionospheric phenomena. We will employs these ionospheric observation sensors simultaneously with our CP-SAR to monitor ionosphere and global land deformation. Therefore we could mapping pre-cursors of earthquake by using our microsatellites in the future.

4. Ground Station

Fig. 11 shows our satellite ground station with S band for command-telemetry and X band for mission data downlink. The 3.6m diameter of antenna and main control room of satellite ground station locates at Center for Environmental Remote Sensing, Chiba University. Command Unit (S band) has output power 100 Watts, frequency 2,025 to 2,120 MHz, LHCP and PCM, BPSK, PM and FSK modulations, and bitrate 1,024 BPSK, 9.6 kbps FSK. Telemetry Unit (S Band) works with frequency 2,200 to 2,300 MHz, LHCP and PCM, BPSK, PM and FSK modulations, bitrate 2.4 Mbps BPSK, 38.4 kbps FSK. Data Receiver Unit (X band) works with frequency 8,025 to 8,300 MHz, LHCP, QPSK modulation, bitrate 20 Mbps QPSK.

5. Summary

In this paper, we introduce the progress of development on CP-SAR onboard UAV, Boeing 737-200 aircraft, and microsatellite in our laboratory. The CP-SAR sensor is designed as small, lightweight and low power consumption system. The CP-SAR sensor is developed to radiate and receive elliptically polarized wave, including circularly and linearly polarized waves. In the near future, this sensor will be installed on Boeing 737-200 aircraft and microsatellite that will be applicable for land cover mapping, disaster monitoring, snow cover and oceanography monitoring etc. We also develop ionospheric observation sensors that is introduced in this paper too. In the future, these sensors could be employed for observation of ionosphere and global land deformation simultaneously for disaster monitoring and prediction.

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References

Sri Sumantyo, J.T. (2011), "Microwave Remote Sensing Research and Education at Center for Environmental Remote Sensing, Chiba University," IEEE Geoscience and Remote Sensing Society (GRSS) Newsletter, Issue #159, pp. 32-38.

Sri Sumantyo, J.T. (2012), Chapter 11. Circularly Polarized Synthetic Aperture Radar onboard Unmanned Aerial Vehicle (CP-SAR UAV), Autonomous Control Systems and Vehicles, Kenzo Nonami edn., Springer.

Yohandri, V. Wissan, I. Firmansyah, P. Rizki Akbar, J.T. Sri Sumantyo, and H. Kuze, (2011)"Development of Circularly Polarized Array Antenna for Synthetic Aperture Radar Sensor Installed on UAV," Progress in Electromagnetics Research C, Vol. 19, pp. 119-133.