Development of Advanced Microwave Sensor For Maritime Surveillance

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Synthetic Aperture Radar (SAR)

Other names
- Side looking radar
- Microwave radar
- Imaging radar

Flight direction

Cloud/haze/fog

SAR image

Foot print

Optic Sensor

Eruption of volcano of Indonesia Merapi 2006/Apr/26th
(Up)Optical ©AVNIR-2/JAXA
(Right)SAR ©PALSAR/JAXA, METI

Synthetic Aperture Radar (SAR)
Airborne SAR Applications

- Global Warming
- Volcanic Eruption
- Desertification
- Forest Monitoring
- Deforestation
- Lineament
- Lava Flow
- Earthquake
- Ocean Current
- Sea Ice
- Glacier
- Wrecked Ship
- Polar Ice
- Oil Pollution
- Ocean Wave
**Earth Observation using the GAIA-I and GAIA-II**

**GNSS-RO onboard microsatellite (GAIA-I):**
- Indirectly observation of land deformation using GNSS-RO sensor
- Investigation of relationship of global land deformation and electron density change in ionosphere
- Mapping of Earth surface temperature, water vapor, sea surface wind, sea surface height (tsunami), gravity etc.
- Investigation of earthquake precursor and its mechanism in wide area and low resolution
- 50 km class of microsatellite

**CP-SAR onboard microsatellite (GAIA-II):**
- Directly observation of land deformation using CP-SAR sensor
- Local observation of land deformation and high resolution
- Investigation of global land deformation precisely
- Observation of land deformation in high resolution

**GAIA-I**
- Wide area and low resolution of land deformation monitoring using GNSS-RO
- Continental land deformation (Nankai through earthquake etc.)

**GAIA-II**
- Observation of land deformation in high resolution using CP-SAR sensor

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**JMRSL**

**CHIBA UNIVERSITY**
Roadmap of Synthetic Aperture Radar Development

**6 Programs**

**Institute of Global Prominent Research**

FY 2015-2022

- **Space Environment**
  - Development of Microsatellite SAR System
  - Ground Station
  - UAV SAR Flight Test
  - Boeing 737 fight test

**2016**

- Microsatellite SAR Mission System: Bus System: Lapan

**2017**

- Calibration and validation using Boeing 737-200 and UAV

**2018**

- Microsatellite SAR Mission System: Bus System: Lapan

**2019**

- 2018 Microsatellite SAR Validation and Calibration

**2020**

- 2019 Microsatellite SAR Applications Development

**2021**

- 2020 Microsatellite SAR Constellation

**2022**

- 2021 Microsatellite SAR Constellation

**2023**

- 2022 Microsatellite SAR Constellation

- Deformation Monitoring

**2024+**

- 2023 Microsatellite SAR Constellation

- Global Environment & Land

Circularly Polarized Synthetic Aperture Radar (CP-SAR) Terms

- Microsatellite SAR for global land deformation monitoring using L Band →
- Comparison of Linear Polarized SAR and Circular Polarized SAR ↓

Circularly Polarized SAR (CP-SAR)
Application: Monitoring of volcanic activity, active fault, landslide, land deformation, earthquake etc.

LP SAR (conventional system)
Lack of scattering information

Scattering
Various scattering information → Various application development

Optic Sensor VS SAR Sensor

Optic Sensor
- Monitoring of volcanic activities of Mt. Fuji using Circular polarization characteristic to observe tilted angle of land surface
- Scattering from Volcano and urban area

SAR Sensor
- Sahara desert
- Ground water distribution

Source: Prof. Yosio Yamaguchi

Radar (CP-SAR)

Incident Wave: Circular Polarization (CP)

Canopy
Land Deformation
Under ground

Vertical Mode
Horizontal Mode

Incident Wave: Vertical Polarization (LP)
Incident Wave: Horizontal Polarization

Low ← Frequency → High

P L C X

Tilted angle image
Mount Fuji

Various application development

Chiba University
Scattering of Linear Polarization (LP)

Scattering of Circular Polarization (CP)

SAR Technology

1. Technology:
   Circularly Polarized Synthetic Aperture Radar (CP-SAR) as improvement of Linear Polarized Synthetic Aperture Radar (LP SAR)

2. Development of SAR System
   • SAR system developing since 2005
   • L, C, X band SAR system
   • UAV, Aircraft and Microsatellite onboard

3. Collaborators:
   • Japan government and companies
   • Malaysia (MMU, USM, Uniten etc)
   • Indonesia government and companies
   • Taiwan (NSPO)
   • ESA (DIFFERENT)
   • ISAS-JAXA
   • NASA KARI – KPLO etc
Benefit of CP-SAR

• Circular polarizations (CP) performs better than the HH polarization at lower incidence angles (off nadir angle) [1-2].
• CP exhibits multiple benefits over linear polarization including CP avoids polarization losses due to misalignment
• CP is no need to keep the transmitting and receiving antenna in the same alignment; It has the ability to decrease interference between direct and reflected signal due to multipath propagation
• The CP has the advantage of compactness and low power requirement, since the transmission of CP microwave is not affected by the Faraday rotation effect in the ionosphere [3]

etc

References
Needs

1. Disaster Monitoring
   Peatland, land deformation
   Fire spot monitoring
   Volcanic and earthquake monitoring
   Landslide precursor

2. Fishery and Maritime
   Illegal fishing and armed fishing ship
   Oil spill monitoring etc

3. Search and Rescue (SAR)
   • Heavy rain and cloud/haze environment
   • Forest

4. Infrastructure Monitoring
   Maintenance of highway, seaport, railway, electricity transmission line, dam, housing etc

5. Research and Education on SAR Technology
   • Development on new SAR technology
   • Development on SAR applications etc

Malaysian highway and electricity infrastructure monitoring
X Band SAR for Boeing 737-200

<table>
<thead>
<tr>
<th>Items</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Frequency</td>
<td>9.4GHz</td>
</tr>
<tr>
<td>Frequency Bandwidth</td>
<td>800MHz</td>
</tr>
<tr>
<td>Transmit Power</td>
<td>1500W peak</td>
</tr>
<tr>
<td>Slant Range Resolution</td>
<td>1m</td>
</tr>
<tr>
<td>Azimuth Resolution</td>
<td>5m</td>
</tr>
<tr>
<td>Flight Altitude</td>
<td>~5,000m</td>
</tr>
</tbody>
</table>

CP-SAR Antenna: Tilted 30 degrees for downward

X Band CP-SAR System

Spectrum analyzer
Local Unit
Oscilloscope
TX Unit
RX Unit
19inch size
AWG
[Instruments]
X Band SAR Installation

Wave guide
Oscillator
RX
TX and Power supply
Oscilloscope
AWG
Flight test 7 August 2017
Makassar & Pare-Pare
Rolling observation

Flight test 7 August 2017
Makassar & Pare-Pare
Cruising observation
C Band SAR for Aircraft


Cessna Model 182 (Series 1997) Aircraft

C Band SAR (Center frequency: 5.6 GHz, BW: 400 MHz) for disaster and plantation monitoring
HINOTORI-C1 MISSION
As a brief explanation regarding the system, the system is consist of 5 modules, namely (with estimated size and weight),

1) Power and Control Unit (Dimension: 14 cm x 48 cm x 52 cm, Weight: 10 kg)
2) SAR TX Module (Dimension: 14 cm x 48 cm x 48 cm, Weight: 5 kg)
3) SAR RX Module (Dimension: 14 cm x 48 cm x 48 cm, Weight: 5 kg)
4) Server (Computer) (Dimension: 9 cm x 48 cm x 76 cm, Weight: 25 kg)
5) Uninterruptible Power Supply (Dimension: 5 cm x 48 cm x 68 cm, Weight: 25 kg)

All modules are with 19" rack mount enclosure with different height and different depth. The longest in depth module is the server.

There is a need to reserve some space in the front (around 20 cm) and at the back (around 10 cm) for the cabling.
Natural Object Observation

#1 #2 #3 #4 #5 #6 #7 #8 #9

Gading Airport

Surakarta City

Yogyakarta City

Bantul Regency

Gunung Kidul Regency

Klaten Regency

Sukoharjo Regency

Karanganyar Regency

Wonogiri Regency

Ngawi Regency

Magelang City

Magelang

Ngawi

Surakarta City

Surakarta

Klaten

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Concept of Circularly Polarized Synthetic Aperture Radar (CP-SAR)

Concept of Circularly Polarized Synthetic Aperture Radar (CP-SAR)


QPS JMRSL CHIBA UNIVERSITY
Measurement System of SAR for Microsatellite
Satellite Ground Station of JMRSL

S Band: Command TX & Telemetry RX

X Band: Mission Data RX

2F Center For Environmental Remote Sensing Building (Josaphat Laboratory)

Sub Ground Control Room

Main Ground Control Room
Synthetic Aperture Radar (SAR)
Previous Research Results: FY 1999 - 2002
Electromagnetic Modelling of SAR Scattering for Burnt Coal Seam Monitoring


Peatland Ground Survey and Spaceborne SAR Monitoring
(ALOS-2 25 March 2017)

Google Earth

JMRSL
Josiah Microwave Remote Sensing Laboratory

CHIBA UNIVERSITY
Soil Roughness and DGPS Measurement 21-28 March 2017
Applications: Monitoring of Sedimentation at Jakarta Coastal line

Coastal Line 1915 – 1999 of Jakarta Strait

Picture source: http://www.kuiper.nl

-16m/year

18m/year

35m/year

40m/year

Urban Settlement Zone

Deep Seaport & Economic Zone

Sedimentation at river outlet at northern Jakarta 22 March 2015

JMRSL

Joseph Microwave Remote Sensing Laboratory

CHIBA UNIVERSITY
Analysis Result:
Volume Loss (m³/year)

Volume loss in each watershed using ALOS PALSAR images

Volume loss in watersheds of W03, W04, W05, W10, and W11

Volume loss of sedimentation material does not occurred in W07-W09, therefore the land deformation in these watersheds does not influence to Jakarta Giant Sea Wall.


Applications: Monitoring of Sedimentation at Jakarta Coastal line
Cameroon Highland ground campaign with Malaysian Government JGR, Universiti Sains Malaysia, and JICA on 20 September 2014
Study Site SATREPS 2010:
Landslide at Simpang Pulai – Cameron Highland Road

Reference: 11 February 2011
Landslide (The Star, 26 August 2011)

ALOS PALSAR:
10 February 2007 to 21 February 2011
Application: East-West Highway: Lake Site, Malaysia - SATREPS 2010

Deformation Velocity mm/year

Sedimentation

Landslide/Subsidence

Scale: 1:50,000

Lake site

CHIBA UNIVERSITY

JMRSL

Scale: 1:50,000
Thank you very much for your attention!

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