Deployable Antennas for Small Satellites

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Rise of Micro/Nano-satellites

Micro/nano-satellites have had disruptive impact on space access

Nanosatellite launches by organisations

Graphic credit: Erik Kulu, Nanosats Database, www.nanosats.eu
SmallSat RF Applications

Highly complex RF systems now realizable on small platforms

- Imaging Radar
  - ICEYE (iceye.com)
- Scientific Sensing
  - MIT AERO VISTA
- Weather Monitoring
  - MIT LL TROPICS
- Spectral Monitoring
  - Hawkeye (he360.com)
- Communications
  - MarCO (nasa.jpl.gov)
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...but large antennas are still needed!
Deployable Antenna Challenges

- Compact stow/deploy
- Low mass
- Rigidity
- Low power consumption
- Thermal stability

Deployable antenna example

Deployable Reflectarray

SmallSat

1.8 m

0.6 m

NASA/MIT LL CREWSR (2021 IIP)
Types of Large Antennas for SmallSats

Antennas for low frequencies

Highly-directive fixed-beam antennas

Highly-directive scanning antennas
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Deployable Vector Sensor Antenna

- MIT AERO, VISTA satellites will sense aurora radio emissions
- Deployable antennas sense 0.1 – 15MHz
- Multi-antenna configuration localizes radio emissions
Vector Sensor Prototype

- Antenna concept validated with balloon-mounted prototype
- Localization of signals in target band demonstrated
- AERO/VISTA cubesat launch targeted in 2022
Types of Large Antennas for SmallSats

- Antennas for low frequencies
- Highly-directive fixed-beam antennas
- Highly-directive scanning antennas
Inflatable Reflector Antenna

Enables large, ultra-light dish antennas deployed from small volume

- Primary Reflector 2.4 m
- Secondary Reflector 0.25 m
- Antenna Feed
- Toroid
- Primary Inflatable Chamber
- Secondary Inflatable Chamber
- RF transparent material
- Inflatable chamber
- Primary reflector
- Secondary reflector

1.1 m total height
2.7 m overall diameter

Prototype Reflector

• Design validated through measurement
• Measured RMS surface error ~2.7mm
• Deflated volume of outer torus ~1.25U
Wire Bending for Large Reflectors

Lead: Prof. Zachary Cordero, MIT

CNC wire bending can enable in-space manufacturing of large reflectors

CNC Wire Bender

Bend-Formed parabolic dish

1 m
Types of Large Antennas for SmallSats

- Antennas for low frequencies
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- Highly-directive scanning antennas
Lightweight Scanning Array Technology

- **LWAESA**: Lightweight Active Electronically-Scanning Array
- **DESRa**: Deployable Electronically-Scanning Reflectarray
- **RFAA**: Rigid-Flex Antenna Array
- **RF Fiber Array**

**Typical Arrays**
- 300 kg/m²
- 60 kg/m²
- 30 kg/m²

**RADARSAT-2**
- 6 kg/m²
- 2-4 kg/m²
- 1.5 kg/m²

**0.05 kg/m²** (Linear array)
Novel low-mass antenna array enables use on small platforms

Electronically steered beam

Unfolding array panels

Antenna elements

Lightweight castellated substrate

Electronics/signal distribution
Prototype with castellated substrate validated with measurements

Novel castellated substrate
Flexible, ultra-light array can be rolled and unrolled for deployment

Unrolling flexible antenna array

Rigid antenna substrate
Flexible circuit material
Array electronics

Electronically steered beam

RFAA
Rigid-Flex Antenna Array
RFAA Prototype

Concept validated experimentally after numerous roll cycles

Measured Antenna Pattern, 10 GHz

- No roll/unroll cycles
- After 50 roll/unroll cycles
DESRa scans beam by illuminating reconfigurable reflective surface.
## Large Scanning Apertures

<table>
<thead>
<tr>
<th></th>
<th>Phased Array</th>
<th>DESRa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power consumption</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Thermal management</td>
<td>Complex</td>
<td>Simple</td>
</tr>
<tr>
<td>Scanning range</td>
<td>Wide</td>
<td>Wide</td>
</tr>
<tr>
<td>Cost</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>
2.2 m² prototype demonstrated highly directive scanned beam

Electronically scanned patterns, 9 GHz

0 deg. Scan

15 deg. Scan

30 deg. Scan

45 deg. Scan

Normalized Gain [dB]

Normalized Gain [dB]

Normalized Gain [dB]

Normalized Gain [dB]

Elevation Angle [deg]

Elevation Angle [deg]

Elevation Angle [deg]

Elevation Angle [deg]

Feed antenna
Simple deployment scheme provides 2.2m² aperture from 0.4m²

Deployment Scheme

Deployment EDU
Summary

• SmallSats enable new RF capabilities, pursued by more entities
• Deployable antennas critical for realization of large apertures
• MIT LL has demonstrated innovative deployable antennas for:
  – Low frequency systems
  – Highly-directive fixed-beam antennas
  – Highly-directive scanning antennas

HF Vector Sensor
Inflatable Reflector
Lightweight Scanning Arrays
BACKUP
Structural grids integrated within antenna for thin, symmetrical design

- Antenna w/ structural sheet
- Structural sheet
- Antenna stackup
- DESRa
- Aluminum structural grid
- Aluminum structural grid