DBSAR’s First Multimode Flight Campaign

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Introduction

• The Digital Beamforming SAR (DBSAR) is an airborne imaging radar system that combines phased array technology, reconfigurable on-board processing and waveform generation, and advances in signal processing to enable techniques not possible with conventional SARs.

• The system exploits the versatility inherently in phased-array technology with a state-of-the-art data acquisition and real-time processor in order to implement multi-mode measurement techniques in a single radar system.

• Operational modes include scatterometry over multiple antenna beams, Synthetic Aperture Radar (SAR) over several antenna beams, or Altimetry.

• The radar was flight tested in October 2008 on board of the NASA P3 aircraft over the Delmarva Peninsula, MD.
System Architecture

Some of its main features include:

- 1-Dimensional scanning (across track in nominal configuration)
- Polarimetric operation (HH, VV, VH, HV)
- Software defined radar functions,
- In-phase and quadrature (I&Q) high data rate acquisition mode,
- Real-time onboard processing,
- Adjustable transmitter illumination (from narrow-beamwidth high-gain beam steering to wide-beamwidth illumination),
- Reconfigurable waveform generation,
- Noise source and closed loop calibration schemes,
- Real-time data monitoring through a customized graphical interface unit.
System Architecture

- Antenna is a microstrip phased array with 64 active elements
- 8 sub-arrays enable cross-track scanning over a wide range of angles
- Transmit modules perform digital phase steering and amplitude taper
- DBSAR was designed for operation on board of the NASA P3 aircraft

Radar and NASA P3 Aircraft

LIS Architecture
## Radar Characteristics

### RF Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1.26 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>20 MHz</td>
</tr>
<tr>
<td>PRF</td>
<td>40 Hz - 10 KHz</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>1 – 100 µs</td>
</tr>
<tr>
<td>Number of Transmitters</td>
<td>8</td>
</tr>
<tr>
<td>Output Power</td>
<td>16 W</td>
</tr>
<tr>
<td>Beam Steering Angles</td>
<td>± 50 degrees</td>
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</tbody>
</table>

### Antenna

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Microstrip Patch</td>
</tr>
<tr>
<td>Number of Patches</td>
<td>80</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>20 MHz</td>
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<tr>
<td>Polarization</td>
<td>Dual</td>
</tr>
<tr>
<td>3 dB Beamwidth</td>
<td>12 Degrees</td>
</tr>
<tr>
<td>Two-Way Side Lobes</td>
<td>&lt; − 26 dB</td>
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<tr>
<td>Subarray Gain</td>
<td>≥ 10.5 dB</td>
</tr>
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</table>

### Miscellaneous

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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<tr>
<td>Dimensions (m)</td>
<td>1.2 x 1 x 0.5</td>
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<tr>
<td>Power Draw (W)</td>
<td>350</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>106</td>
</tr>
<tr>
<td>Cooling System</td>
<td>Vortex Tubes/ Compressed N₂</td>
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</table>
The Real-time Processor

- Fully Reconfigurable
- Custom design
- Three Stratix II FPGAs
- Eight A/D converters
- Six SRAMs
- ARM microcontroller
- 1-Gb Ethernet interface
- Size (cm): 17 x 24 x 4
- Power: 94 W max
SMAP-VEX Airborne Campaign 2008

- The Soil Moisture Active Passive Mission (SMAP) is currently addressing numerous issues related to the soil moisture retrieval algorithms.

- 7 Flights were conducted on the NASA P3 at the beginning of October 2008 over the Choptank area, MD.

Radar Integrated to P3 aircraft
DBSAR Operational Modes

• Scatterometry over multiple antenna beams
  1. Narrow Beam mode → simultaneous transmission and reception on all subarrays.
  2. Wide Beam mode → transmission on a single subarray, and simultaneous reception on all subarrays.

• Synthetic Aperture Radar (SAR) Imaging over several antenna beams
  1. Narrow Beam mode: Strip map Imaging
  2. Wide Beam mode: Left and right of the track imaging

• Altimetry on Nadir beam of SAR mode
Scatterometer Operational Mode 1

**Scatterometer:** Narrow beam on transmission

- A narrow beam is generated at a particular look angle by electronically steering the array.
- Signal returns are collected with the full aperture.
- A single beam is synthesized at the same look angle.
Scatterometer
Operational Mode 1

Scatterometer: Wide beam on transmission
Scatterometer
Operational Mode 2

Scatterometer: Wide beam on transmission

- A broad beam is generated by energizing a small section of the antenna
- The beam illuminates entire field of view
- Signal returns are collected with the full aperture
Scatterometer
Operational Mode 2

Scatterometer: Wide beam on transmission

- A broad beam is generated by energizing a small section of the antenna
- The beam illuminates entire field of view
- Signal returns are collected with the full aperture
- Many beams are synthesized simultaneously on receive
Scatterometer
Operational Mode 2
Scatterometer: Wide beam on transmission
Operational Mode 1
Narrow beam transmission

- One or several beams are generated by steering
- The beam illuminates a target area
- Signal returns are collected with the full aperture
- Selected beams are synthesized simultaneously
- SAR processing is performed on each beam
SAR
Operational Mode 1
Narrow beam transmission
SAR
Operational Mode 2
Wide beam TX, imaging on both sides of the track

• A broad beam is generated by energizing a small section of the antenna
• The beam illuminates entire field of view
• Signal returns are collected with the full aperture
SAR
Operational Mode 2
Wide beam TX, imaging on both sides of the track

• A broad beam is generated by energizing a small section of the antenna
• The beam illuminates entire field of view
• Signal returns are collected with the full aperture
• Several beams are synthesized simultaneously
• SAR processing is performed on each beam
SAR
Operational Mode 2
Wide beam TX, imaging on both sides of the track
The DBSAR Modes
Simultaneous SAR and Altimetry

• One or several beams are generated by steering
• The beam illuminates a target area including nadir
• Signal returns are collected with the full aperture
• Selected beams are synthesized simultaneously
• Range and azimuth compression is performed on each of the beams on the side of the track
• Altimetry processing is performed on the nadir beam
Altimetry Mode
Nadir beam of SAR mode
Concluding Remarks

• Results from the first multi-mode campaign indicated a very successful performance of the radar system.

• DBSAR was recently upgraded with polarimetric operation (hh, vv, hv, vh) which enhances the science capability of the system.

• DBSAR’s next flight campaign is scheduled for August 2010 when the system will be used to retrieve biomass over forests on the US east coast.