Signals of Opportunity Airborne Demonstrator (SoOp-AD): Results of First Field Experiment

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Outline

- Root Zone Soil Moisture (RZSM)
- Potential advantage of P-band SoOp
- Overview of SoOp-AD Airborne instrument
- Little Washita, OK campaign: Oct 2016
- Data Processing and First Results
- Future Work
- Conclusions
Root Zone Soil Moisture (RZSM)

• Water in top ~1 meter of soil
• Critical link between surface hydrology and deeper process
• Drainage and absorption by plant roots
• Connection between near-term precipitation and long-term availability of fresh water
• Presently available globally – only through model assimilation of surface soil moisture (e.g. SMAP L4)
Importance of Sensing < 500 MHz

9.4 cm @ 25%, L-Band

17.7 cm @ 25%, P-Band

Sand: 40%, Clay: 20%, Temperature: 20 °C

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Difficulty of Sensing < 500 MHz

**ESA-BIOMASS** 12-m Large Deployable Reflector (LDR) 435 MHz Operations prohibited over N. America and Europe due to Space Objects Tracking Radar (SOTR) [ESA SP-132, 2010]

Difficulty of Sensing < 500 MHz

- Large antenna size to meet resolution requirements
- No protected bands
- High RFI from terrestrial sources

Consequence: L-band (1-2 GHz) may be the current practical lower frequency limit for spaceborne radar or radiometer
P-band Signals of Opportunity (SoOp)

- Re-utilization of existing transmissions (e.g. potential RFI sources)
- Bands allocated for Space-Earth communications
- High power, forward scatter -> High SNR/smaller antenna
- Resolution set by signal bandwidth – not antenna diameter

P-band SoOp may offer first possibility of direct remote sensing of Root-Zone Soil Moisture (RZSM) from space
P-band Signals of Opportunity (SoOp)

- **225–420 MHz** allocation for defense/government use
- Continuous use by US & Others since 1978 (FLTSATCOM)
- Planned utilization through 2024
P-band Signals of Opportunity (SoOp)

- Multiple Low bandwidth (5, 25 KHz) digital channels.
- Well documented and (supposedly) easy to receive by:

**Ionospheric Researchers**

- SCINDA Sensor Suite
- VHF S4 index for
- GPS Receiver
- UHF Antenna

**Hobbyists**

- www.uhf-satcom.com
- www.crypto.com

**Pirates**

- "Nearly illiterate men rigged a radio in less than one minute” [Wired, April 20, 2009]

Signals of Opportunity Airborne Demonstrator (SoOp-AD)

- 2013 Instrument Incubator Program (IIP) Selection

- Objectives:
  - Airborne instrument to demonstrate SoOp concepts at P- and S-band
  - Breadboard digital receiver with “path to space” tested in relevant environment (TRL-5)
  - Airborne science instrument for future algorithm development

- Working requirements:
  - Resolution: 100 m (airborne), 1km (satellite)
  - Sensing depth: 0-30 cm
  - RZSM accuracy of 0.04 (volumetric)
Signals of Opportunity Airborne Demonstrator (SoOp-AD)

- Measurement Model

\[
\begin{align*}
\text{Direct signal} & \quad x_D(t) = \sqrt{C_D} a(t - \tau_D) e^{i \omega_c (t - \tau_D)} \\
\text{Reflected signal} & \quad x_R(t) = \sqrt{C_D \Gamma} a(t - \tau_R) e^{i \omega_c (t - \tau_R)}
\end{align*}
\]

Accounting for Direct-Reflected Interference:
- Null-Steering (post-process)
- Retrieval Forward model
- Vicarious calibration over water

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Signals of Opportunity Airborne Demonstrator (SoOp-AD)

- Antenna Null-Steering (post-process)
Signals of Opportunity Airborne Demonstrator (SoOp-AD)

- Antenna Installation on NASA Langley B-200 Aircraft

P-band elements

2x2 element S-band array (integrated assembly shown with radome cover on aircraft)
Flight Campaign: Little Washita, OK

- Flight planning software: Showing ARS Micronet sites.
First Look at Data

- Functioning of correlator array:

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<th>P1: Bottom H-pol</th>
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First Look at Data

- Flight Date: 10/22/2016
First Look at Data: "Quick Look" Processing
First Look at Data: Antenna Null-Steering and Adjustment

- Lake Ellsworth Overflights

Science Flight 3 (10/22)  
Science Flight 5 (10/25)
First Look at Data: Antenna Null-Steering and Adjustment

- Science Flight 3 (10/22/2016)
First Look at Data: Antenna Null-Steering and Adjustment

- Science Flight 5 (10/25/2016)
First Look at Data: Antenna Null-Steering and Adjustment

- Science Flights 3 and 5 overlay
Summary

- Completed engineering testing of “breadboard” FPGA correlator in “relevant environment” (TRL5)
- Completed first attempt at reflectivity retrieval using null-steering and vicarious antenna calibration
- Work in Progress (under IIP-13):
  - Comparison of reflectivity retrieval vs. in-situ observations
  - Comparison vs. SLAP data
  - Processing of S-band data
  - Processing of full-spectrum P-band data
  - Definition of satellite mission requirements
- Future Work:
  - Soil moisture profile retrieval algorithms
Acknowledgements

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