Status of the Signals of Opportunity Airborne Demonstrator (SoOp-AD)

Purdue University

Simulation, Retrieval Algorithms, Requirements Def.

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Digital Receiver Design

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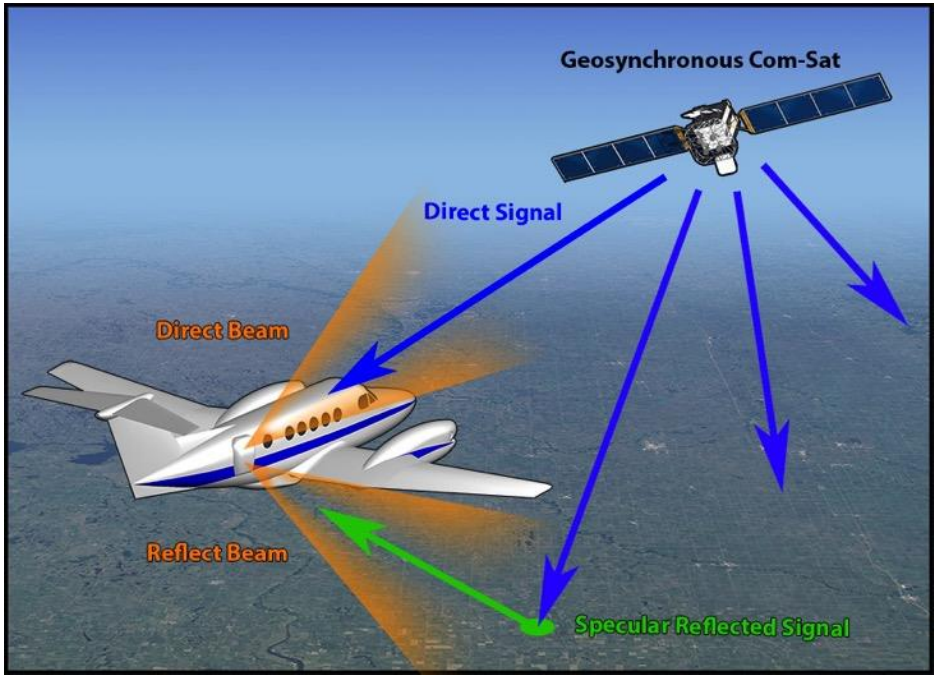
Scattering Model, Signal Processing

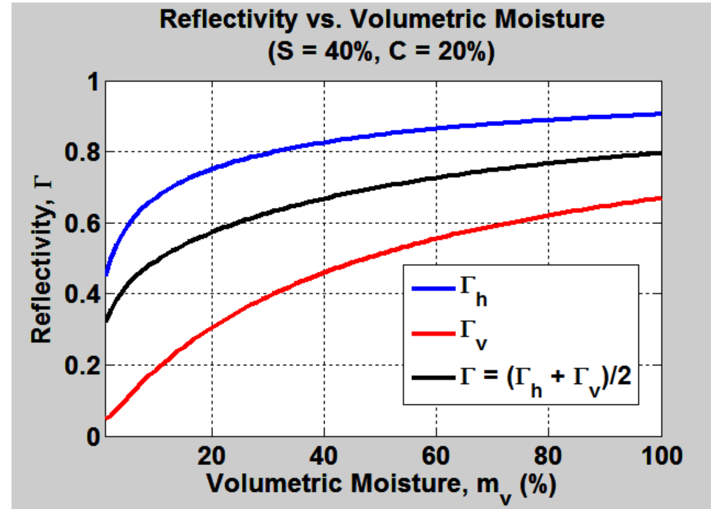
SoOp-AD Measurement Overview

P-Band Reflectometry



We plan to measure Root Zone Soil Moisture (RZSM) through cross-correlation of direct and reflected P-Band geosynchronous communication satellite signals.

Basis of Measurement



Expected Performance

Parameter	SoOp Airborne	SoOp Spaceborne
Resolution*	100m	870m
Antenna Size	75 x 75 cm	75 x 75 cm
Sensing Depth	0-30cm	0-30cm
Sensing Precision**	$0.04m^3/m^3$	$0.04m^3/m^3$

*Specular Reflection Assumed

**SMAP Requirement

SoOp-AD Solution

- SoOp-AD will use geostationary P-Band SATCOM systems
  - 225-420MHz allocation for government use, SoOp-AD will focus on 240-270MHz band: 18 x 25-kHz channels, 20 X 5-kHz channels.
  - Continuous use by US since 1978, follow-on systems planning legacy support
  - SoOp-AD method measures correlation of direct and reflected signals - does not require demod / decode of the transmission.

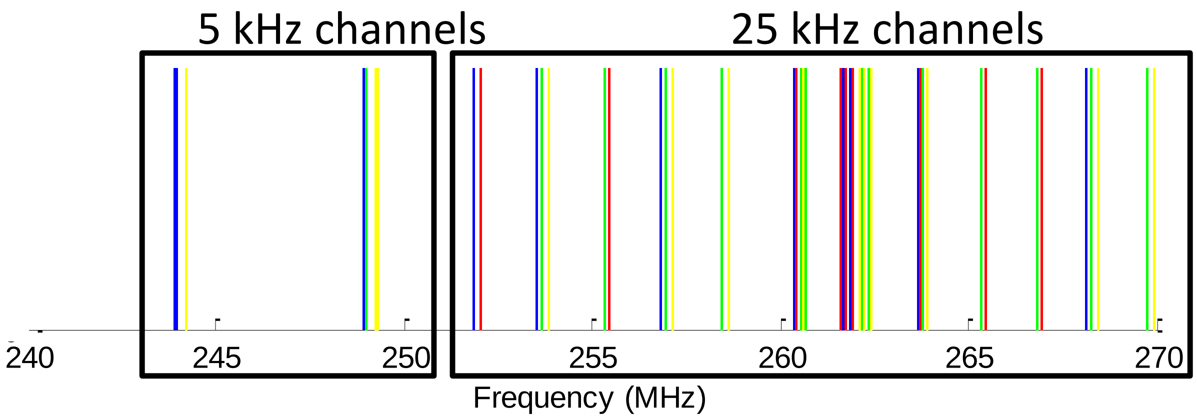
Comparison to Conventional Methods

- L-Band
  - L-band (SMAP) penetrates only few cm of soil
  - Saturation at L-band limits the ability to sense soil moisture through vegetation
  - RZSM from SMAP Level 4 assimilation product
- P-Band Radar
  - Difficult to find allocation in heavily utilized spectrum
  - ESA-BIOMASS cannot operate in North America or Europe due to interference with Space Object Tracking Radar
  - RFI
  - Expensive from space

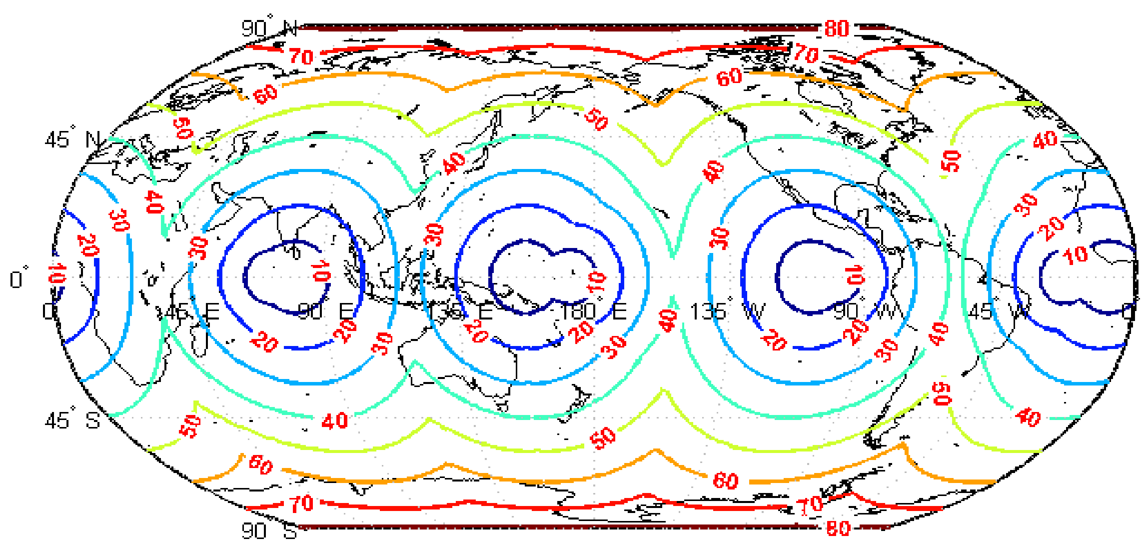
SoOp-AD Project Highlights

- IIP Timeline
  - Awarded in April ’14.
  - System I&T at GSFC is underway.
  - Science flights in Fall of ’16.
- Instrument
  - Antennas: Patch, Dual Linear Pol, Null Steering
  - Receivers: Standard P-Band Receivers w/ internal calibration. S-Band receiver for XM Radio included
  - Digital System: FPGA based. 7TB Storage for raw and/or correlation data
  - Two aircraft racks: 12U Total
- Aircraft Campaign
  - Flying on NASA Langley B200.
  - Co-Flying with SLAP instrument (GSFC’s Active / Passive L-Band).
  - Science flights over the St. Joseph’s Watershed.

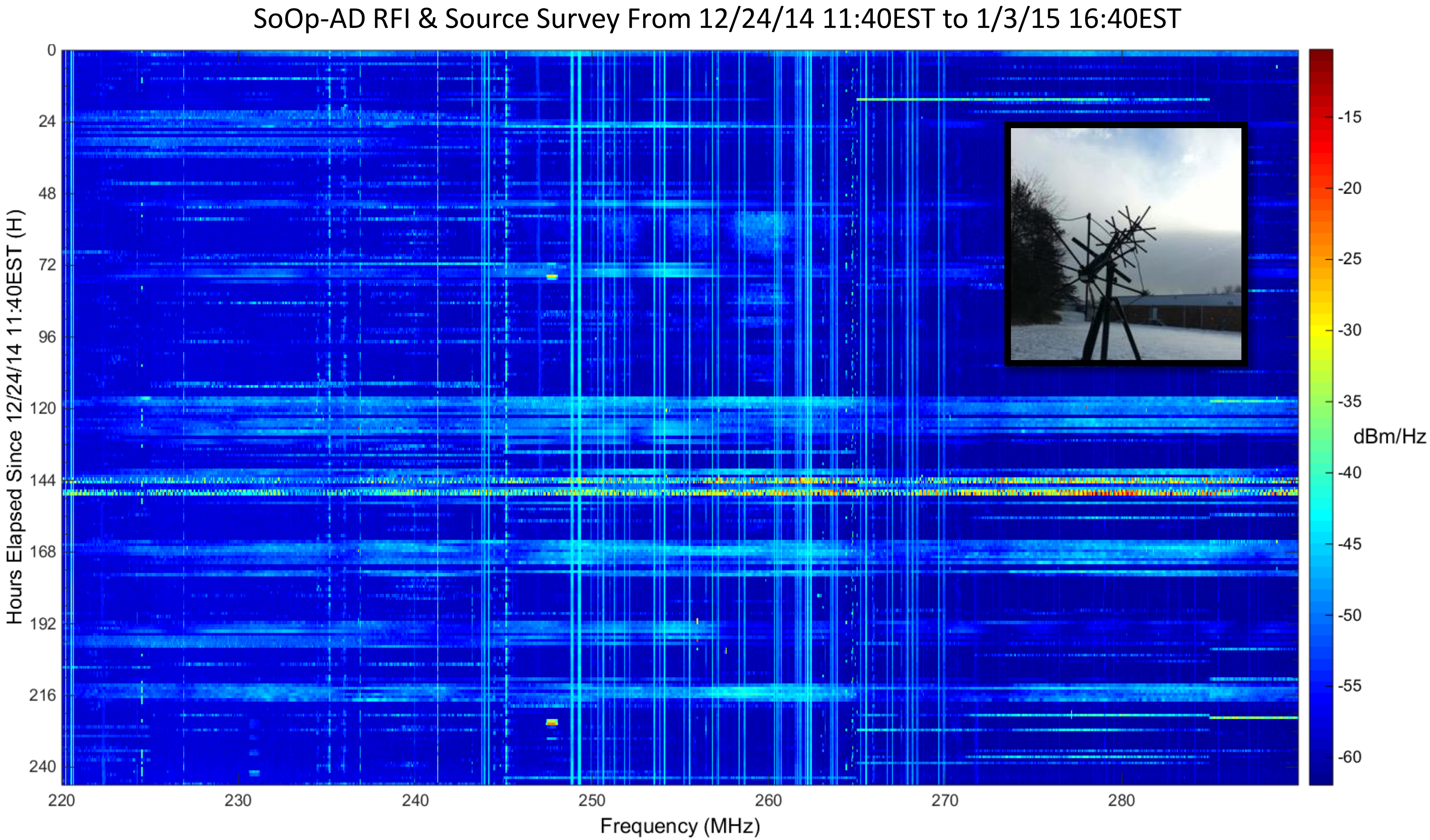
Signal Bands and Coverage



Incidence Angle for Geostationary Sources used by SoOp-AD.



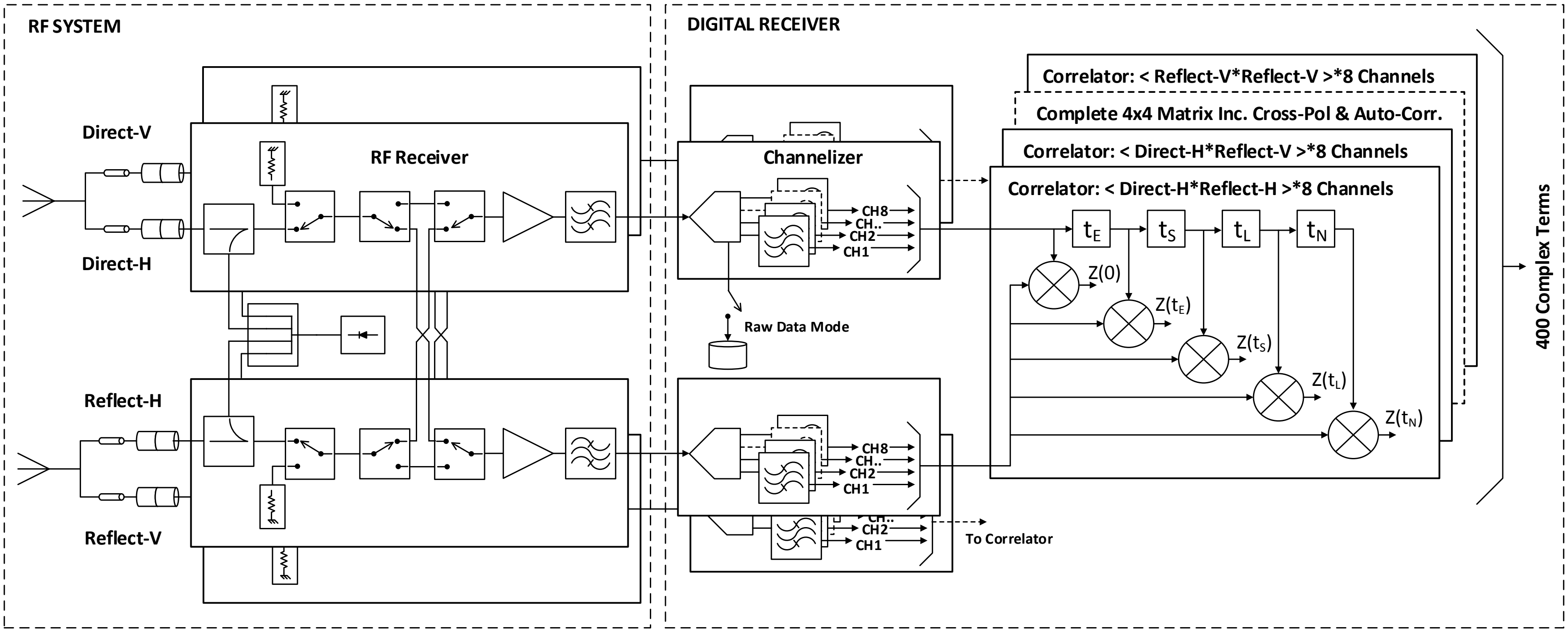
Measured Signal Details & RFI



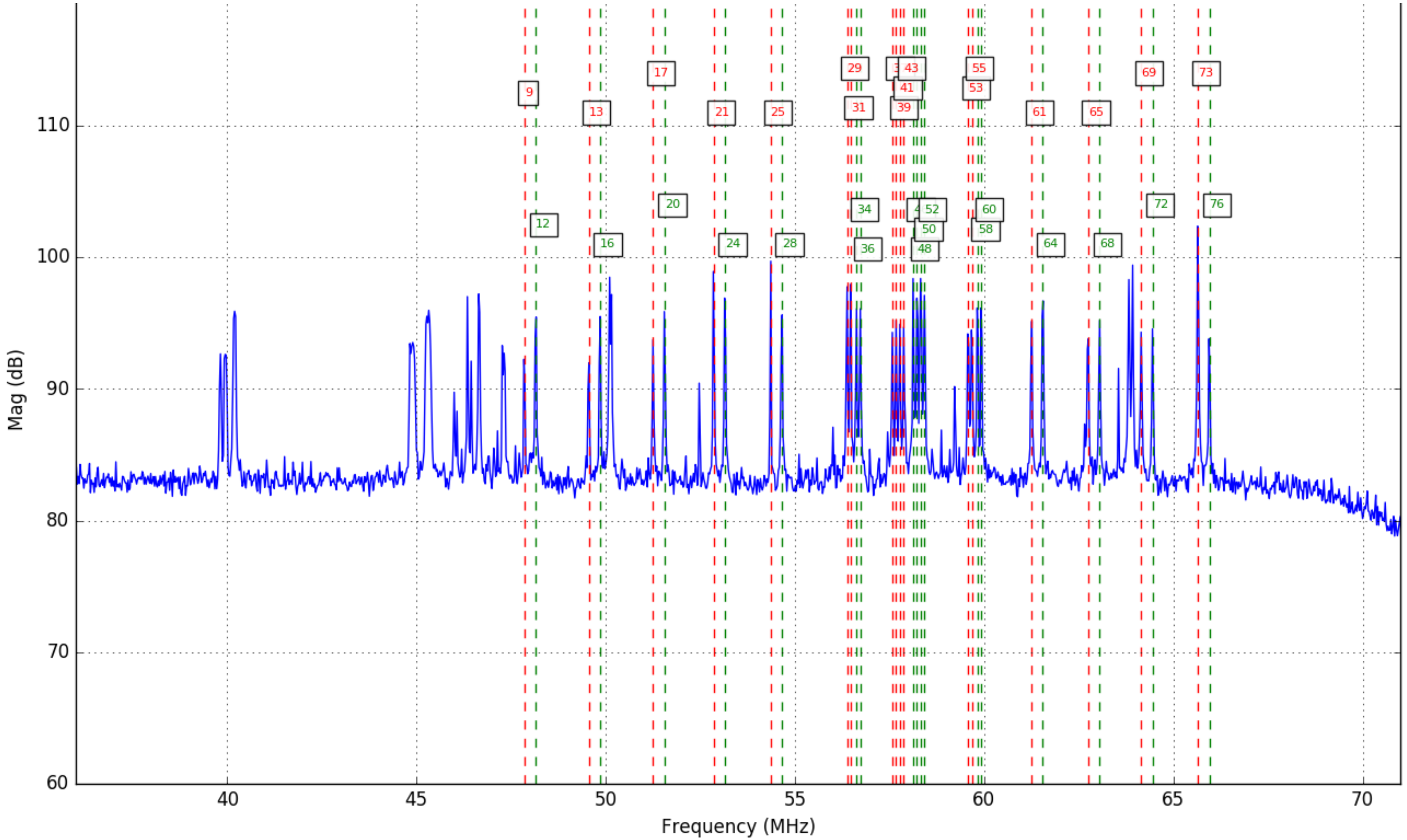
Waterfall spectrum measured at GSFC over 11 days. Note persistence of SATCOM signals and broad-band RFI.

SoOp-AD System Architecture

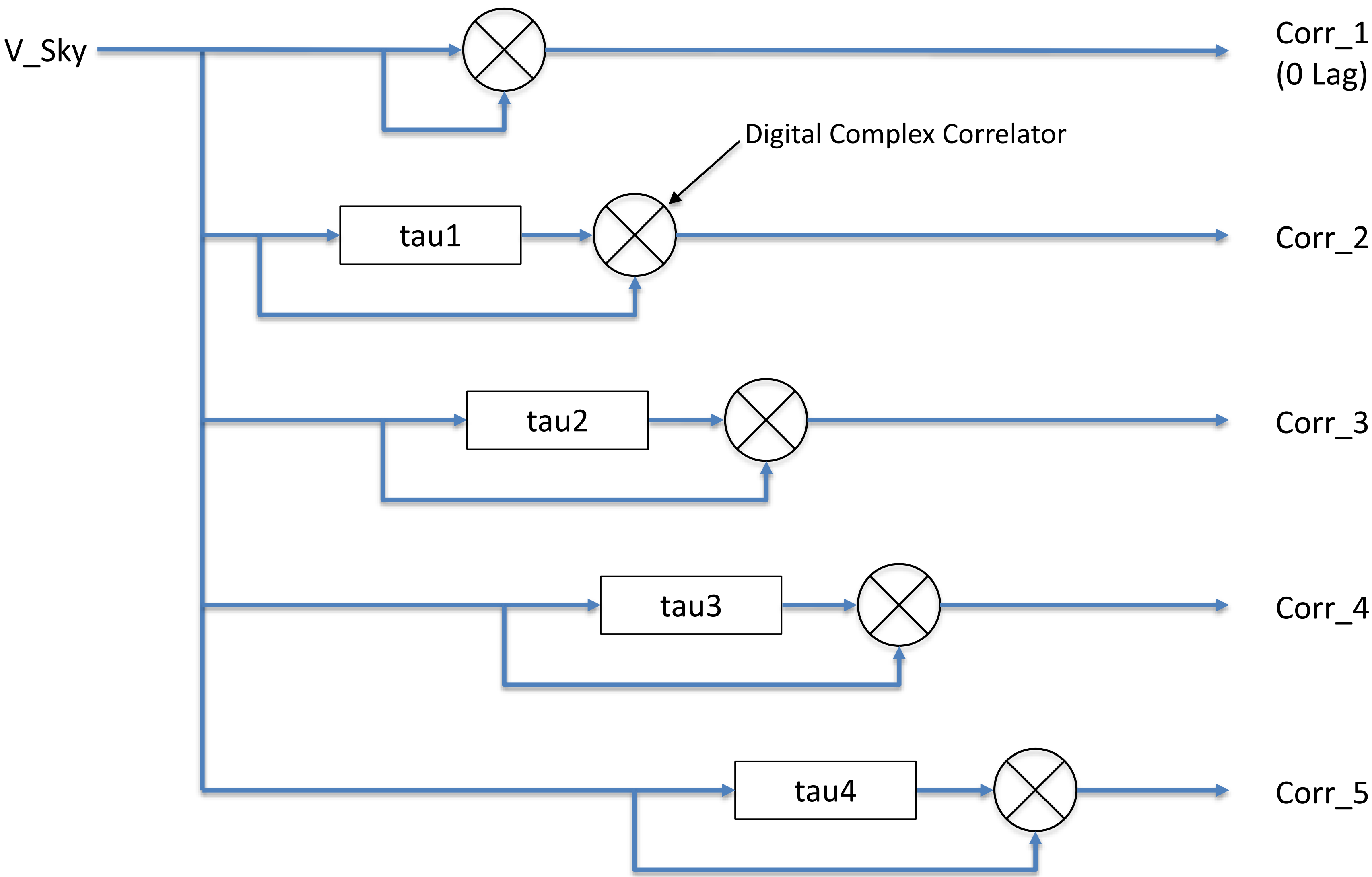
Reflectometry: $$\Gamma_2 = \left(\frac{|\tilde{Z}_{12}(\tau_{RD}|)}{\tilde{Z}_{11}(0) - G_1\sigma_1^2}\right)^2 \frac{G_1}{G_2}\frac{G_{S,D}}{G_{E,R}}$$



Spectrum from SoOp-AD Raw Data Mode

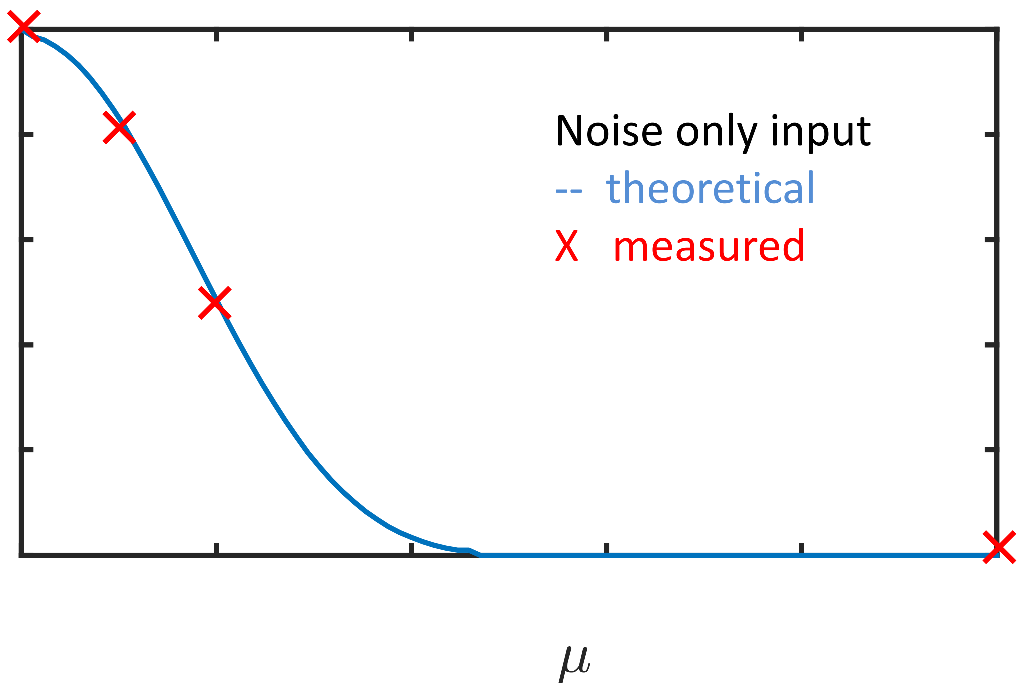


“Auto” Example: (V_Sky, V_Sky*)

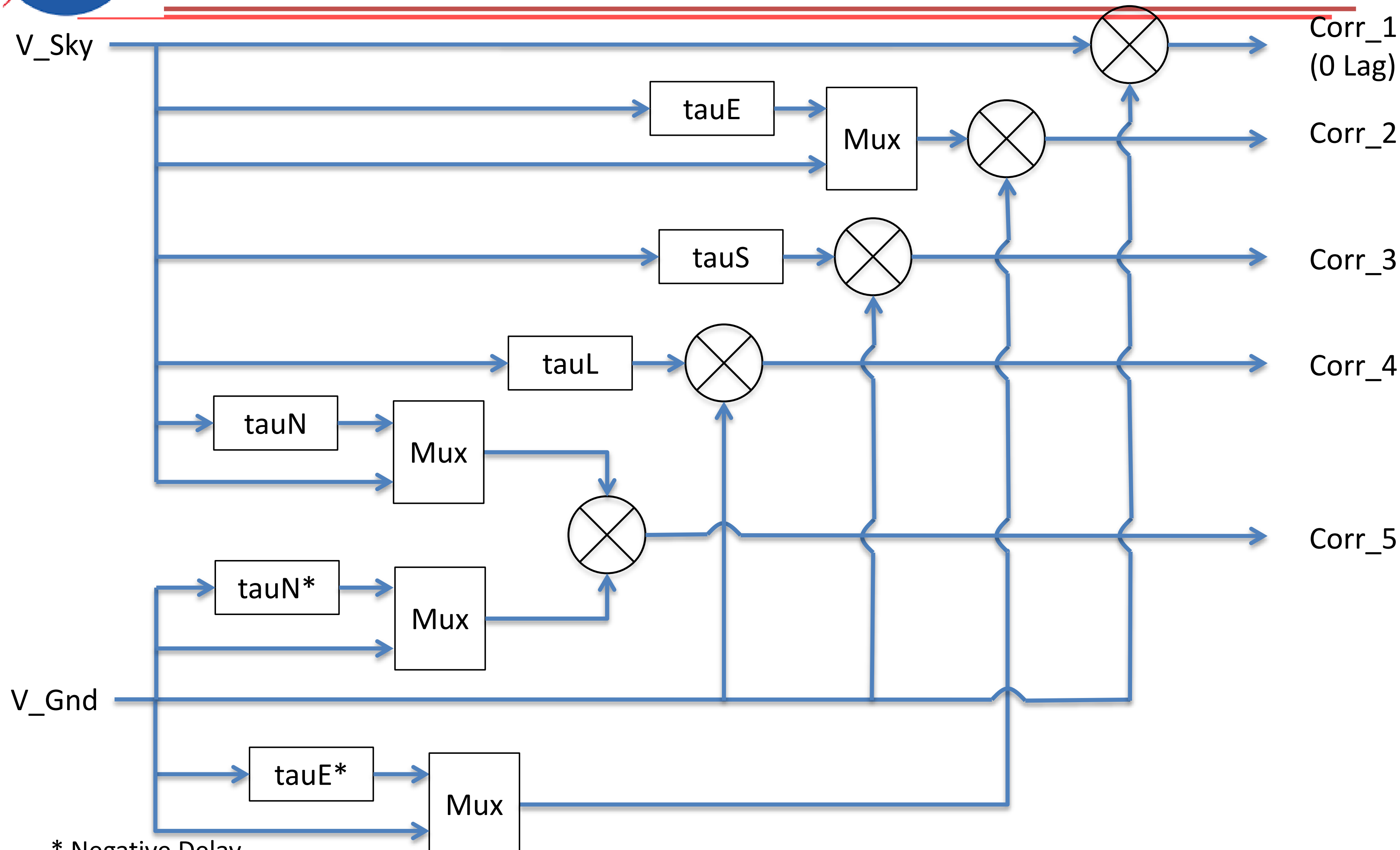


SoOp-AD Auto-Correlator Verification

- Correlators have programmable 4 lags + 0
- 300-kHz noise detection bandwidth
- Test: 0, 1, 2 and 10 us (400 us not shown)



"Cross" Example: (V_Sky, V_Gnd*)



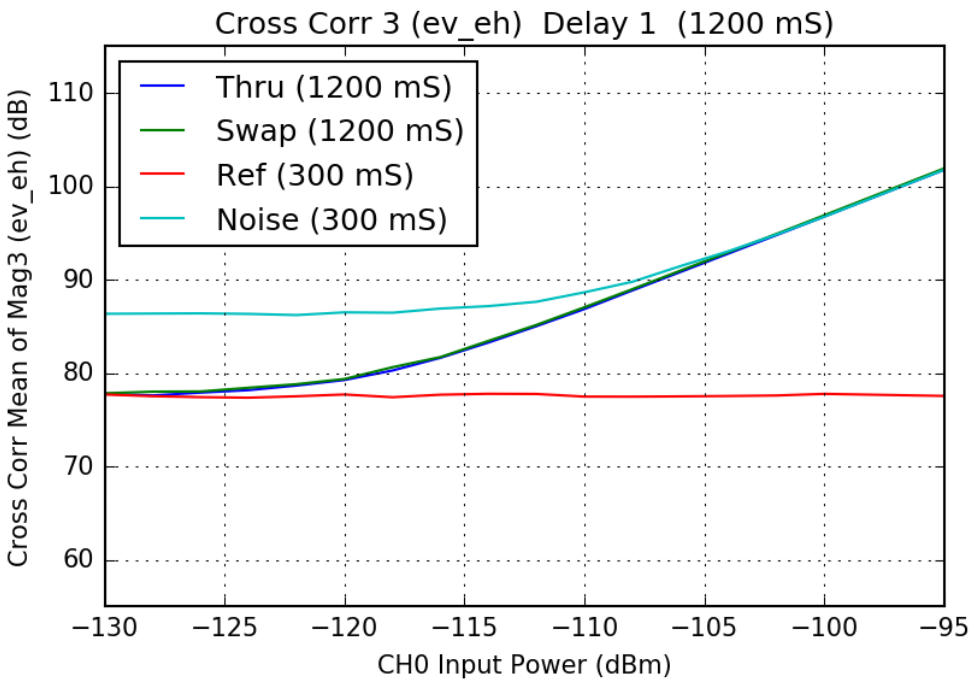
* Negative Delay

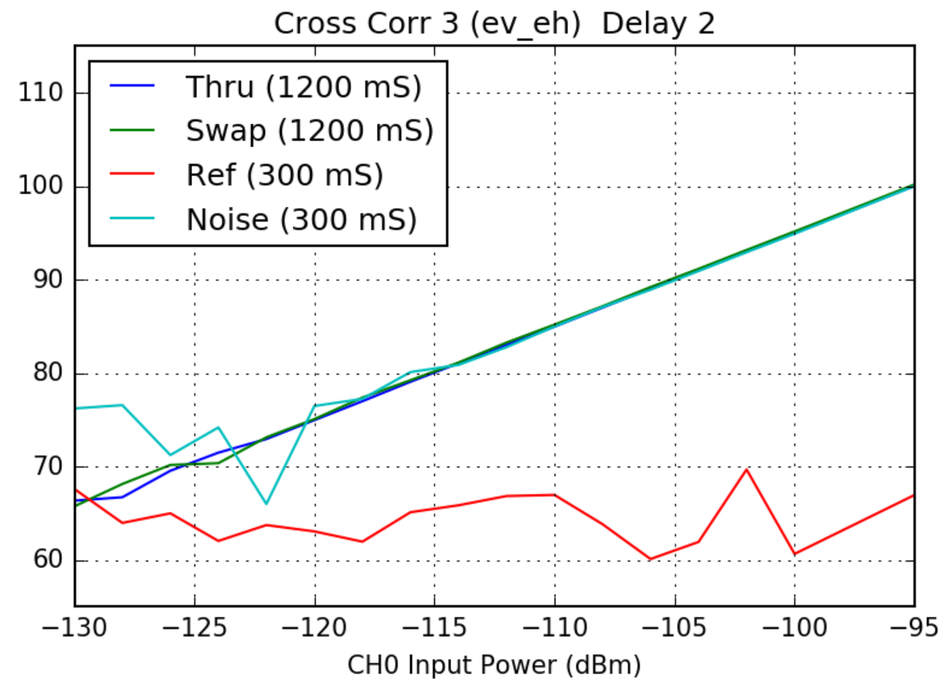
SoOp-AD Cross-Correlator Verification

- AWG QPSK waveform into V&H inputs

0 delay

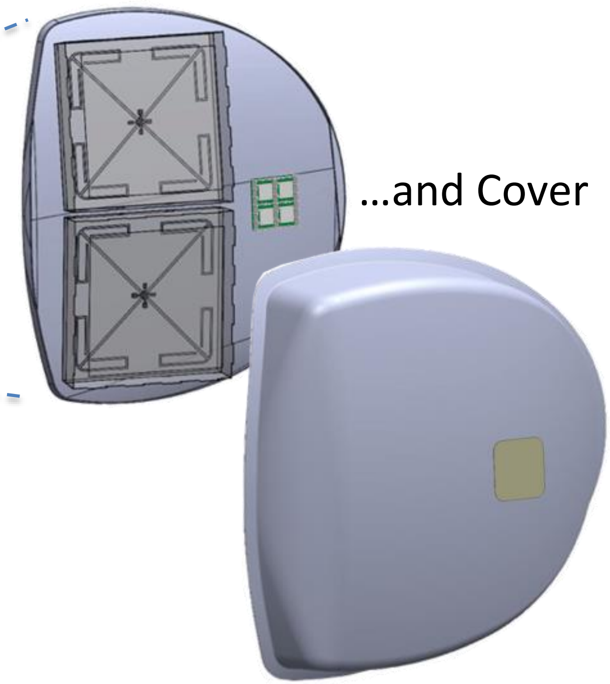
22 us delay





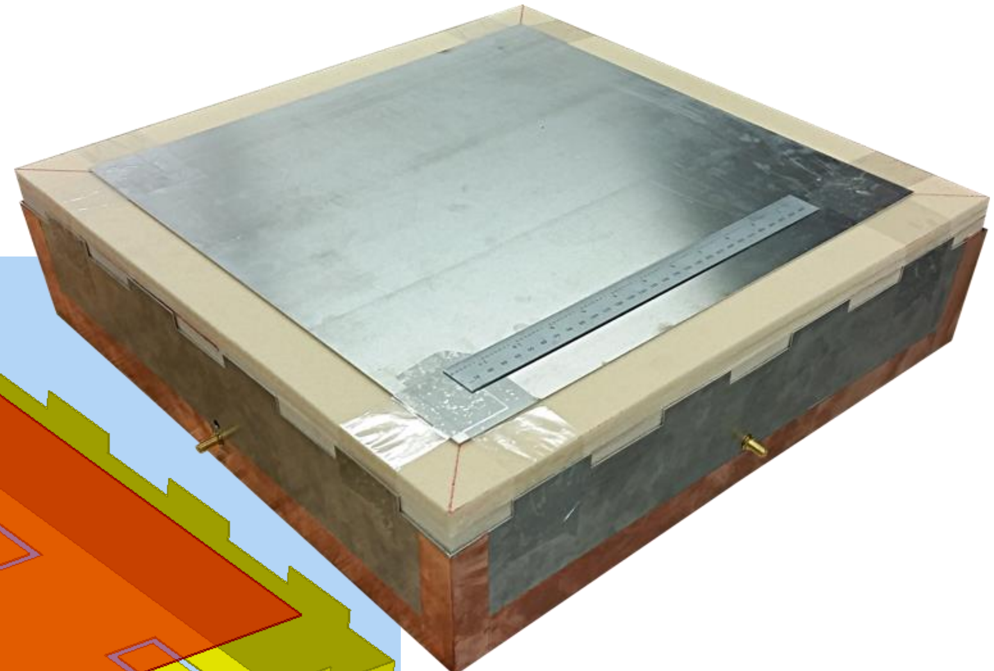
Technology Development: Antennas

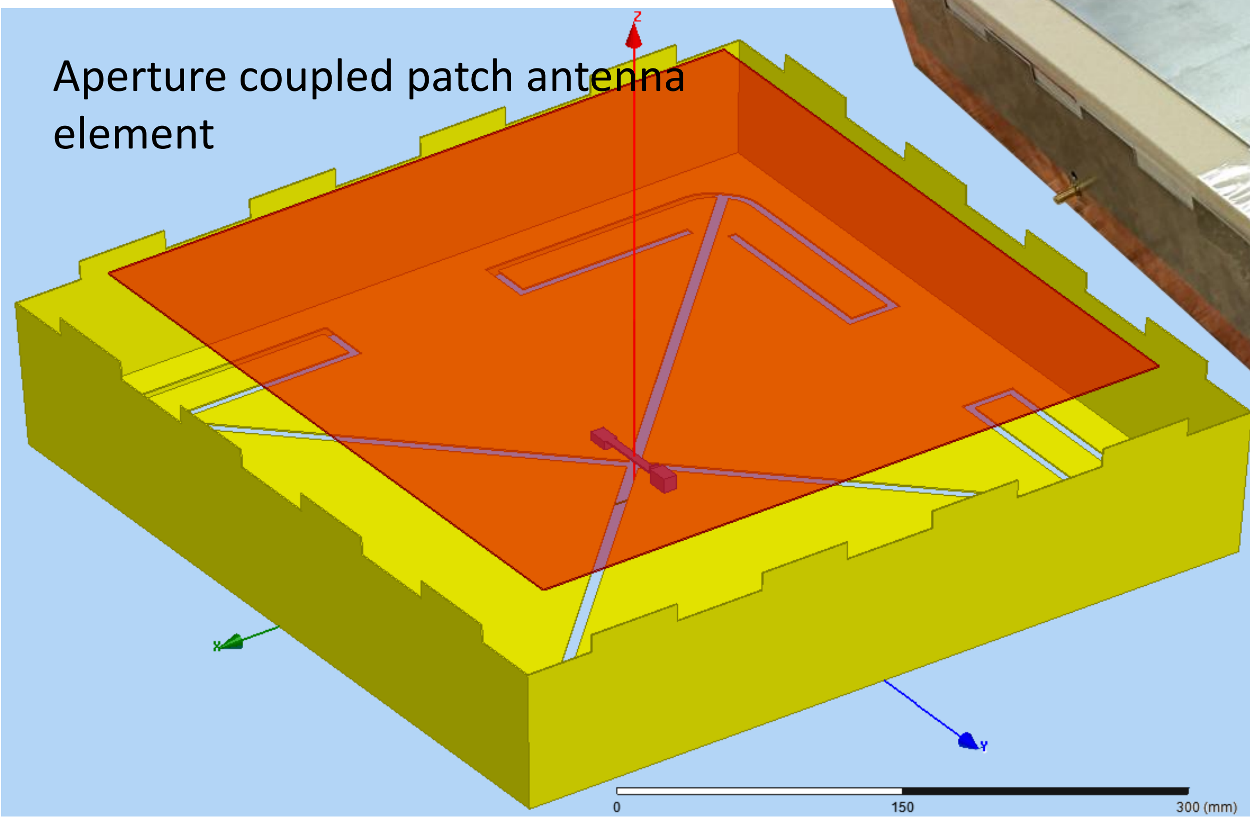
- Antenna radome design for B200 aircraft



Technology Development: Antennas

P-band antenna design

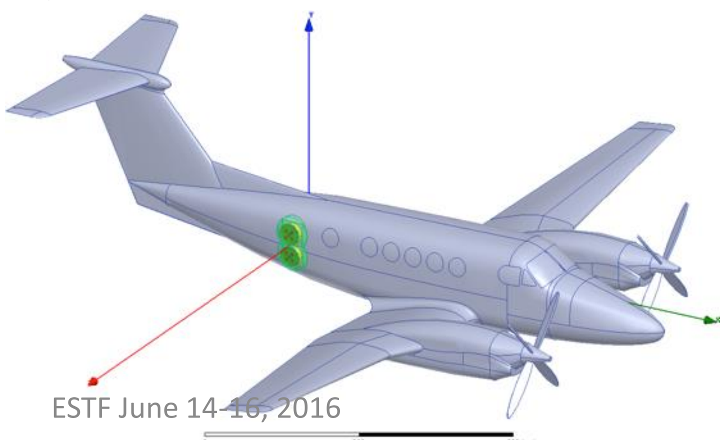


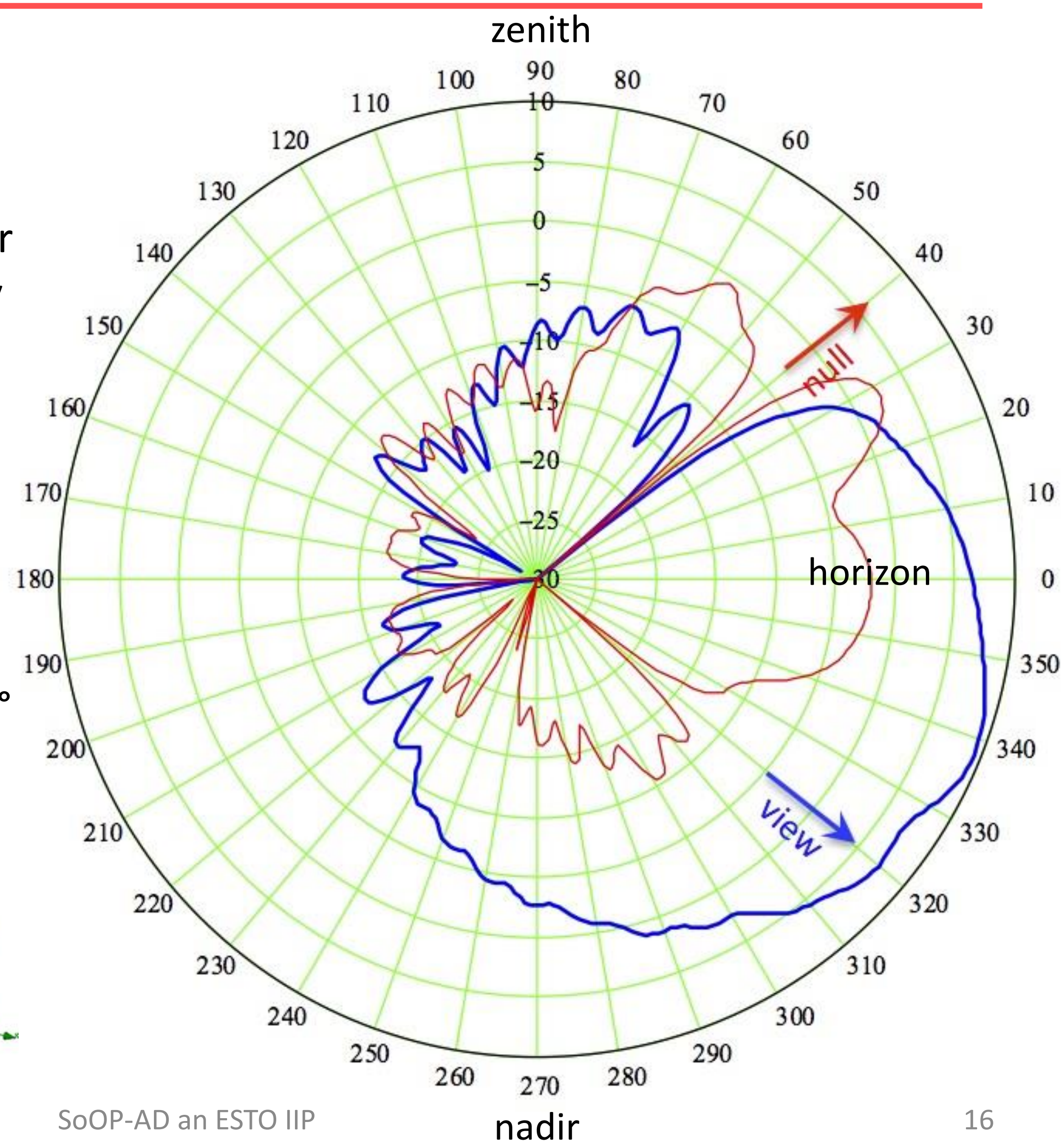


Aperture coupled patch antenna element

Antenna System Considerations

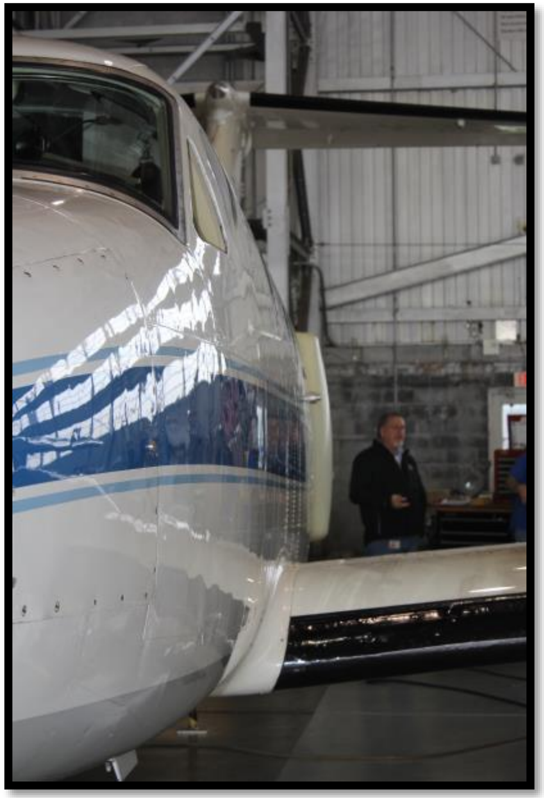
- Direct-to-Reflect isolation is driving requirement – But not in orbit!
- Using two-element interferometer to synthesize a two-element array with null steering in post-processing.
- Simulation: Earth View Beam
  - Co-pol (blue): LHCP
  - X-pol (red): RHCP
- Results simulate a post-processed pattern with a null steered to +40°





Technology Development: Antenna Radome

- Radome designed and fabricated.
- Test-fit Successful.
- Awaiting test flight



Next Steps

- Ground Testing
- Aircraft Safety Test
- Aircraft Campaign in Fall of 2016